LIFE MIDMACC

Mid-mountain adaptation to climate change

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Report with the 1st 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 first year. 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, and the first monitoring campaign is being carried out at the end of 2021 and beginning of 2022 once the cattle had been in the plots.

Following the monitoring protocol developed in the Deliverable 8 (Nadal-Romero *et al.*, 2020b), this document includes the first 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 first 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 **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. 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).

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 (2024)
	Pasture production and quality	Pastoral value Pasture nutritive quality (protein and fibre content) Biomass productivity	Vegetation surveys Sample processing Chemical analysis	Annual survey (spring or summer 2020-2022-2023) Final (2024)
Rainfall simulation	**Hydrological response and soil erosion**	Runoff coefficient Infiltration rate Time to runoff Ponding time Wetting front Sediment concentration Sediment production	Rainfall simulation experiments	After clearing (2020) Annual simulations (2021-2022-2023) Final (2024)

	Variable	Measured variables	Methodology	Periodicity
		Sediment detachment		
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 initial monitoring variables and the 1st 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 initial monitoring variables and the results of the 1st year monitoring campaign (when it has been possible).

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.

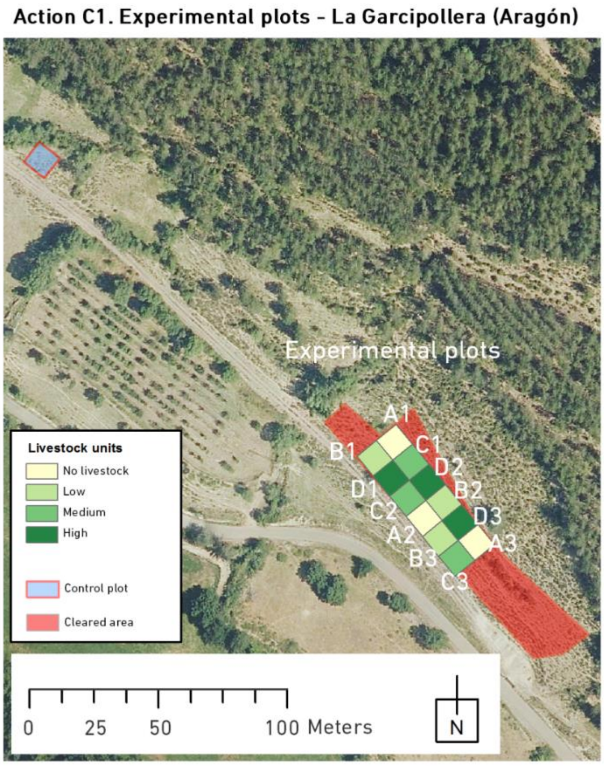


Figure 1. Location of the monitoring plots and replicates of the experimental design.

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 has been carried out in November 2021 (last data are not included in this deliverable due to limited time to carry out the physical and chemical variables in the laboratory), once the animals have entered three times in the experimental plots during the second year of livestock grazing (spring, summer and autumn 2021).

At each monitoring subplot, three soil samples were sampled with an auger at 10 cm increments: 0 cm, 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. In each site, 45 points were selected, and 225 subsamples were recorded and later combined into one soil composite sample per plot and depth. In total 75 composite samples were created in La Garcipollera. The 75 samples have been analysed by the Pyrenean Institute of Ecology (IPE-CSIC), evaluating the following soil variables: field bulk density (BD), pH and electrical conductivity (EC), total carbon concentration (Ctotal), total nitrogen concentration (N), carbonate content ($CaCO_3$), organic carbon (Corg), soil organic carbon (SOC) and nitrogen (TN) stocks, organic matter (OM), grain size distribution (clay, silt and sand contents), organic phosphorus (P), saturated soil moisture (SAT), field capacity (FC), wilting point (WP) and CN ratio.

Figure 2 -Figure 7 present the mean values and standard deviations of the main soil physical and chemical properties (at four depths 0-10, 10-20, 20-30 and > 30 cm) measured in the experimental plots during the initial monitoring variables in La Garcipollera Research Station. Statistical results did not show significant differences between the management subplots and the control subplots at initial conditions. To see all the data, Table 24 supplementary material can be checked.

Figure 2 shows that all the samples presented pH values higher than 7, corresponding to basic soils (ranging between 7.9 and 8.5). pH values slightly increased with depth in all the cases. In the case of electrical conductivity, mean values ranged between 118 and 204 µs/cm, being these values higher in the topsoil samples.

Figure 3 presents the mean Corg and N contents. It should be highlighted the high values obtained in the topsoil samples (0 and 0-10 cm). In all the cases, values decreased with depth. Mean values in the mineral soil samples ranged between 1.5 and 3.8%. Nitrogen values followed the same pattern and mean values oscillated between 0.2 and 0.3%. In both cases, high standard deviations were obtained in the first 10 cm.

CN ratio is an index of the quality of the soil organic substrate. Excluding the organic horizon (0 cm), the CN ratio values varied between 9.9 and 12.4. Lower values were obtained in depth. These values indicate that the soil is equilibrated and exist a control between mineral nitrogen and carbon in the soil (Figure 4).

Organic P values sharply decreased with depth (Figure 4). Maximum values were around 5 mg/kg P, and minimum values were around 1 mg/kg P. High standard deviations were recorded in all the cases.

Figure 5 shows the $CaCO_3$ contents. Values between 40 and 50% were obtained, related to a calcareous lithology (Eocene Flysch) in the study area.

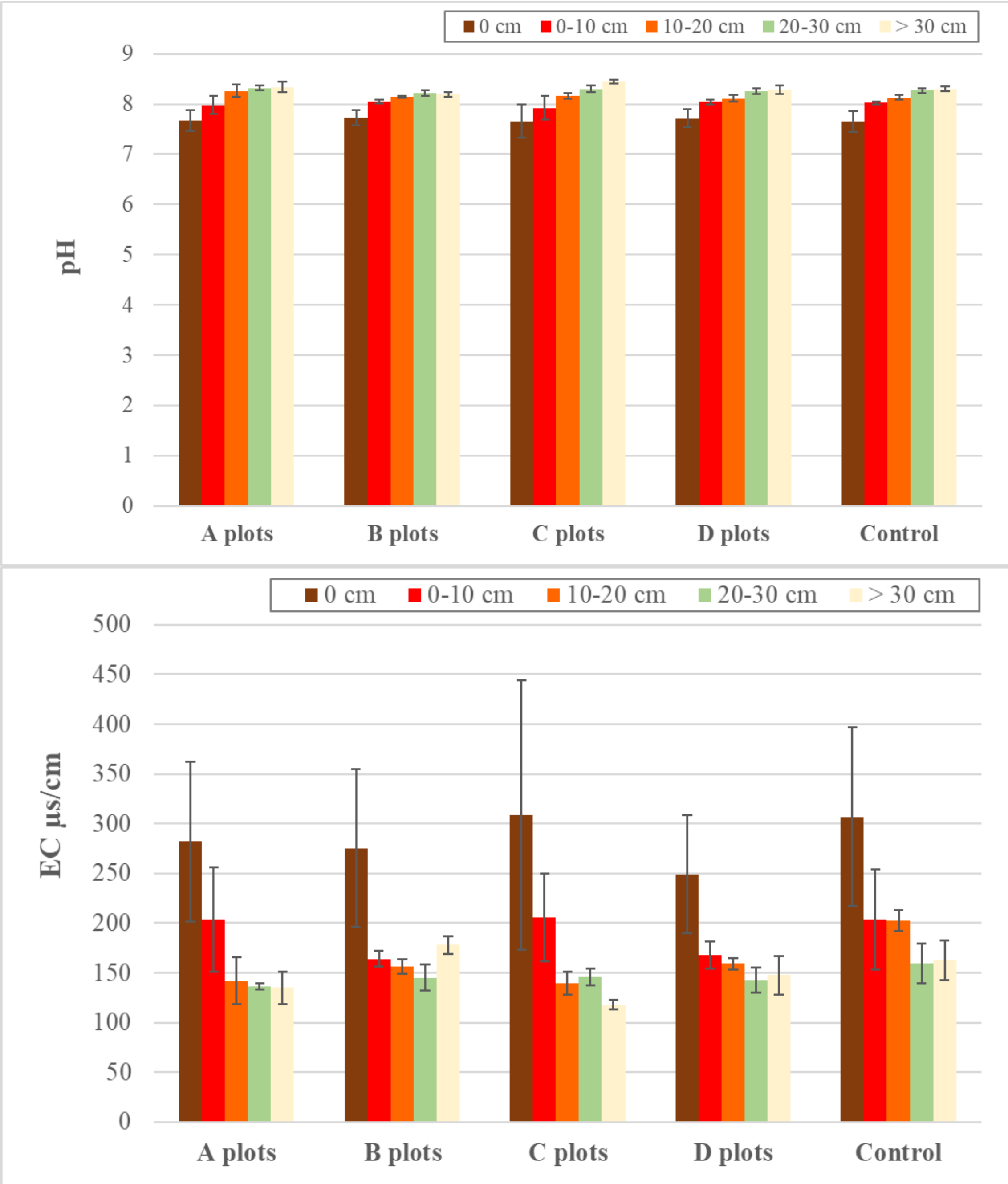


Figure 2. pH and electrical conductivity values of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

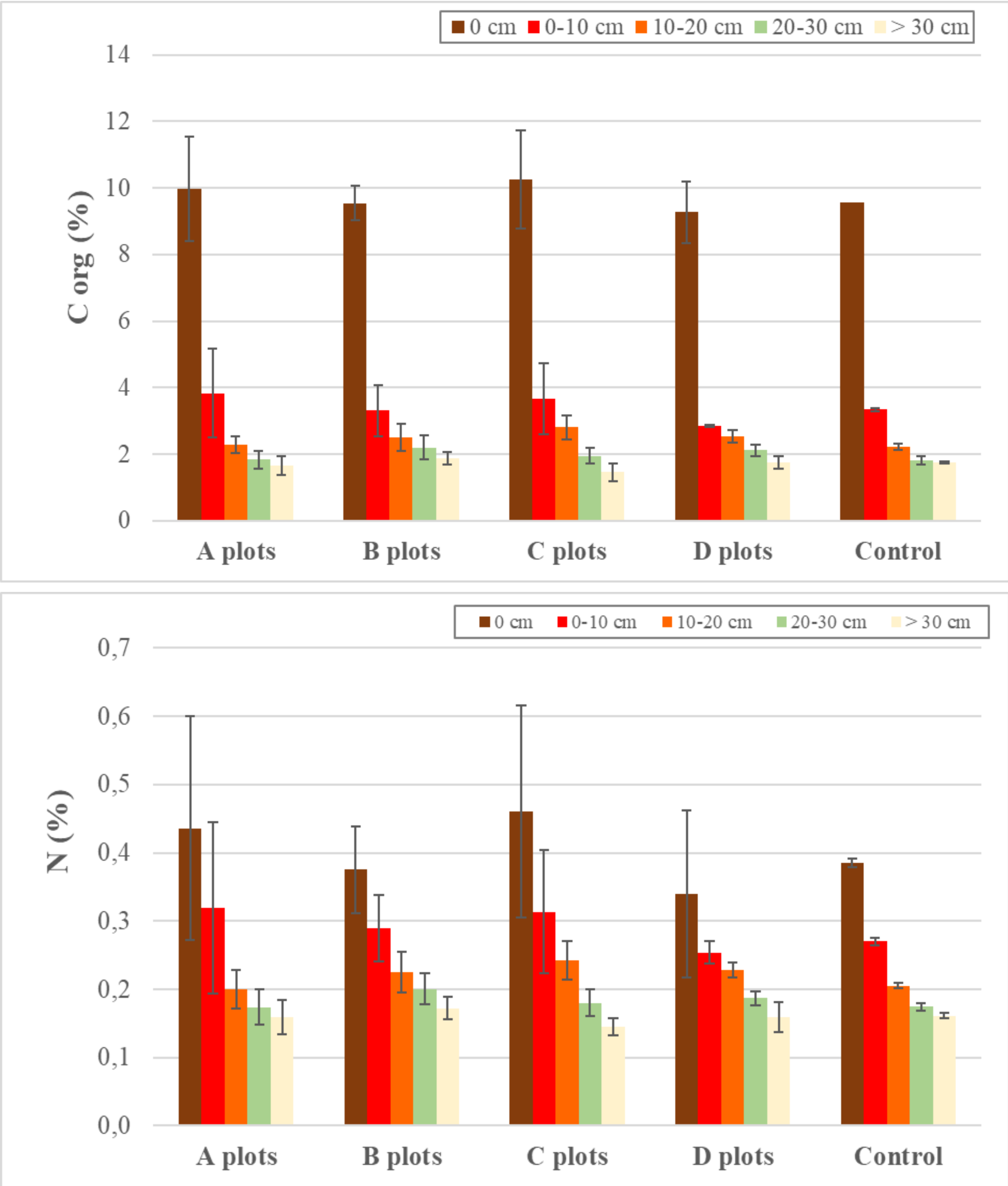


Figure 3. Organic Carbon (Corg) and Nitrogen (N) content of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

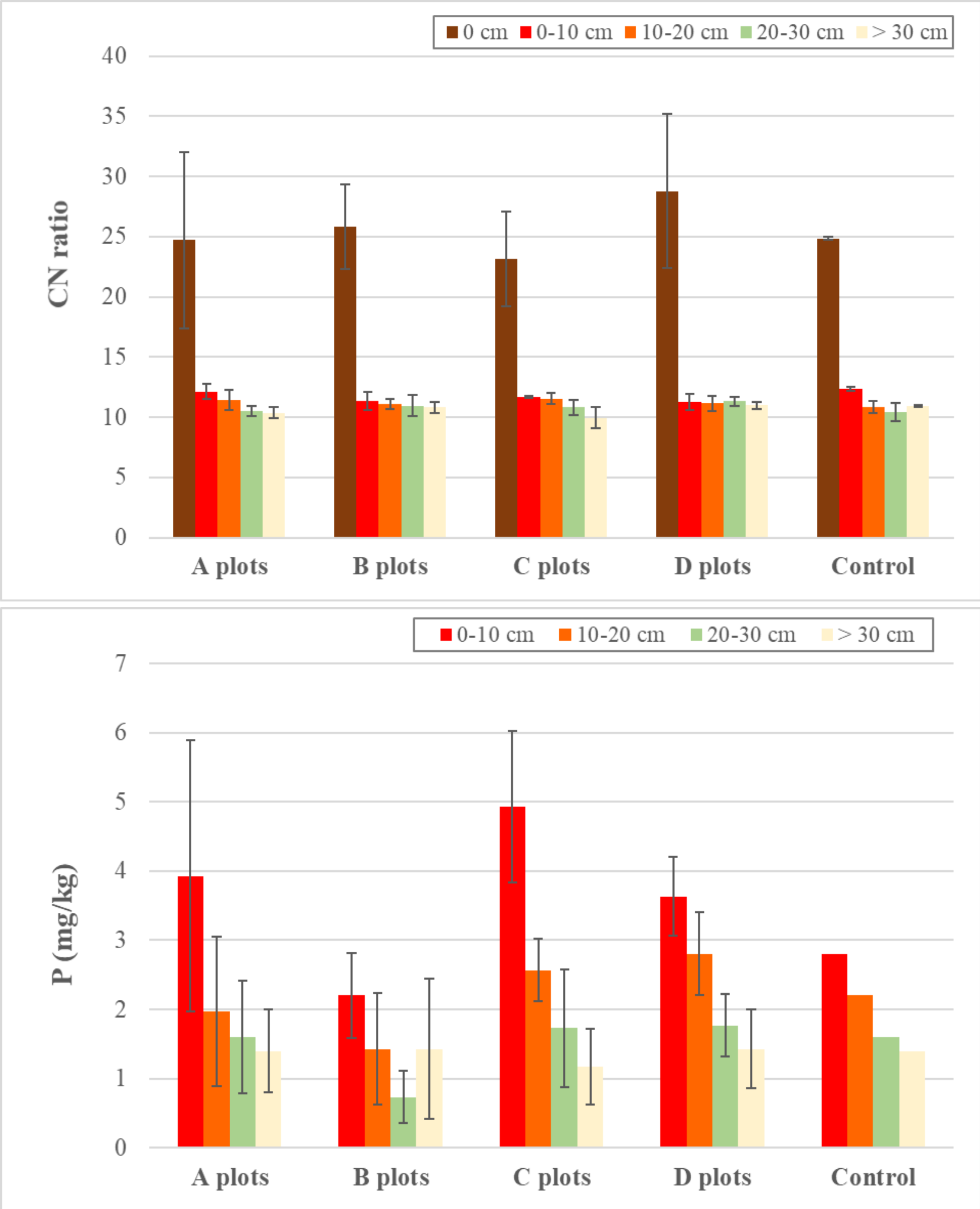


Figure 4. Organic carbon and Nitrogen ratio (CN ratio) and organic phosphorus (P) content of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

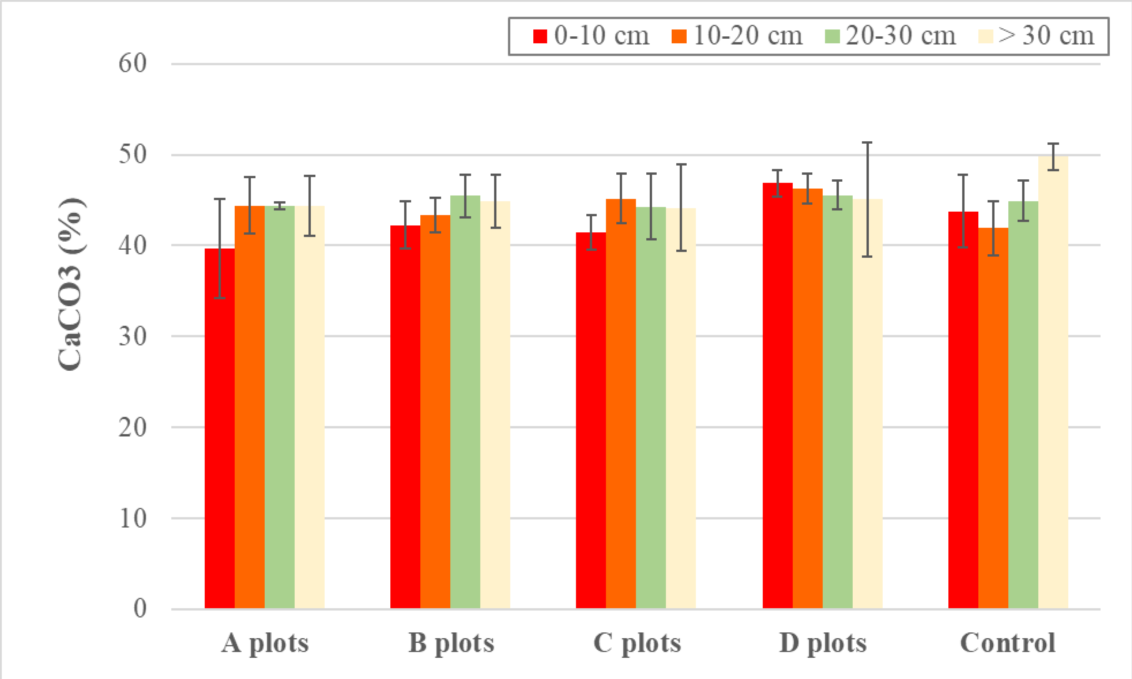


Figure 5. Carbonate content ($CaCO_3$) content of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

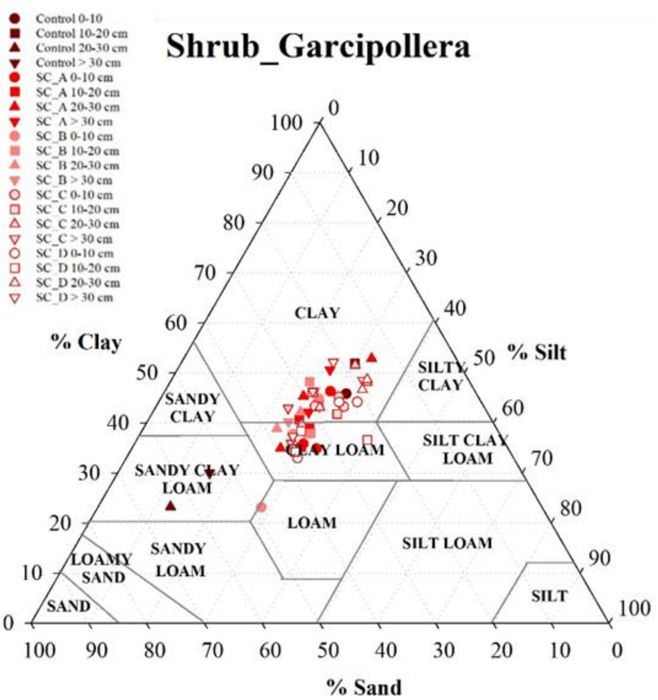


Figure 6. Clay, silt and sand contents (grain size distribution) of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

Figure 6 presents the texture diagram representing the percentages of clay, silt and sand contents of the different soil samples. Most of the soil samples presented a clay-loam and clay texture, with some exception in the control samples (sandy clay loam). Clay values oscillated between 23 and 52%, silt values between 12 and 32%, and sand values between 18 and 64%.

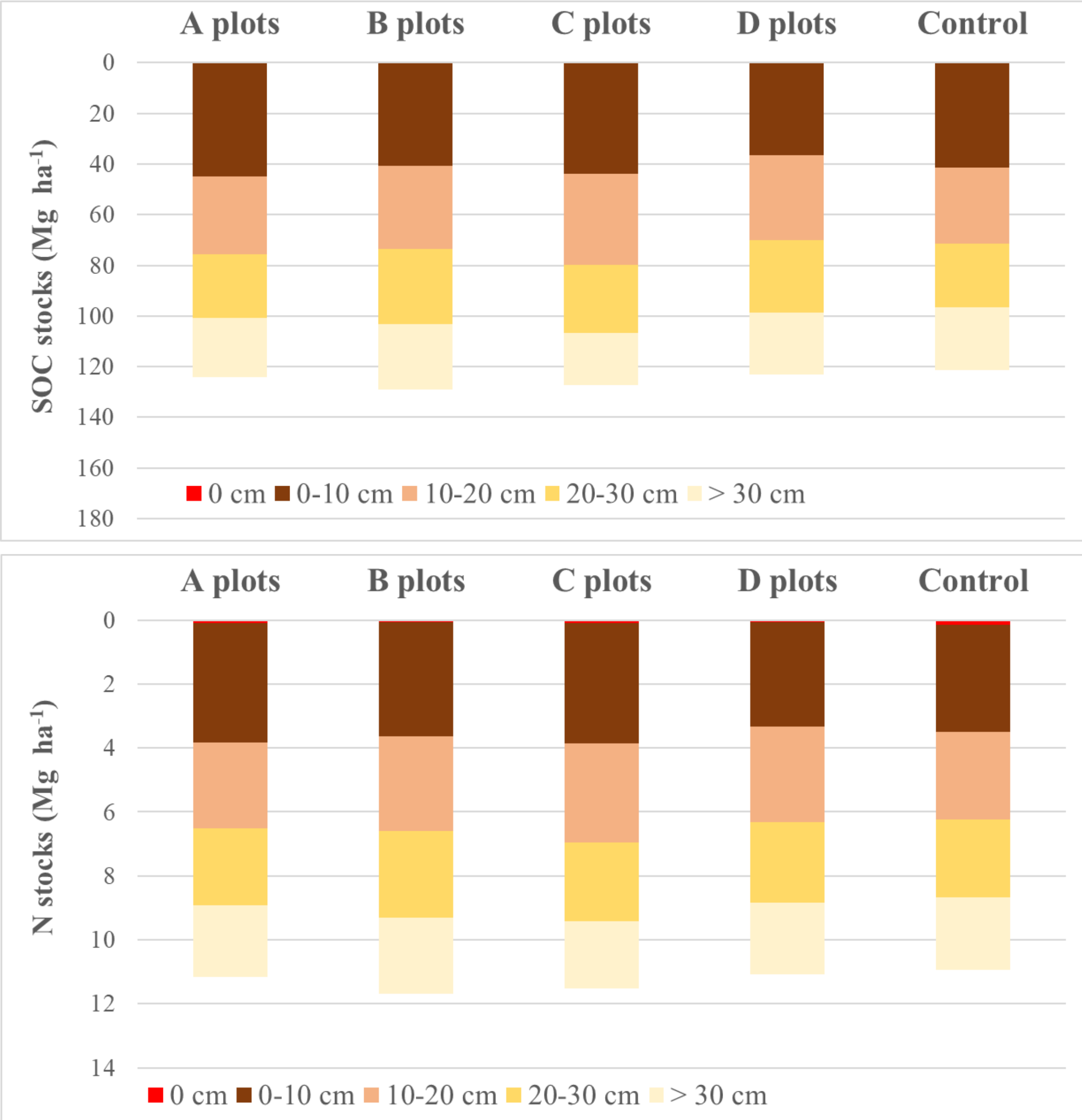


Figure 7. Soil organic carbon (SOC) and nitrogen (N) stocks of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

Finally, Figure 7 presents the soil organic carbon and nitrogen stocks of the complete soil profile. No significant differences were observed considering the complete profiles, neither considering the different depths. That is a good point, as we can consider that the initial conditions are the same in all the pilot plots. SOC stocks were around 120 Mg ha^{-1} and N stocks around 11 Mg ha^{-1}.

The first-year monitoring campaign carried out in autumn 2021 will provide the first results about the changes occurred in the main soil properties related to carbon and nitrogen dynamics in the first 10 cm. The analysis of this campaign is currently in process.

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 8).

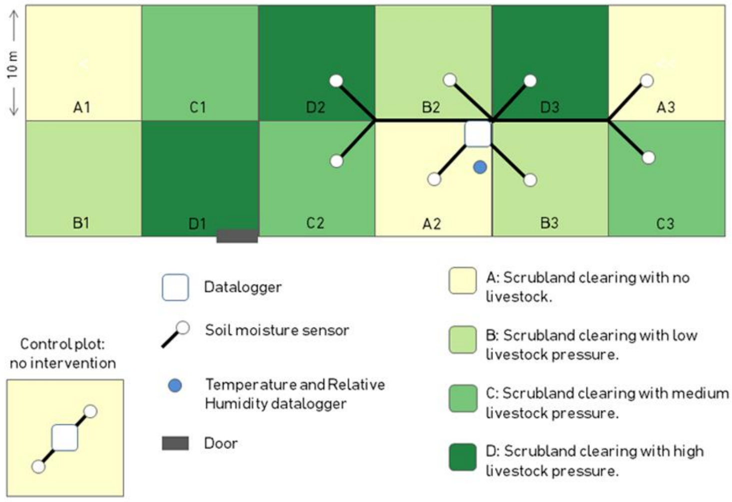


Figure 8. Original monitoring design of the livestock and monitoring subplots.

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 9) 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.

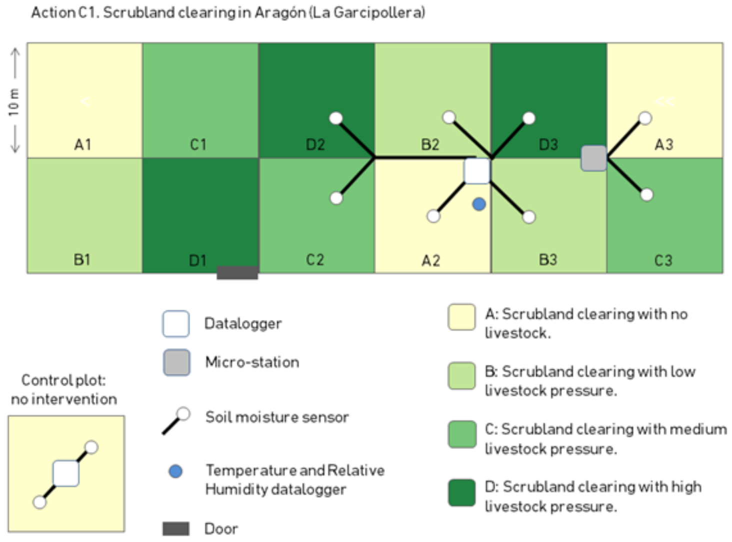


Figure 9. Diagram of the livestock and monitoring subplots.

Figure 10 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.

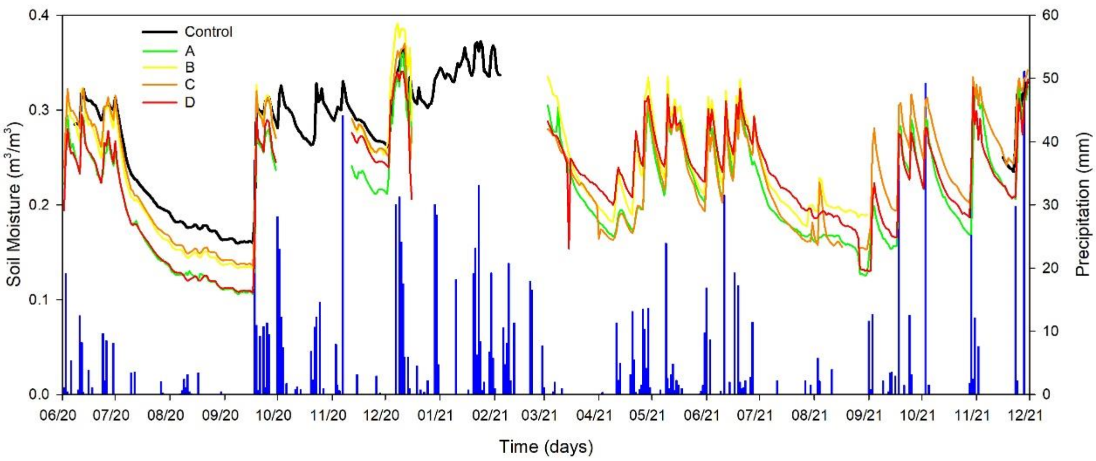


Figure 10. Soil humidity and precipitation in scrubland cleared experimental plot (La Garcipollera).

Despite the lack of data for different periods (the most important gap is the one recorded in the control plot, due to an error not found in the solar panel, from 05-02-2021 to 15-11-2021). Figure 10 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. However, as we present the first period of data, statistical analyses have not been carried out. Next year, when more results will be available, conclusions regarding the comparison among treatments will be drawn.

3.2. Monitoring results of the Pastures

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

3.2.1. Biodiversity

Vegetation surveys are carried out in late spring or early summer (May-June). 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 done in June 2022 in order to record the intermediate status of the pastures.

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. Indeed, we found higher herbaceous species richness in subplots submitted to scrubland clearing than in non-managed subplots (Table 2). Specifically, we found significantly more species of geophytes and therophytes, and a higher cover of hemichryptophytes, geophytes and therophytes in the cleared areas compared to the control area. Regarding functional types, we found significantly more forbs species in the cleared plots than in the control plot.

		Control	Scrubland clearing		
Variables		Mean ± SE	Mean ± SE	F	p-value
Shannon index		1.90 ± 0.12	2.05 ± 0.09	0.9294	0.3494
Total herbaceous richness		11.89 ± 1.23	16.56 ± 1.09	8.0364	**<0.05***
Chamaephytes	Richness (n)	0.78 ± 0.15	1.11 ± 0.20	1.8	0.1984
	Relative cover (%)	3.43 ± 0.89	4.02 ± 0.70	0.2672	0.6123
Hemichryptophytes	Richness (n)	9.56 ± 1.00	11.56 ± 0.87	2.2777	0.1507
	Relative cover (%)	93.90 ± 1.59	89.60 ± 1.18	4.7331	**<0.05***
Geophytes	Richness (n)	0 ± 0	0.44 ± 0.18	6.4	**<0.05***
	Relative cover (%)	0 ± 0	1.01 ± 0.49	4.2183	**0.056***
Therophytes	Richness (n)	1.56 ± 0.41	3.44 ± 0.44	9.7143	**<0.01****
	Relative cover (%)	2.66 ± 0.84	5.37 ± 0.83	5.2683	**<0.05***
Legumes	Richness (n)	1.22 ± 0.32	1.56 ± 0.41	0.4045	0.5338
	Relative cover (%)	2.89 ± 0.96	3.91 ± 1.79	0.2519	0.6226
Grasses	Richness (n)	4.22 ± 0.49	4.89 ± 0.31	1.3091	0.2694
	Relative cover (%)	68.11 ± 4.42	75.98 ± 2.89	2.228	0.155
Forbs	Richness (n)	6.44 ± 0.80	10.11 ± 0.72	11.647	**<0.01****
	Relative cover (%)	29.00 ± 4.04	20.11 ± 2.60	3.4247	0.083

Table 2. Effect of the AFM (scrubland clearing) in biodiversity variables: Shannon index, herbaceous species richness and in the richness and relative cover of the different Raunkiaer lifeforms (chamaephytes, hemichryptophytes, geophytes and therophytes) and in the different functional types (legumes, grasses and other forbs).

On the other hand, we expected not to find any effects of the livestock treatments since in the first year (2020) vegetation surveys were set previous to sheep entry in the plots. As expected, we did not find significant differences between livestock treatments in the majority of the variables studied. However, we found significant differences between treatments in the relative cover of chamaephytes and in the richness and relative cover of geophytes (Table 3). In the following vegetation samplings (intermediate and final), we expect to find more diversity in the plots submitted to low and medium grazing intensity than in the plots not submitted to livestock and submitted to high grazing intensity.

Variables		No livestock Mean ± SE	Low Mean ± SE	Medium Mean ± SE	High Mean ± SE	F	p-value
Shannon index		2.05 ± 0.09	2.11 ± 0.11	2.28 ± 0.03	2.04 ± 0.11	1.5301	0.2256
Total herbaceous richness		16.56 ± 1.09	15.67 ± 0.85	19.11 ± 1.18	16.67 ± 0.82	2.1878	0.1087
Chamaephytes	Richness (n)	1.11 ± 0.20	0.89 ± 0.31	1.33 ± 0.24	1.11 ± 0.11	0.6465	0.5909
	Relative cover (%)	4.02 ± 0.70 ab	2.92 ± 0.98 a	5.07 ± 1.09 ab	7.30 ± 1.51 b	2.8356	**0.0536***
Hemichryptophytes	Richness (n)	11.56 ± 0.87	10.67 ± 0.53	12.22 ± 0.89	11.78 ± 0.64	0.764	0.5226
	Relative cover (%)	89.60 ± 1.18	84.34 ± 2.38	79.92 ± 4.35	84.39 ± 3.07	1.772	0.1723
Geophytes	Richness (n)	0.44 ± 0.18 ab	0.78 ± 0.22 b	0.78 ± 0.22 b	0.11 ± 0.11 a	2.8696	**0.0517***
	Relative cover (%)	1.01 ± 0.49 ab	9.30 ± 2.49 ab	3.19 ± 0.86 b	0.11 ± 0.11 a	4.7036	**<0.01****
Therophytes	Richness (n)	3.44 ± 0.44	3.11 ± 0.39	4.78 ± 0.36	3.67 ± 0.55	2.651	0.066
	Relative cover (%)	5.37 ± 0.83	9.30 ± 2.49	11.83 ± 4.22	8.20 ± 2.70	0.8961	0.4538
Legumes	Richness (n)	1.56 ± 0.41	1.22 ± 0.36	2.22 ± 0.28	1.89 ± 0.54	1.106	0.361
	Relative cover (%)	3.91 ± 1.79	6.88 ± 2.52	7.81 ± 2.05	5.47 ± 2.43	0.5901	0.626
Grasses	Richness (n)	4.89 ± 0.31	4.67 ± 0.29	5.00 ± 0.37	4.78 ± 0.43	0.1626	0.9207
	Relative cover (%)	75.98 ± 2.89	65.62 ± 5.89	62.47 ± 3.51	66.99 ± 5.10	1.6521	0.1969
Forbs	Richness (n)	10.11 ± 0.72	9.56 ± 0.78	11.89 ± 0.82	10.00 ± 0.83	1.6922	0.1883
	Relative cover (%)	20.11 ± 2.60	25.91 ± 3.77	29.72 ± 2.06	27.54 ± 3.95	1.6598	0.1952

Table 3. Livestock effect on the scrubland cleared areas in biodiversity variables: Shannon index, herbaceous species richness and in the richness and relative cover of the different Raunkiaer lifeforms (chamaephytes, hemichryptophytes, geophytes and therophytes) and in the different functional types (legumes, grasses and other forbs).

3.2.2. Pasture production and quality

Pasture production and quality samplings are carried out in late spring or early summer (May-June). We aim to record the pasture production and quality in an initial status and in a final status (intermediate status is not recorded since cumulative effects on the pastures are not significant after one year, only). The first sampling was done in June 2020 in order to record the initial status of the pasture in the experimental plots. The final status of the experimental plots will be recorded in 2023.

In the first sampling, we expected to find a positive effect of the scrubland clearing in the production and quality of the herbaceous pasture because of the elimination of woody competitors for light, space and nutrients. We expect that this positive effect of scrubland clearing will maintain over time in the experimental plots. Regarding pasture production, we did not find a significant effect of the scrubland clearing on biomass (Table 4). However, we found significant differences between treatments in some of the nutritive quality variables studied. Higher content of proteins and lower content of non-digestible fibers will indicate a higher pasture quality. We found a significantly higher percentage of cellulose, acid-detergent fibers (ADF), acid-detergent lignin (ADL) and acid-detergent ashes (ADA) in the samples collected in the scrubland clearing plots than in the control area. On the other hand, we found a significantly lower content of digestible dry matter (DDM) and a lower relative feed value (RFV) in the samples collected in the scrubland clearing subplots than in the control area (Table 4). In general, the relative feed value indicates that the pasture in the control subplot shows a higher feed quality than the pasture in the scrubland clearing subplots.

	Control	Scrubland clearing		
Variables	**Mean ± SE**	**Mean ± SE**	**F**	**p-value**
Biomass (kg DM/ha)	568.21 ± 68.67	789.24 ± 109.28	2.933	0.1061
CP (%)	10.61 ± 0.31	11.32 ± 0.32	2.5316	0.1311
Cellulose (%)	26.41 ± 0.88	41.12 ± 3.48	16.746	**<0.001*** **
Hemicellulose (%)	27.70 ± 1.26	11.09 ± 4.92	10.699	**<0.01** **
NDF (%)	60.89 ± 1.58	62.66 ± 1.65	0.5908	0.4533
ADF (%)	33.19 ± 0.78	51.57 ± 3.90	21.349	**<0.001*** **
ADL (%)	6.78 ± 0.67	10.44 ± 0.62	16.115	**<0.01** **
ADA (%)	1.06 ± 0.05	1.26 ± 0.06	7.2338	**<0.05* **
DMI	1.98 ± 0.05	1.92 ± 0.05	0.6633	0.4274
DDM	63.04 ± 0.60	48.73 ± 3.03	21.355	**<0.001*** **
RFV	96.94 ± 3.16	72.30 ± 3.87	24.314	**<0.001*** **

*Table 4. Biomass production and nutritive quality variables in non-managed plots with no livestock and managed plots with no livestock. * Variables: CP=crude protein; Cel=cellulose; Hemi=hemicellulose; NDF=neutral-detergent fiber; ADF=acid-detergent fiber; ADL=acid-detergent lignin; ADA=acid-detergent ashes; DMI= dry matter intake; DDM= digestible dry matter; RFV = relative feed value*

Contrarily, in the initial status (2020), we expected not to find any effects of the livestock treatments in the herbaceous pasture, neither in production nor in quality since vegetation samples (and their subsequent processing and analyses) were collected previous to the entry of the cows. According to what expected, we did not observe significant differences between livestock treatments neither in the herbaceous biomass production nor in the nutritive quality variables measured (Table 5).

	No livestock	Low	Medium	High		
Variables	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**	**F**	**p-value**
Biomass (kg DM/ha)	568.21 ± 68.67	644.49 ± 82.39	774.76 ± 75.84	618.18 ± 93.29	0.9301	0.4375
CP (%)	11.32 ± 0.32	11.86 ± 0.24	12 ± 0.18	11.33 ± 0.29	1.8474	0.1585
Cellulose (%)	41.12 ± 3.48	38.67 ± 3.32	37.70 ± 2.89	38.59 ± 3.47	0.1974	0.8974
Hemicellulose (%)	11.09 ± 4.92	11.92 ± 4.77	12.93 ± 5.56	10.07 ± 4.25	0.0641	0.9797
NDF (%)	62.66 ± 1.65	60.17 ± 1.89	61.02 ± 2.21	59.20 ± 1.58	0.6301	0.6009
ADF (%)	51.57 ± 3.90	48.25 ± 4.32	48.09 ± 3.89	49.13 ± 4.07	0.157	0.9244
ADL (%)	10.44 ± 0.62	9.58 ± 1.03	10.39 ± 1.14	10.53 ± 0.91	0.2192	0.8823
ADA (%)	1.26 ± 0.06	1.51 ± 0.14	1.32 ± 0.14	1.40 ± 0.09	0.9124	0.4459
DMI	1.92 ± 0.05	2.01 ± 0.07	1.99 ± 0.07	2.04 ± 0.05	0.6314	0.6002
DDM	48.73 ± 3.03	51.31 ± 3.36	51.43 ± 3.03	50.63 ± 3.17	0.1567	0.9246
RFV	72.30 ± 3.87	79.91 ± 5.35	78.46 ± 3.60	80.12 ± 5.51	0.6198	0.6073

*Table 5. Biomass production and nutritive quality variables in scrubland clearing plots with no livestock and scrubland clearing plots with livestock. * Variables: CP=crude protein; Cel=cellulose; Hemi=hemicellulose; NDF=neutral-detergent fiber; ADF=acid-detergent fiber; ADL=acid-detergent lignin; ADA=acid-detergent ashes; DMI= dry matter intake; DDM= digestible dry matter; RFV = relative feed value.*

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. The first experiments were carried in October 2020 in order to monitor the initial conditions, i.e., in the cleared subplots without grazing and in the control plot. In December 2020, after the livestock grazed for the third time within the year, new rainfall simulations were performed in all the subplots and the control plot. A detailed description of the rainfall simulations experiments is described in Nadal-Romero et al., 2020 (Deliverable 8). Here we present the results of these experiments. Although three experiments were performed per land management type (3 replicas), 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.

Under initial conditions, the scrubland (control) subplot showed a much lower hydrological response, with a lower runoff coefficient (RC) and longer time to runoff (TR), than the cleared subplot without grazing (Table 6). However, the sediment response (SC, SP and SD) was much higher in the scrubland subplot than the cleared subplot, suggesting the protective role of the herbaceous cover (> 80% in the three cases).

A similar behaviour was found in November and December, after the livestock has grazed for the third time within the year (results of the first campaign 2020, Table 8). In general, RC was higher in the cleared subplots than in the control subplot, with the maximum value of RC and the quickest runoff response under the highest livestock density (0.94 and 4.1 min, respectively). The results also showed an increase in the sedimentological response with an increase in the livestock density, with the response of the subplots C (medium livestock density) similar to that of the scrubland (control) subplot, the highest values in the D subplots (high livestock density), and that of the subplots B with no response. In that case, the cleared subplots without grazing (A) showed a higher sediment response than the control subplot, illustrating the high variability of the data obtained by the rainfall simulations and the need of more experiments to obtain more robust results.

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
Garcipollera	Control	0.16	24.80	13.5	10	6.19	1.54	33.33
	Control	0.00	15.80	NA	10	0.00	0.00	0.00
	Cleared without livestock (A)	0.95	28.76	6.6	10	0.57	1.07	23.08

Table 6. All hydrogeological and sedimentological variables extracted from rainfall simulations in Garcipollera in October 2020 (initial conditions). Simulations without runoff are represented in Time to runoff variable with a NA and with a 0 value in Sediment concentration, production, and detachment. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
Garcipollera	Control	0.08±0.11	20.30±6.36	13.5±9.50	10±0.00	3.10±4.38	0.77±1.09	16.66±23.57
	Cleared without livestock (A)	0.95	28.76	6.6	10	0.57	1.07	23.08

Table 7. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in Garcipollera in October 2020 (initial conditions). All values have a n=2, except in A with n=1. All values represent mean ± standard error. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
Garcipollera	Control	0,11	26.89	8.2	NA	0.13	0.45	2.79
		0.36	26.36	9.6	10	0.51	0.45	9.85
	Cleared without livestock (A)	1,31	33.34	7.3	10	1.31	0.41	28.41
		0,02	39.60	4.3	8	0.04	0.85	0.91
	Cleared with low pressure (B)	0,00	26.70	NA	10	0.00	0.00	0.00
		0,00	37.95	NA	6	0.00	0.00	0.00
	Cleared with medium pressure (C)	0,89	30.41	8.5	10	0.71	0.43	15.27
		0,21	30.79	8.7	8	0.09	0.19	1.93
	Cleared with high pressure (D)	0,84	21.34	4.3	10	1.09	0.54	23.52
		1,04	21.26	3.8	10	0.65	0.30	14.10

Table 8. All hydrogeological and sedimentological variables extracted from rainfall simulations in Garcipollera in December 2020. Simulations without runoff are represented in Time to runoff variable with a NA and with a 0 value in Sediment concentration, production, and detachment. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm $^{-1}$)	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
Garcipollera	Control	0.24±0.18	26.76±0.18	8.90±0.99	10.00±0.00	0.32±0.27	0.45±00	6.32±4.99
	Cleared without livestock (A	0.67±0.91	36.47±4.43	5.8±2.06	9±1.41	0.68±0.90	0.63±0.31	14.66±19.45
	Cleared with low pressure (B))	0.00±0.00	32.33±7.95	NA	8±2.83	0.00±0.00	0.00±0.00	0.00±0.00
	Cleared with medium pressure (C)	0.55±0.48	30.60±0.27	8.6±0.12	9±1.41	0.40±0.44	0.31±0.17	8.60±9.43
	Cleared with low pressure (B)	0.94±0.14	21.30±0.05	4.1±0.38	10±0.00	0.87±0.31	0.42±0.17	18.81±6.66

Table 9. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in simulations in Garcipollera in December 2020. All values have a n=2. All values represent mean ± standard error. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

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 02-12-2021, the maximum temperature has been 36.4 and 38.1 ºC for T1 and T2 respectively (7-08-2021), and the minimum -11.3 and -12.6 ºC for T1 and T2 respectively (08-01-2021) (see Figure 11 for more details).

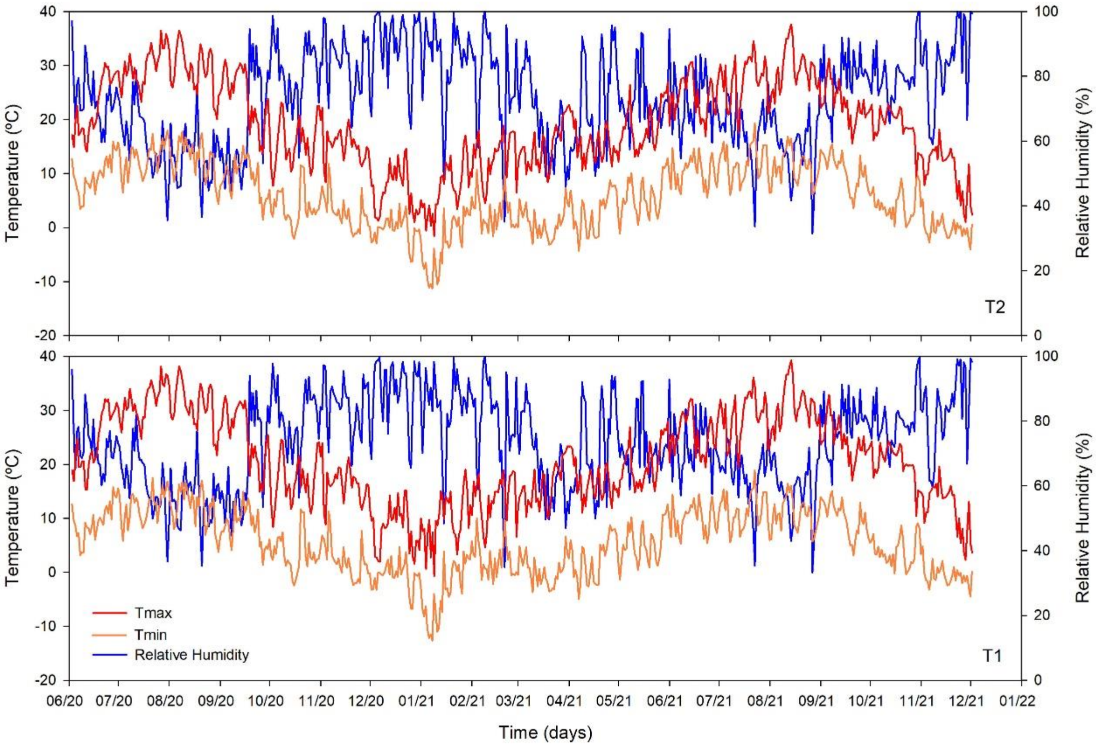


Figure 11. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plots located in La Garcipollera.

Figure 12 shows monthly averages of maximum temperature, minimum temperature and mean monthly precipitation for the period 06-2020 to 11-2021 (18 months) recorded in the experimental plots located in La Garcipollera. It should be highlighted the low values recorded in March: in fact, on the Iberian Peninsula, the average value barely reached 17 mm, compared to the 47 mm of the average value for the reference period (1981-2010). High values were recorded in December and January, 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.

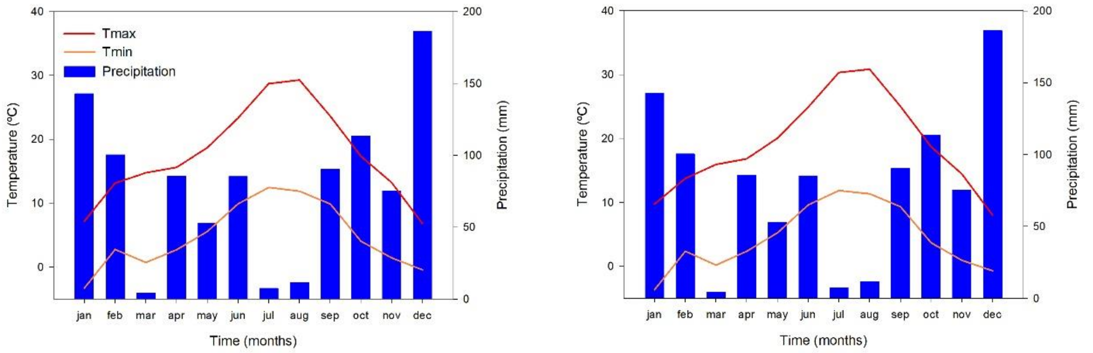


Figure 12. Climogram scrubland cleared experimental plot. Left: T2 - under a tree, right: T1 - in the subplot A2.

4. Results of the initial monitoring variables and the 1st monitoring campaign in San Román, La Rioja

The pilot experience has been implemented in the Leza Valley (Iberian System, Spain) in two scrubland clearing areas. This chapter includes the initial monitoring variables and the results of the 1st year monitoring campaign 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).

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.

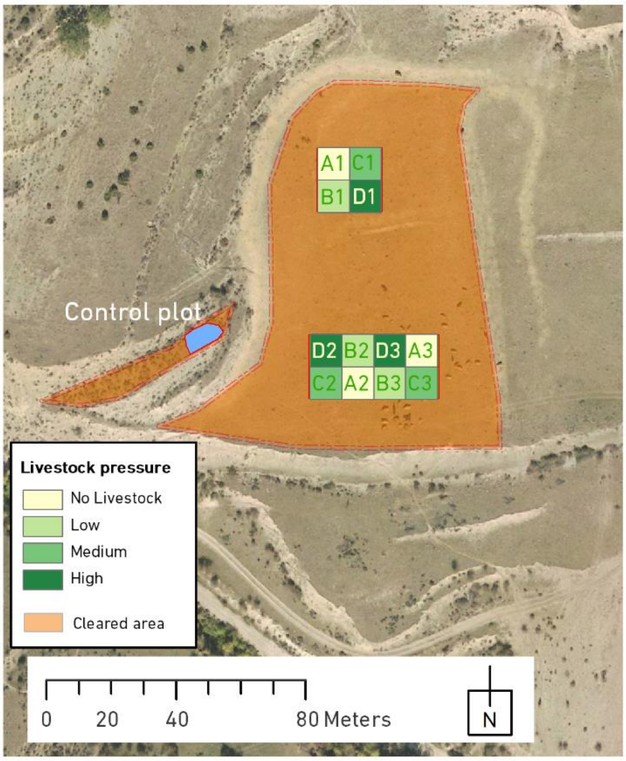


Figure 13. Location of the monitoring plots and replicates of the experimental design.

4.1. Monitoring results of the Soil

4.1.1. Soil characteristics

The first soil samplings were carried out in June 2020 and the first year monitoring campaign is going to be carried out at the beginning of 2022, once the animals have entered three times in the experimental plots during the second year of livestock grazing (spring, summer and autumn 2021).

At each monitoring subplot, three soil samples were sampled with an auger at 10 cm increments: 0 cm, 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. In each site, 45 points were selected and 225 subsamples were recorded and later combined into one soil composite sample per plot and depth. In total 75 composite samples were created in San Román. The 75 samples have been analysed by the Pyrenean Institute of Ecology (IPE-CSIC), evaluating the following soil variables: field bulk density (BD), pH and electrical conductivity (EC), total carbon concentration (Ctotal), total nitrogen concentration (N), carbonate content ($CaCO_3$), organic carbon (Corg), soil organic carbon (SOC) and nitrogen (TN) stocks, organic matter (OM), grain size distribution, organic phosphorus (P), saturated soil moisture (SAT), field capacity (FC), wilting point (WP) and CN ratio.

Figure 14 -Figure *19* present the mean values and standard deviation of the main soil physical and chemical properties (at four depths 0-10, 10-20, 20-30 and > 30 cm) measured in the experimental plots during the initial monitoring variables the pilot plots located in San Román de Cameros (La Rioja). To see all the data, Table 25 supplementary material can be checked.

No significant differences were found between the management plots and the control plots at initial conditions. Significant differences were found between topsoil samples and depth samples in some of the soil properties.

Figure 14 shows that all the samples presented pH values higher than 7, corresponding to basic soils (ranging between 7.5 and 8.5). pH values slightly increased with depth in all the cases, with low variability. In the case of electrical conductivity, mean values ranged between 151 and 464 µs/cm, being these values higher in the topsoil samples, and decreasing with depth.

Organic carbon contents ranged between 1.5 and 7.0%. Contents sharply decreased in depth and significant differences were observed between the topsoil and depth soil samples. Nitrogen contents oscillated between 0.1 and 0.6%, decreasing in all the cases with depth (Figure 15).

Figure 16 presents the CN ratio. Generally, values decreased with depth, but not significant differences were observed between top and depth soil samples. Values ranged between 9.6 and 12. As the case of La Garcipollera, these values indicate that the soil is equilibrated and exist a control between mineral nitrogen and carbon in the soil. Organic P values sharply decreased with depth (Figure 16). Maximum values were around 17 mg/kg P, and minimum values were around 1.1. High standard deviations were recorded in all the cases.

Figure 17 shows the $CaCO_3$ mean contents. Values ranged between 23 and 39%. A general increase was observed with depth, suggesting dilution processes of $CaCO_3$ in the topsoil.

Most of the soil samples presented clay-loam and clay textures (Figure 18). Clay oscillated between 26 and 44%, silt between 25 and 39% and sand content ranged between 19 and 51%.

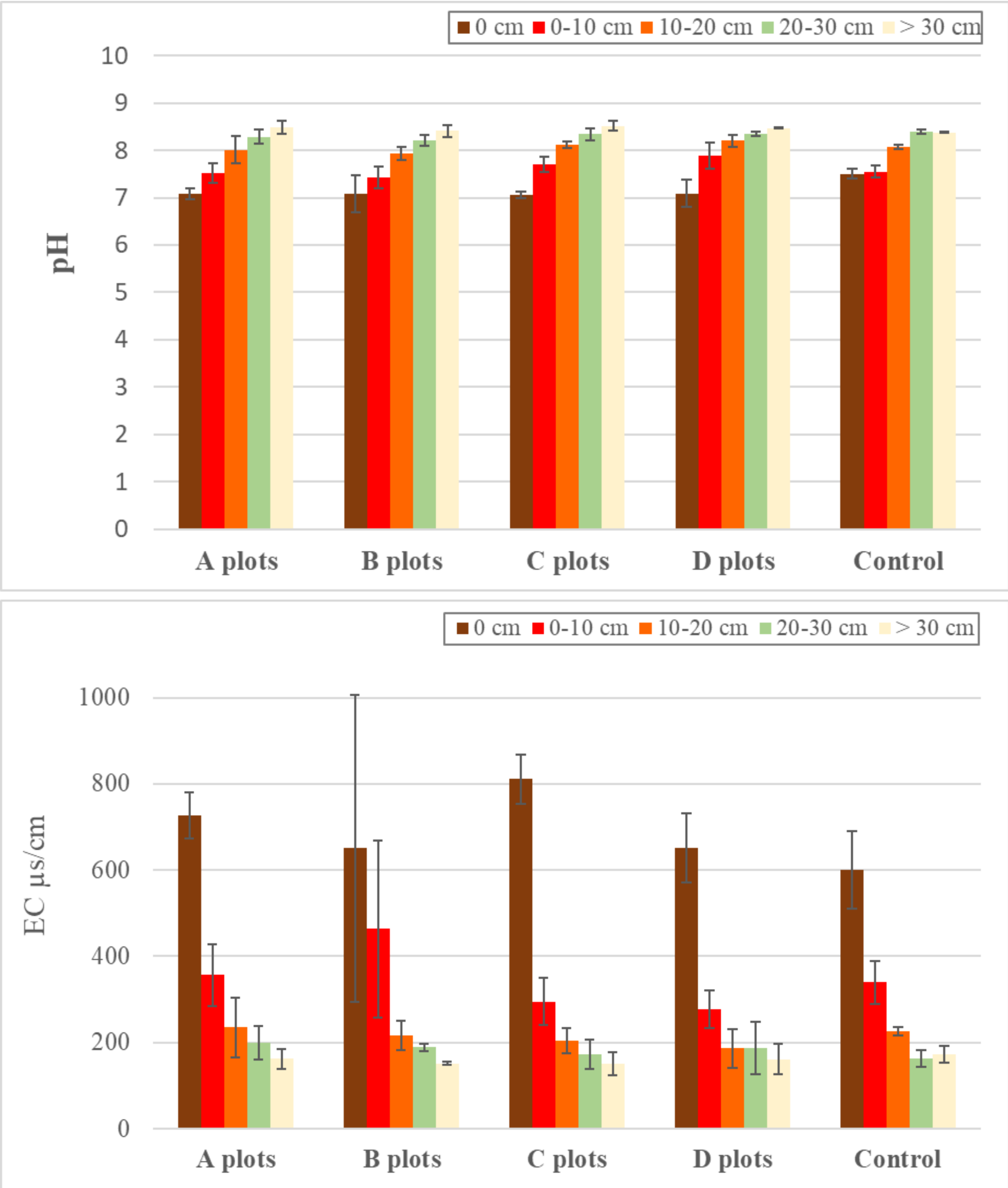


Figure 14. pH and electrical conductivity values of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

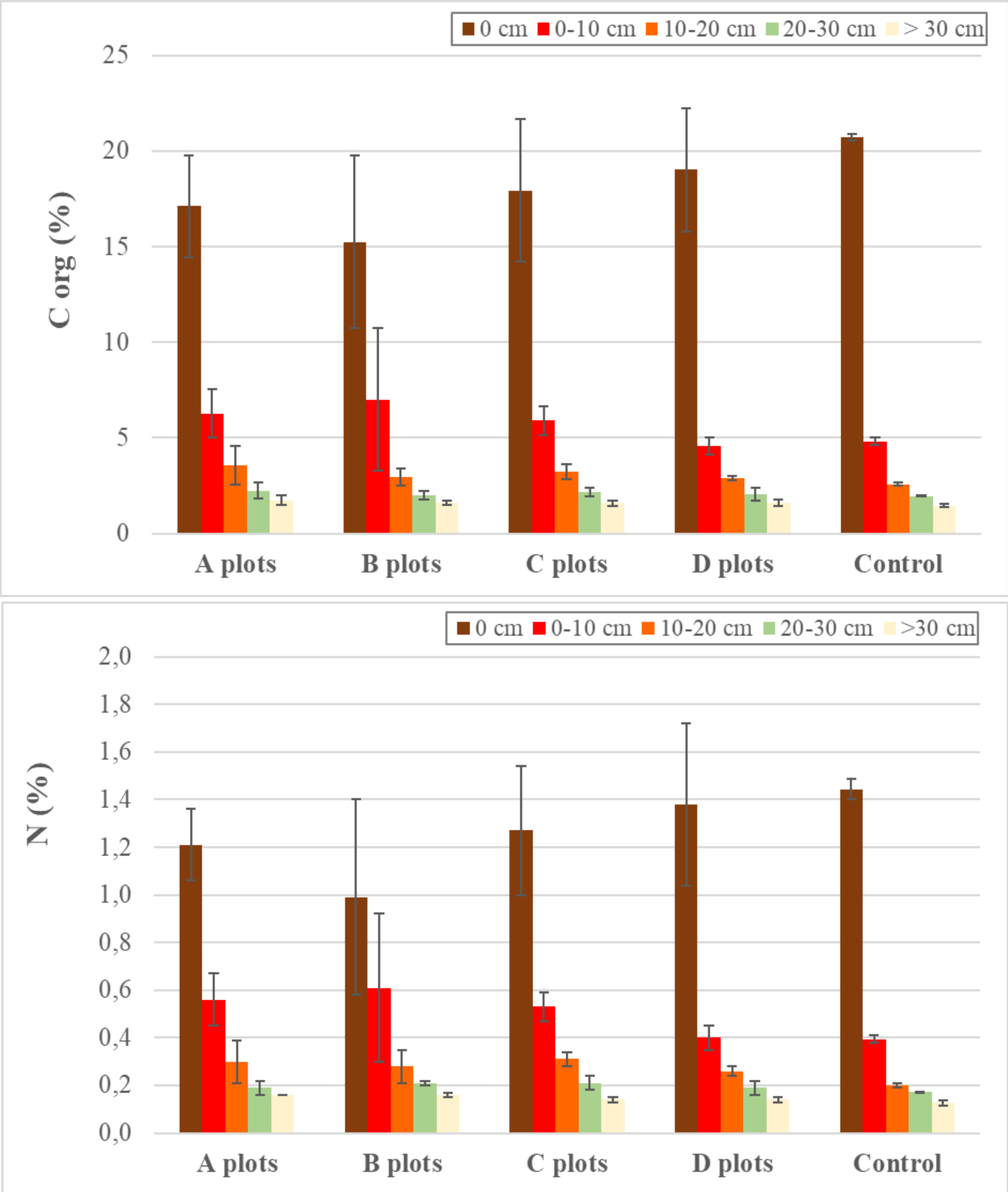


Figure 15. Organic Carbon (C org) and Nitrogen (N) content of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

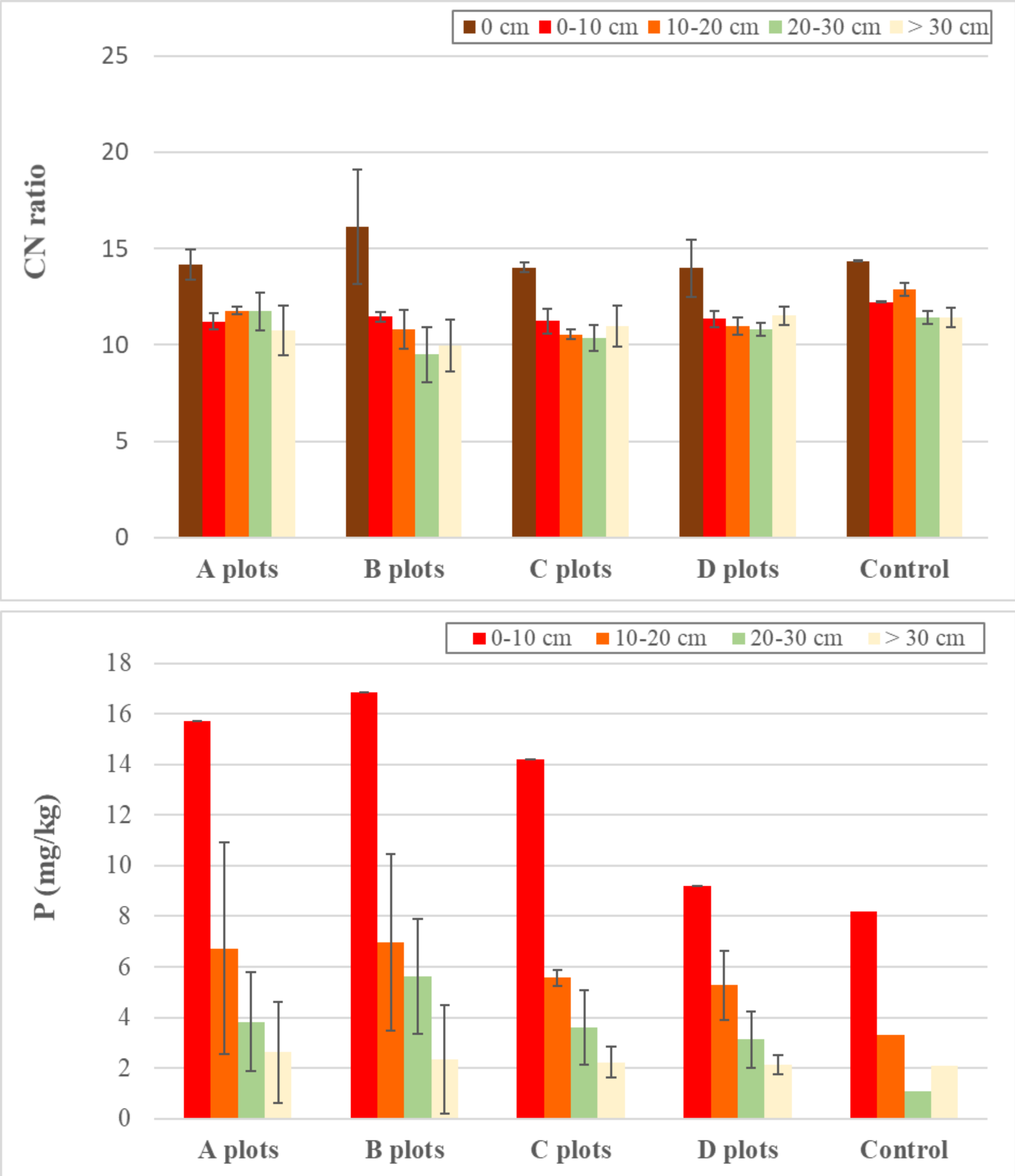


Figure 16. Organic carbon and Nitrogen ratio (CN ratio) and organic phosphorus (P) content of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

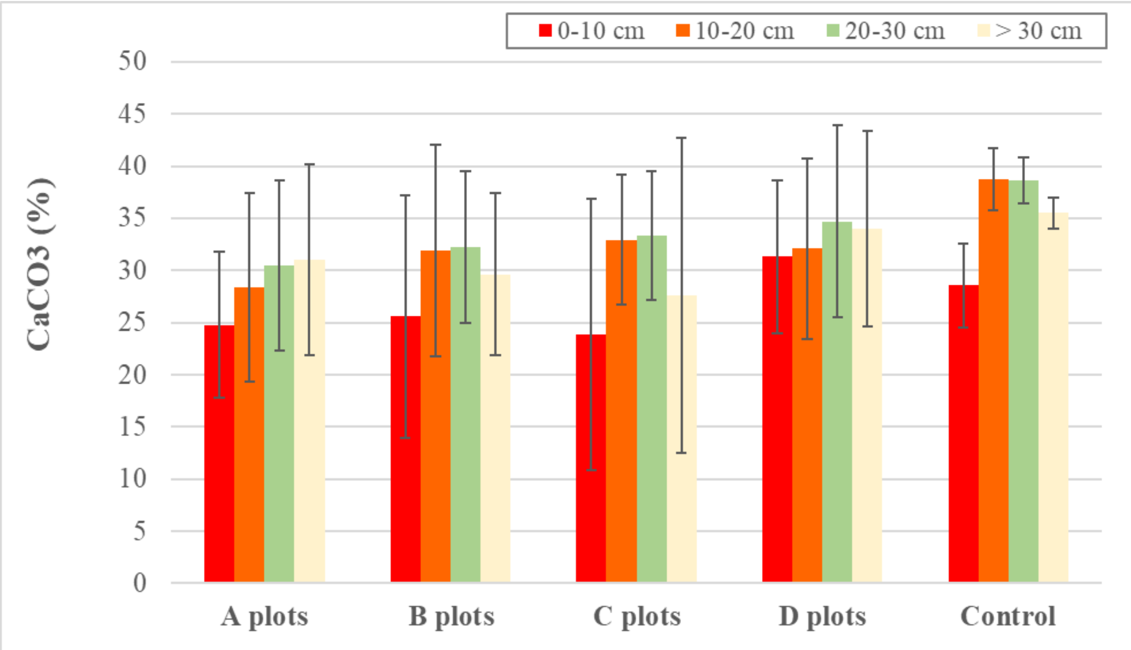


Figure 17. Carbonate content ($CaCO_3$) content of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

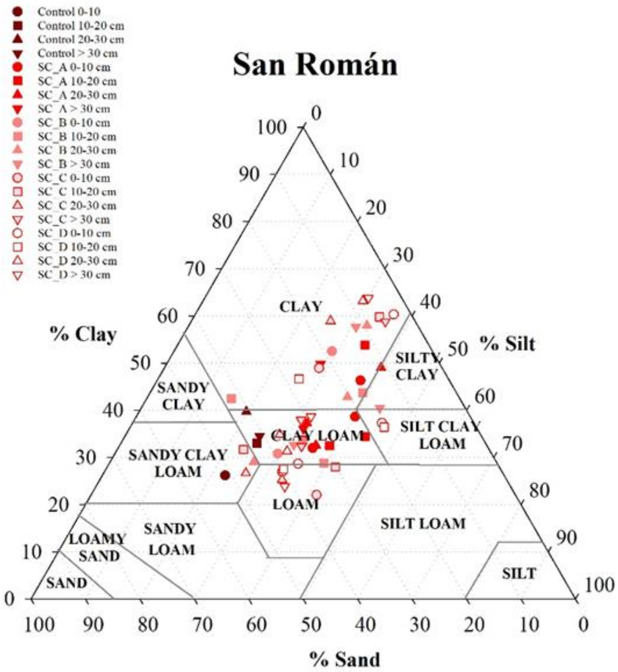


Figure 18. Clay, silt and sand contents (grain size distribution) of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

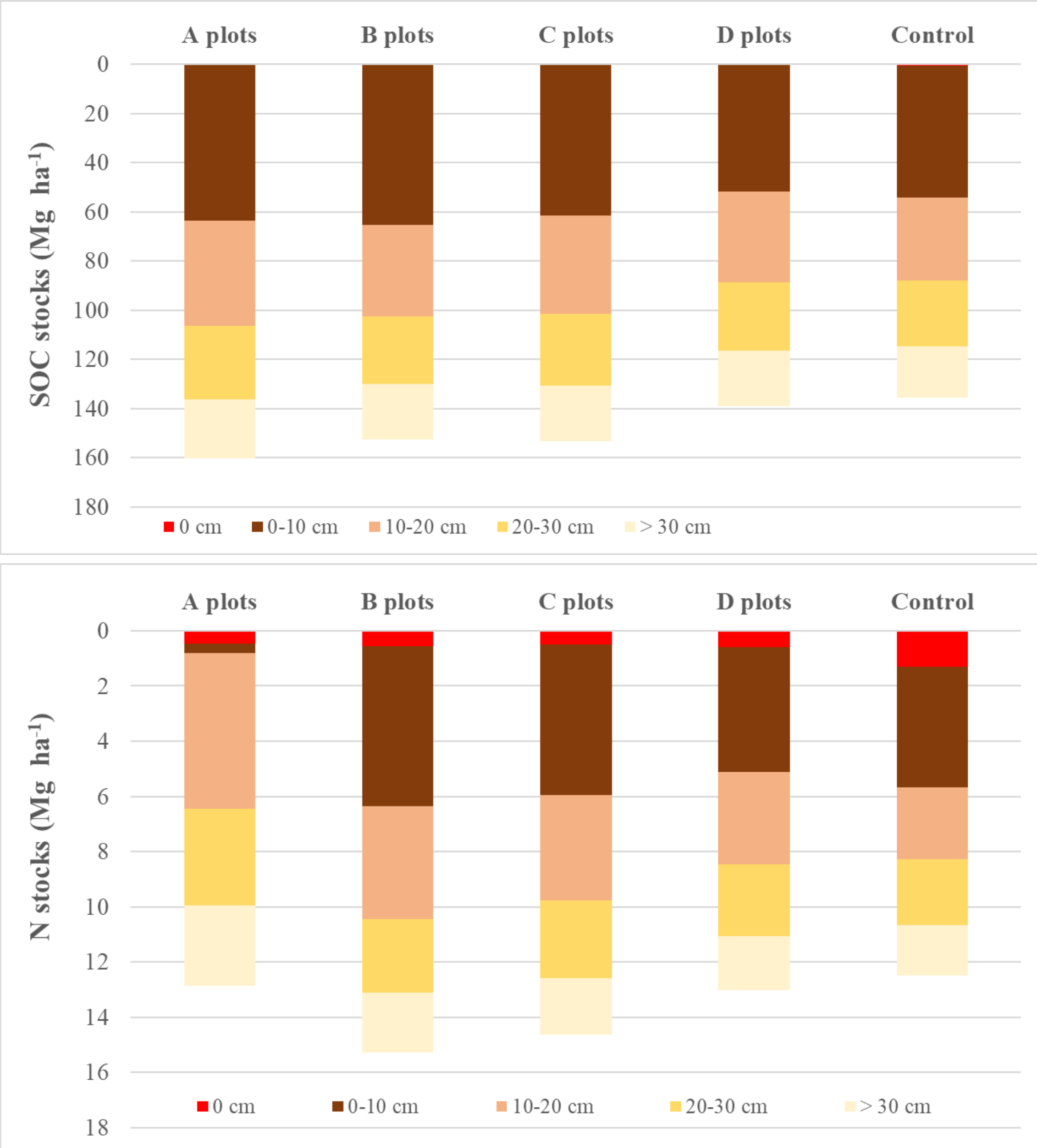


Figure 19. Soil organic carbon (SOC) and nitrogen (N) stocks of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

Figure 19 shows the soil organic carbon and nitrogen stocks per depth and the complete soil profile. No significant differences were observed between the different managements. Total SOC profiles ranged between 140 and 160 Mg ha^{-1} and total nitrogen stocks ranged between 12 and 15 Mg ha^{-1}.

The first-year monitoring campaign that will be carried out at the beginning of 2022 will provide the first results about the changes occurred in the main soil properties related to carbon and nitrogen in the first 10 cm.

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 20). In this case, although 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, which has been working since the new installation.

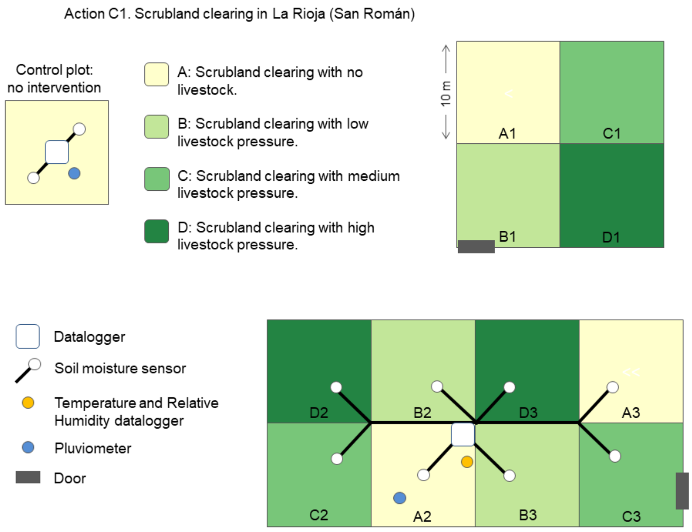


Figure 20. Original monitoring design of the livestock and monitoring subplots.

Figure 21 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.

Despite the lack of data in the first part of the study period (from 04-07-2020 to 19-12-2020) 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 last events (autumn 2021) in which several peaks in soil moisture were observed. We will try to solve this problem through a filling gap statistical procedure using close weather stations located in the area. Differences can be observed between the different treatments, especially during dry periods (see *Figure 21*). However, as we present the first period of data, statistical analyses have not been carried out. Note that next year, when more results will be available, conclusions regarding the comparison among treatments will be drawn.

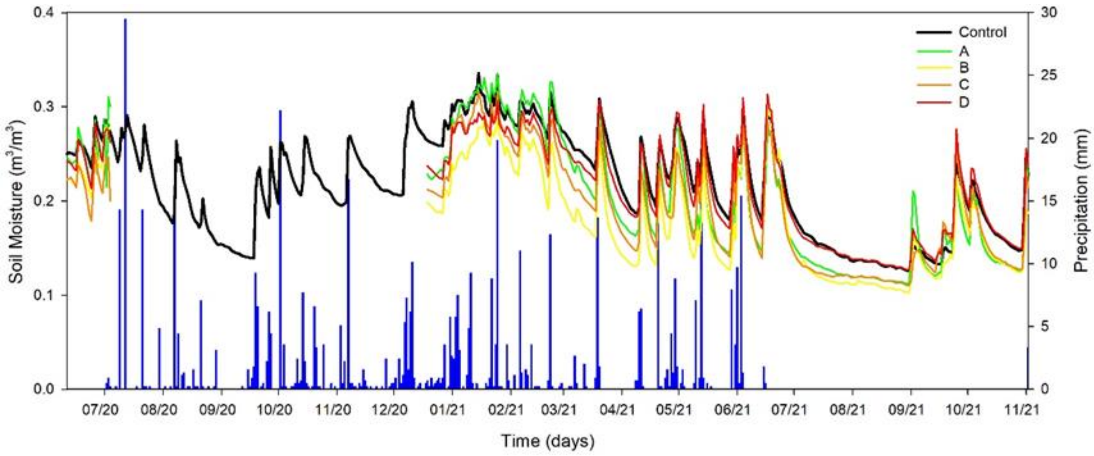


Figure 21. Soil humidity and precipitation in scrubland cleared experimental plot (San Román).

4.2. Monitoring results of the Pastures

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

4.2.1. Biodiversity

Vegetation surveys are carried out in late spring or early summer (May-June). 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 done in June 2022 in order to record the intermediate status of the pastures.

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. Indeed, we found higher herbaceous species richness in subplots submitted to scrubland clearing than in non-managed subplots (Table 10). Specifically, we found significantly more species of chamaephytes and hemichryptophytes and a higher cover of hemichryptophytes and therophytes in the cleared areas compared to the control area. Regarding functional types, we found significantly more forb species and a higher relative cover of legumes and forbs in the cleared areas then in the control plots (Table 10).

On the other hand, we expected not to find any effects of the livestock treatments since in the first year (2020) vegetation surveys were set previous to sheep entry in the plots. As expected, we did not find significant differences between livestock treatments in the majority of the variables studied. However, we found significant differences between treatments in the relative cover of grasses, being significantly higher in the medium grazing intensity than in the low grazing intensity (Table 11). In the following vegetation samplings (intermediate and final), we expect to find more diversity in the plots submitted to low and medium grazing intensity than in the plots not submitted to livestock and submitted to high grazing intensity.

Variables		Control Mean ± SE	Scrubland clearing Mean ± SE	F	p-value
Shannon index		2.30 ± 0.10	2.23 ± 0.04	0.3762	0.5483
Total herbaceous richness		19.56 ± 1.04	15.44 ± 1.20	6.6699	**<0.05***
Chamaephytes	Richness (n)	0.89 ± 0.11	0.11 ± 0.11	24.5	**<0.001*****
	Relative cover (%)	2.22 ± 0.73	0.08 ± 0.08	8.5795	**<0.01****
Hemichryptophytes	Richness (n)	14.89 ± 0.72	11.33 ± 0.60	14.473	**<0.01****
	Relative cover (%)	83.60 ± 3.70	59.84 ± 4.61	16.149	**<0.001*****
Geophytes	Richness (n)	1 ± 0.17	0.89 ± 0.35	0.0816	0.7788
	Relative cover (%)	4.48 ± 2.20	3.68 ± 1.71	0.0826	0.7775
Therophytes	Richness (n)	2.78 ± 0.40	3.11 ± 0.51	0.2628	0.6152
	Relative cover (%)	9.71 ± 2.51	36.40 ± 3.75	35.074	**<0.001*****
Legumes	Richness (n)	3.33 ± 0.33	4.22 ± 0.32	3.6571	0.0739
	Relative cover (%)	20.63 ± 4.73	43.41 ± 3.44	15.179	**<0.01****
Grasses	Richness (n)	4.56 ± 0.67	5.67 ± 0.37	2.1053	0.1661
	Relative cover (%)	42.36 ± 6.70	42.93 ± 3.43	0.0056	0.9414
Forbs	Richness (n)	11.67 ± 0.73	5.56 ± 1.04	23.136	**<0.001*****
	Relative cover (%)	37.01 ± 6.12	13.66 ± 1.52	13.688	**<0.01****

Table 10. Effect of the AFM (scrubland clearing) in biodiversity variables: Shannon index, herbaceous species richness and in the richness and relative cover of the different Raunkiaer lifeforms (chamaephytes, hemichryptophytes, geophytes and therophytes) and in the different functional types (legumes, grasses and other forbs).

Variables		No livestock Mean ± SE	Low Mean ± SE	Medium Mean ± SE	High Mean ± SE	F	p-value
Shannon index		2.23 ± 0.04	2.18 ± 0.04	2.18 ± 0.08	2.13 ± 0.04	0.6541	0.5862
Total herbaceous richness		15.44 ± 1.20	14.33 ± 1.12	15.89 ± 1.38	14.78 ± 0.66	0.3791	0.7687
Chamaephytes	Richness (n)	0.11 ± 0.11	0 ± 0	0.33 ± 0.24	0.44 ± 0.24	1.3008	0.2911
	Relative cover (%)	0.08 ± 0.08	0 ± 0	0.91 ± 0.60	0.27 ± 0.16	1.7123	0.1842
Hemichryptophytes	Richness (n)	11.33 ± 0.60	9.67 ± 0.85	10.89 ± 0.75	10.22 ± 0.64	1.0439	0.3865
	Relative cover (%)	59.84 ± 4.61	60.76 ± 3.38	65.98 ± 2.18	59.93 ± 4.63	0.5832	0.6303
Geophytes	Richness (n)	0.89 ± 0.35	1.11 ± 0.35	1.11 ± 0.35	1 ± 0.24	0.1063	0.9558
	Relative cover (%)	3.68 ± 1.71	5.35 ± 2.81	3.60 ± 1.22	9.61 ± 5.42	0.7624	0.5235
Therophytes	Richness (n)	3.11 ± 0.51	3.56 ± 0.47	3.56 ± 0.41	3.11 ± 0.31	0.3497	0.7896
	Relative cover (%)	36.40 ± 3.75	33.89 ± 4.44	29.51 ± 2.88	30.19 ± 5.22	0.6045	0.6169
Legumes	Richness (n)	4.22 ± 0.32	4.11 ± 0.35	4.22 ± 0.32	4 ± 0.33	0.1019	0.9584
	Relative cover (%)	43.41 ± 3.44	45.57 ± 5.02	38.13 ± 3.71	38.67 ± 4.68	0.7258	0.5441
Grasses	Richness (n)	5.67 ± 0.37	4.89 ± 0.45	5.78 ± 0.40	5.22 ± 0.36	1.0564	0.3813
	Relative cover (%)	42.93 ± 3.43 ab	34.47 ± 2.78 a	47.87 ± 2.74 b	38.66 ± 2.95 ab	3.6669	**<0.05***
Forbs	Richness (n)	5.56 ± 1.04	5.33 ± 0.87	5.89 ± 1.02	5.56 ± 0.69	0.0626	0.9792
	Relative cover (%)	13.66 ± 1.52	19.95 ± 4.15	14.05 ± 2.26	22.67 ± 5.78	1.3619	0.272

Table 11. Livestock effect on the scrubland cleared areas in biodiversity variables: Shannon index, herbaceous species richness and in the richness and relative cover of the different Raunkiaer lifeforms (chamaephytes, hemichryptophytes, geophytes and therophytes) and in the different functional types (legumes, grasses and other forbs).

4.2.2. Pasture production and quality

Pasture production and quality samplings are carried out in late spring or early summer (May-June). We aim to record the pasture production and quality in an initial status and in a final status (intermediate status is not recorded since cumulative effects on the pastures are not significant after one year, only). The first sampling was done in June 2020 in order to record the initial status of the pasture in the experimental plots. The final status of the experimental plots will be recorded in 2023.

In the first sampling, we expected to find a positive effect of the scrubland clearing in the production and quality of the herbaceous pasture because of the elimination of woody competitors for light, space and nutrients. We expect that this positive effect of scrubland clearing will maintain over time in the experimental plots. As expected, we found significantly more biomass production in the areas submitted to scrubland clearing than in the control (Table 12). We also found significant differences between treatments in crude protein (CP), neutral-detergent fibers (NDF), acid-detergent ashes (ADA), dry matter intake (DMI) and relative feed value (RFV). Specifically, we found higher crude protein, dry matter intake and relative feed value and lower fibers (NDF and ADA) in the scrubland clearing subplots than in the control (Table 12), which explains a higher pasture feed quality in scrubland clearing areas.

	Control	Scrubland clearing		
Variables	**Mean ± SE**	**Mean ± SE**	**F**	**p-value**
Biomass (kg DM/ha)	925.37 ± 146.51	3842.59 ± 553.43	25.97	**<0.001*** **
CP (%)	10.95 ± 0.29	14.51 ± 0.48	37.505	**<0.001*** **
Cellulose (%)	24.09 ± 0.56	22.85 ± 0.52	2.6257	0.126
Hemicellulose (%)	24.69 ± 0.68	23.08 ± 0.58	3.256	0.091
NDF (%)	54.14 ± 1.04	51.19 ± 0.83	4.9861	**<0.05***
ADF (%)	29.45 ± 0.44	28.11 ± 0.50	3.9725	0.0648
ADL (%)	5.36 ± 0.24	5.26 ± 0.19	0.0958	0.7612
ADA (%)	1.29 ± 0.13	0.80 ± 0.06	11.905	**<0.01****
DMI	2.22 ± 0.04	2.35 ± 0.04	4.8501	**<0.05***
DDM	65.96 ± 0.34	67.00 ± 0.39	3.9525	0.0654
RFV	113.70 ± 2.77	122.08 ± 2.57	4.9272	**<0.05***

*Table 12. Biomass production and nutritive quality variables in non-managed plots with no livestock and managed plots with no livestock. * Variables: CP=crude protein; Cel=cellulose; Hemi=hemicellulose; NDF=neutral-detergent fiber; ADF=acid-detergent fiber; ADL=acid-detergent lignin; ADA=acid-detergent ashes; DMI= dry matter intake; DDM= digestible dry matter; RFV = relative feed value*

Contrarily, in the initial status (2020), we expected not to find any effects of the livestock treatments in the herbaceous pasture, neither in production nor in quality since vegetation samples (and their subsequent processing and analyses) were collected previous to the entry of the cows. According to what expected, we did not observe significant differences between livestock treatments neither in the herbaceous biomass production nor in the nutritive quality variables measured (Table 13), except for acid-detergent fibers, which are significantly higher in the high grazing intensity than in the low grazing intensity.

	No livestock	Low	Medium	High		
Variables	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**	**F**	**p-value**
Biomass (kg DM/ha)	3842.6 ± 553.4	3797.9 ± 390.2	3914.8 ± 245.3	2941.5 ± 266.2	1.4213	0.2547
CP (%)	14.51 ± 0.48	14.46 ± 0.4	13.73 ± 0.57	13.35 ± 0.74	1.0271	0.3936
Cellulose (%)	22.85 ± 0.52	23.76 ± 0.77	23.74 ± 0.52	24.54 ± 0.99	0.9031	0.4504
Hemicellulose (%)	23.08 ± 0.58	23.66 ± 0.82	24.01 ± 0.91	20.84 ± 1.89	1.4985	0.2337
NDF (%)	51.19 ± 0.83	51.90 ± 1.37	52.77 ± 1.16	51.20 ± 2.19	0.2584	0.8548
ADF (%)	28,11 ± 0.50	28.24 ± 0.76	28.76 ± 0.49	30.35 ± 1.05	1.945	0.1422
ADL (%)	5.26 ± 0.19 ab	4.48 ± 0.28 a	5.01 ± 0.32 ab	5.81 ± 0.34 b	3.6375	**<0.05***
ADA (%)	0.80 ± 0.06	0.86 ± 0.09	0.95 ± 0.10	0.80 ± 0.07	0.7788	0.5145
DMI	2.35 ± 0.04	2.32 ± 0.06	2.28 ± 0.05	2.38 ± 0.11	0.338	0.798
DDM	67.00 ± 0.39	66.90 ± 0.59	66.50 ± 0.38	65.26 ± 0.82	1.9433	0.1425
RFV	122.08 ± 2.57	120.78 ± 4.19	117.75 ± 3.13	120.68 ± 6.19	0.1851	0.9057

*Table 13. Biomass production and nutritive quality variables in scrubland clearing plots with no livestock and scrubland clearing plots with livestock. * Variables: CP=crude protein; Cel=cellulose; Hemi=hemicellulose; NDF=neutral-detergent fiber; ADF=acid-detergent fiber; ADL=acid-detergent lignin; ADA=acid-detergent ashes; DMI= dry matter intake; DDM= digestible dry matter; RFV = relative feed value*

4.3. Monitoring results of Rainfall simulations

In La Rioja, the first experiments were carried in July 2020 in order to monitor the initial conditions, i.e., in the cleared subplots without grazing (A) and in the control subplots. In November and December 2020, after the livestock grazed for the third time within the year, new rainfall simulations were performed in all the subplots and the control subplots.

Under initial conditions, there was no hydrological response in the scrubland nor the A subplots (cleared without grazing). This may be partly due to the low hillslope gradient of the subplots. The response at the end of the year, after the livestock has grazed for the third time, was also very limited, with no runoff and no sediment except for the subplot with the highest livestock density (D) that show a RC of 0.35, a SC of 0.10 g/l and a SD of 2.25 g/m/h (Table 17).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
San Román	Control	0.00	12.10	NA	4.5	0.00	0.00	0.00
	Cleared without livestock (A)	0.00	15.45	NA	4.5	0.00	0.00	0.00
		0.00	11.66	NA	5	0.00	0.00	0.00
		0.00	20.40	NA	5	0.00	0.00	0.00

Table 14. All hydrogeological and sedimentological variables extracted from rainfall simulations in San Román in July 2020 (initial conditions). Simulations without runoff are represented in Time to runoff variable with a NA and with a 0 value in Sediment concentration, production, and detachment. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
San Román	Control	0.00	12.10	NA	5	0.00	0.00	0.00
	Cleared without livestock (A)	0.00±0.00	15.84±4.38	NA	5±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table 15. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in July 2020 (initial conditions). Control San Román with n=1 and A with n=3. All values represent mean ± standard error. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
San Román	Control	0.00	41.33	NA	6	0.00	0.00	0.00
		0.00	7.84	NA	2	0.00	0.00	0.00
		0.00	36.63	NA	10	0.00	0.00	0.00
	Cleared without livestock (A)	0.00	24.94	NA	2	0.00	0.00	0.00
		0.00	11.14	NA	2	0.00	0.00	0.00
		0.00	13.58	NA	1	0.00	0.00	0.00
	Cleared with low pressure (B)	0.00	13.20	NA	7	0.00	0.00	0.00
		0.00	31.24	NA	6	0.00	0.00	0.00
	Cleared with medium pressure (C)	0.00	37.46	NA	8	0.00	0.00	0.00
		0.00	18.26	NA	8	0.00	0.00	0.00
		0.00	32.33	NA	7	0.00	0.00	0.00
	Cleared with high pressure (D)	0.00	25.20	NA	6	0.00	0.00	0.00
		1.04	43.35	11	6	0.31	0.14	6.76
		0.00	14.90	NA	4	0.00	0.00	0.00

Table 16. All hydrogeological and sedimentological variables extracted from rainfall simulations in San Roman in November and December 2020. Simulations without runoff are represented in Time to runoff variable with a NA and with a 0 value in Sediment concentration, production, and detachment. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
San Román	Control	0.00±0.00	28.60±18.3	NA	6±4.00	0.00±0.00	0.00±0.00	0.00±0.00
	Cleared without livestock (A)	0.00±0.00	16.55±7.37	NA	1±0.29	0.00±0.00	0.00±0.00	0.00±0.00
	Cleared with low pressure (B)	0.00±0.00	22.22±12.75	NA	7±0.71	0.00±0.00	0.00±0.00	0.00±0.00
	Cleared with medium pressure (C)	0.00±0.00	29.35±9.94	NA	8±0.58	0.00±0.00	0.00±0.00	0.00±0.00
	Cleared with high pressure (D)	0.35±0.60	27.82±14.40	11±0.00	5±1.44	0.10±0.18	0.05±0.08	2.25±3.90

Table 17. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in November and December 2020. All values have a n=3, except in San Román B with n=2. All values represent mean ± standard error. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

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 (19 months). Two Temperature/Relative Humidity sensors were installed, one in the experimental plots (T1) and the other under a tree (T2) closed to the experimental plots, and a rain gauge, to analyse differences between sites. In this period, until 02-12-2021, the maximum temperature has been 40.3 and 38.6 ºC for T1 and T2 respectively (14-08-2021), and the minimum -10.3 and -9.1 ºC for T1 and T2 respectively (07-01-2021; 08-01-2021) (see Figure 22).

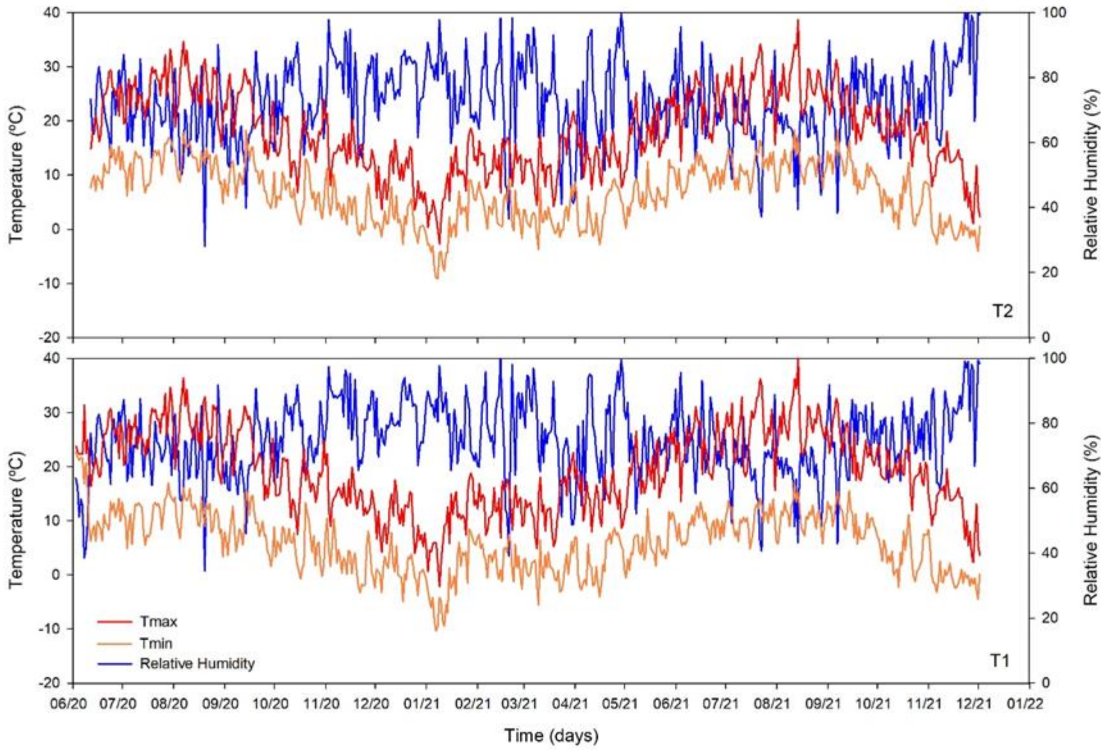


Figure 22. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plots in San Román (La Rioja).

Figure 23 shows monthly averages of maximum and minimum temperature and mean monthly precipitation for the period 06-2020 to 12-2021 (19 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 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.

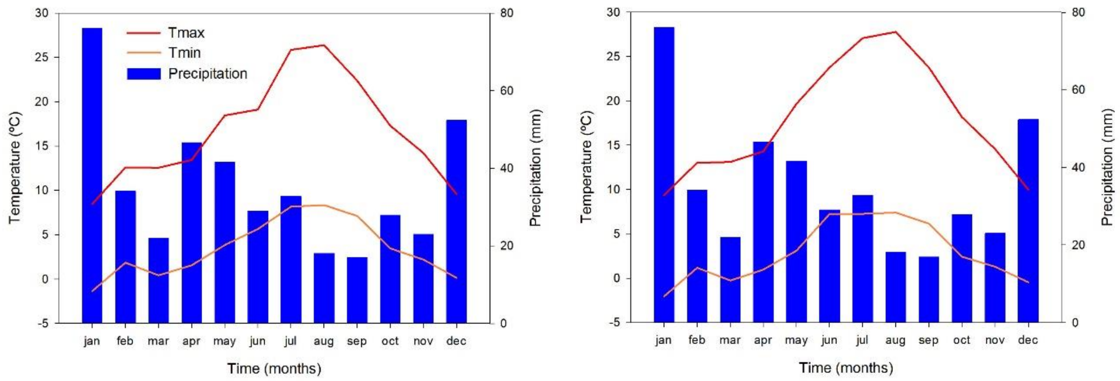


Figure 23. Climogram scrubland cleared experimental plot (San Roman). Left: T2 - under a tree, right: T1 - in the subplot A2.

5. Results of the initial monitoring variables and the 1st 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.

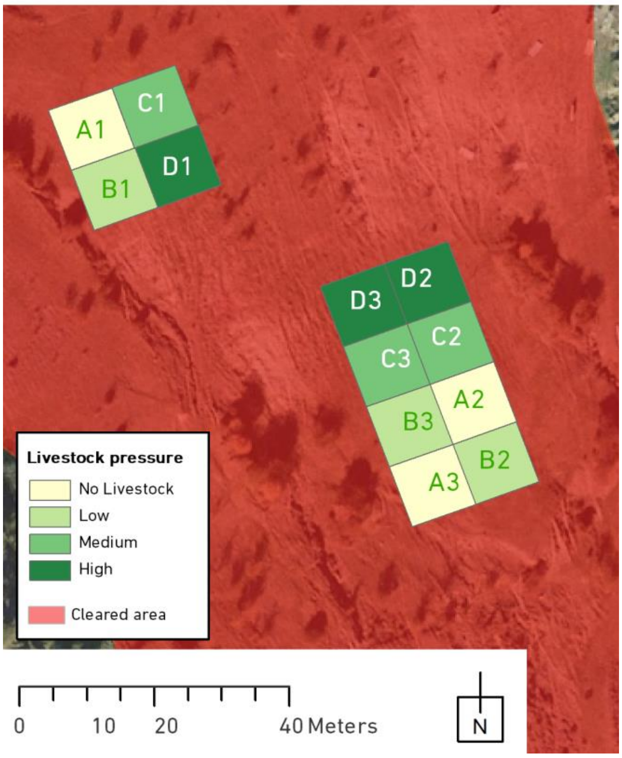
We include a summary of the implemented pilot experience and the experimental design of the monitoring network, to facilitate the understanding of the monitoring results. A more detailed description of the implemented actions can be consulted in Nadal-Romero *et al.* (2019, 2020a, 2020b).

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 24. Location of the monitoring plots and replicates of the experimental design.

5.1. Monitoring results of the Soil

5.1.1. Soil characteristics

The first soil samplings were carried out in June 2020 and the first year monitoring campaign is going to be carried out at the beginning of 2022, once the animals have entered three times in the experimental plots during the second year of livestock grazing (spring, summer and autumn 2021).

At each monitoring subplot, three soil samples were sampled with an auger at 10 cm increments: 0 cm, 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. In each site, 45 points were selected and 225 subsamples were recorded and later combined into one soil composite sample per plot and depth. In total 75 composite samples were created in Ajamil. The 75 samples have been analysed by the Pyrenean Institute of Ecology (IPE-CSIC), evaluating the following soil variables: Field bulk density (BD), pH and electrical conductivity (EC), total carbon concentration (Ctotal), total nitrogen concentration (N), carbonate content ($CaCO_3$), organic carbon (Corg), soil organic carbon (SOC) and nitrogen (TN) stocks, organic matter (OM), grain size distribution, organic phosphorus (P), saturated soil moisture (SAT), field capacity (FC), wilting point (WP) and CN ratio.

Figure 25 -Figure 29 present the mean values and standard deviation of the main soil physical and chemical properties (at four depths 0-10, 10-20, 20-30 and > 30 cm) measured in the experimental plots during the initial monitoring variables in the pilot plots located in Ajamil de Cameros (La Rioja). To see all the data, Table 26 supplementary material can be checked.

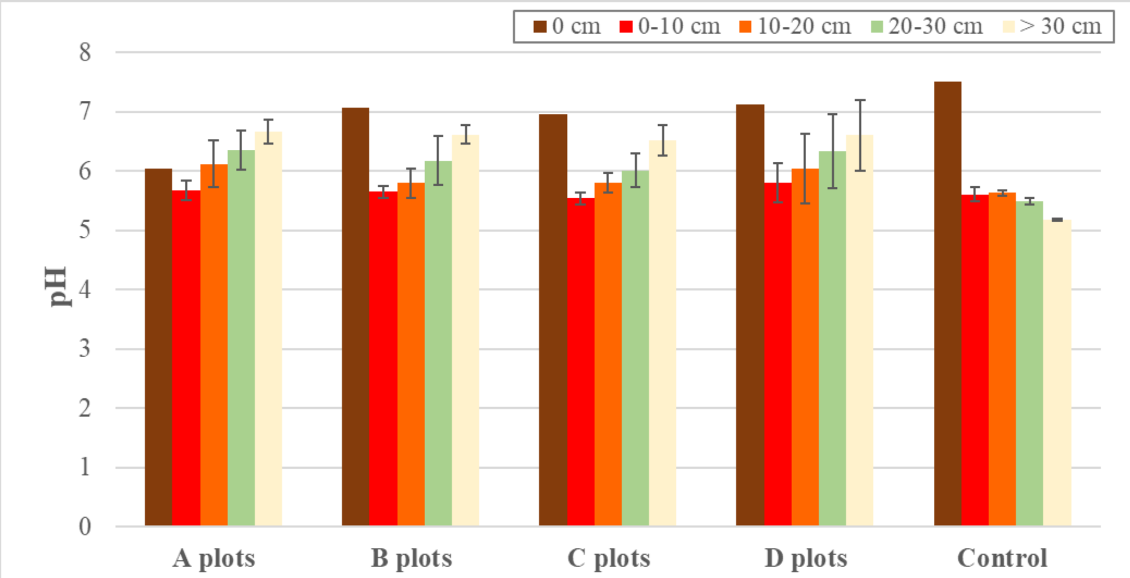
Significant differences were found between the management subplots and the control subplots at initial conditions in some of the physical and chemical variables (i.e. organic carbon content and SOC). We hypothesized that differences between control subplots and management subplot were related to geographical conditions due to the different location between the subplots (i.e. higher altitude in the control plot area). Also, significant differences were found between topsoil samples and depth samples in some of the soil properties.

Figure 25 shows that all the samples presented pH values lower than 7, corresponding to acid soils (ranging between 5.5. and 6.7). pH values slightly increased with depth in all the cases (except in the control plot), with low variability. In the case of electrical conductivity, mean values ranged between 56 and 153 µs/cm, being these values higher in the organic soil samples (0 cm), and decreasing with depth.

Organic carbon contents sharply decreased in depth and significant differences were observed between the topsoil and depth soil samples and between control subplot and management subplots. Values ranged between 2 and 5.1% in the control subplot and between 0.7 and 2.1 in the management subplots. Nitrogen contents oscillated between 0.1 and 0.4%, decreasing in all the cases with depth (see Figure 26).

CN ratio values showed a high variability. Generally, values increased with depth, but not significant differences were observed between top and depth soil samples. Values ranged between 5.2 and 15 (Figure 27). As in the case of La Garcipollera, these values indicate that the soil is equilibrated and exist a control between mineral nitrogen and carbon in the soil. P values sharply decreased in depth. Maximum values were around 7 mg/kg P, and minimum values are around 0.9. High standard deviations were recorded in all the cases (Figure 28).

Most of the soil samples presented silt-loam texture with high values of silt content (between 43 and 67%). Clay oscillated between 22 and 38% and % and sand content ranged between 9 and 21% (Figure 28).



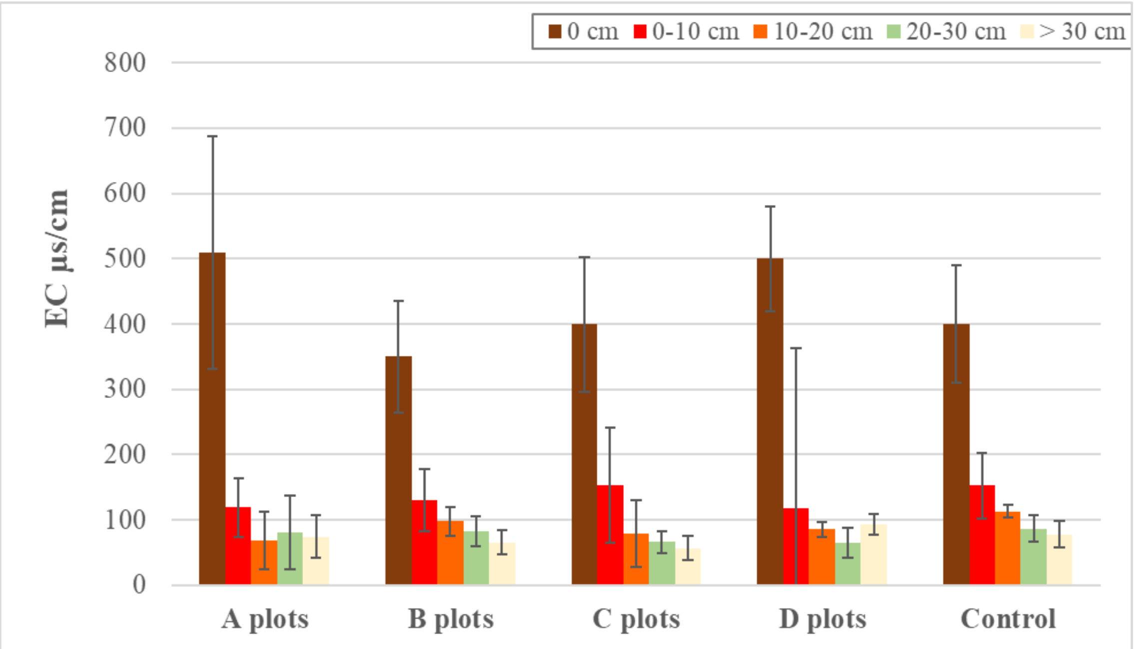


Figure 25. pH and electrical conductivity values of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

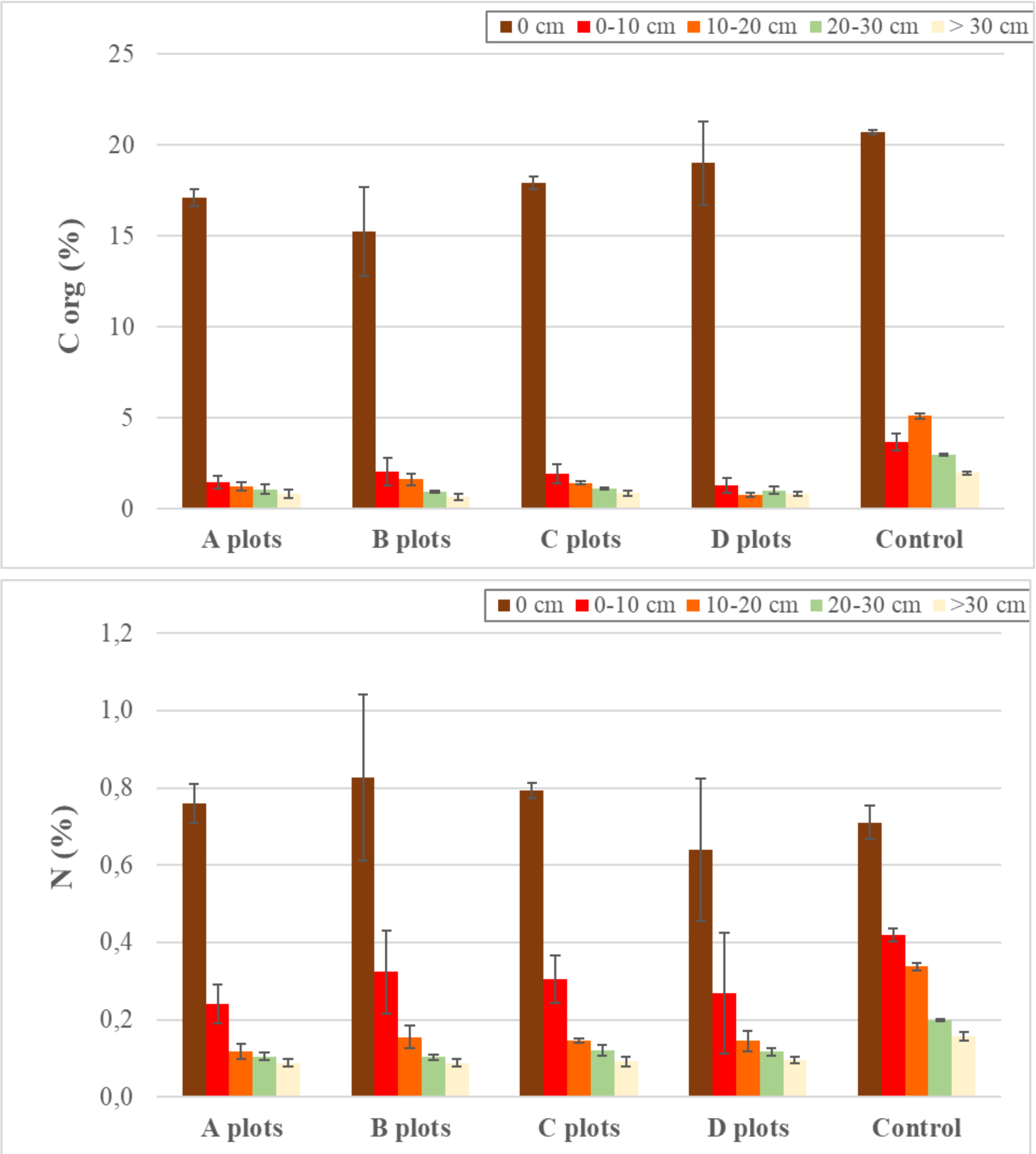


Figure 26. Organic Carbon (C org) and Nitrogen (N) content of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

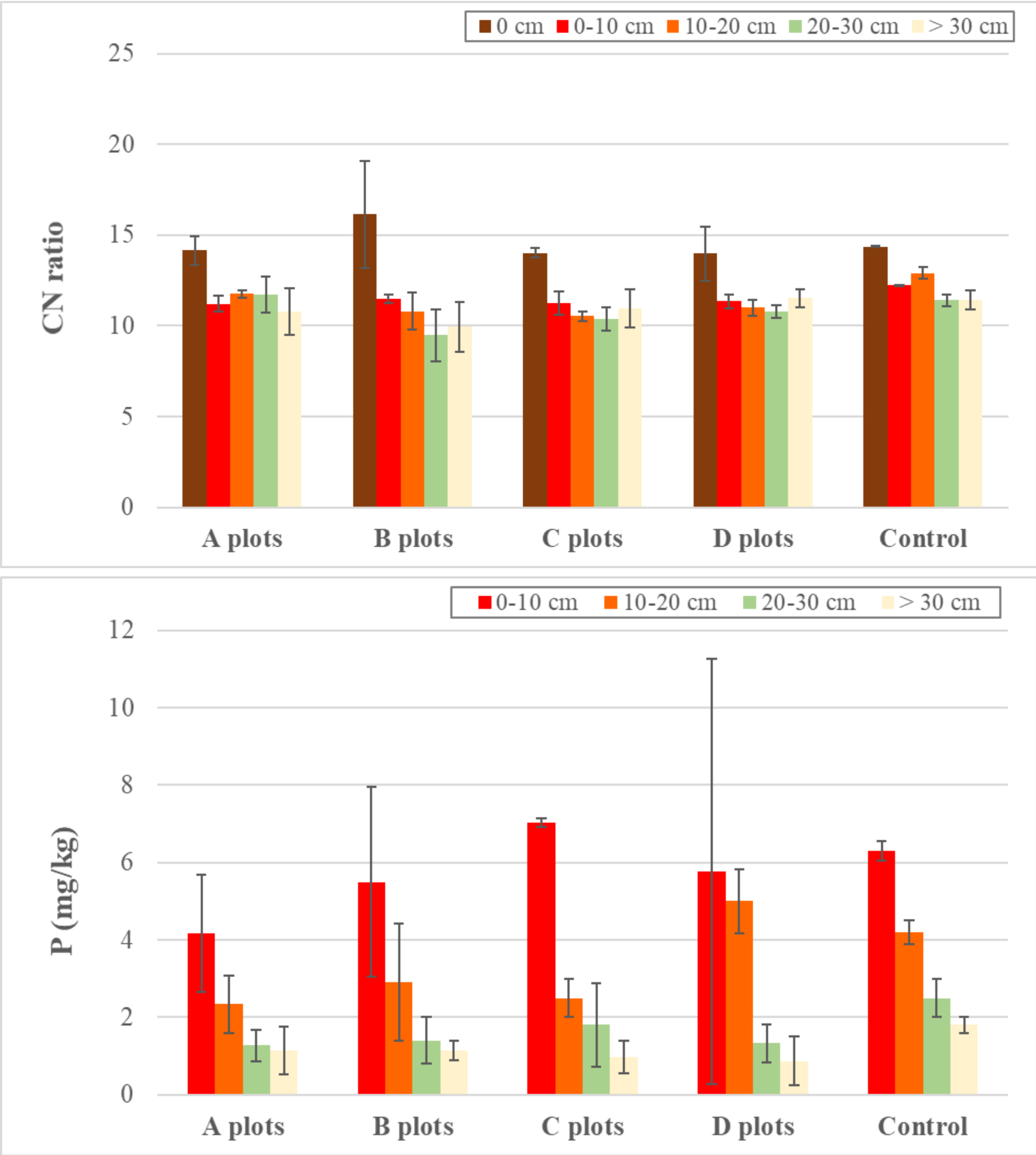


Figure 27. Organic carbon and Nitrogen ratio (CN ratio) and phosphorus (P) content of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

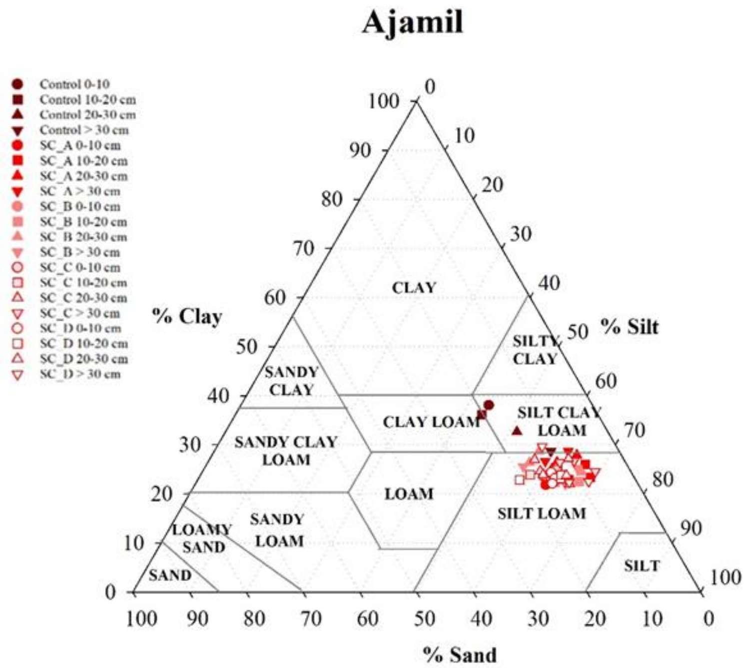


Figure 28. Clay, silt and sand contents (texture) of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

Figure 29 shows the soil organic carbon and nitrogen stocks per depth and the complete soil profile. Significant differences were observed between the different managements. Total SOC profiles ranged between 60 and 80 Mg ha-1 in the management plots and stocks higher than 140 were recorded in the control plot (Figure 29). Total nitrogen stocks ranged between 5 and 11 Mg ha-1 and in the control plot values are close to 14 Mg ha-1.

The first-year monitoring campaign that will be carried out at the beginning of 2022 will provide the first results about the changes occurred in the main soil properties related to carbon and nitrogen in the first 10 cm.

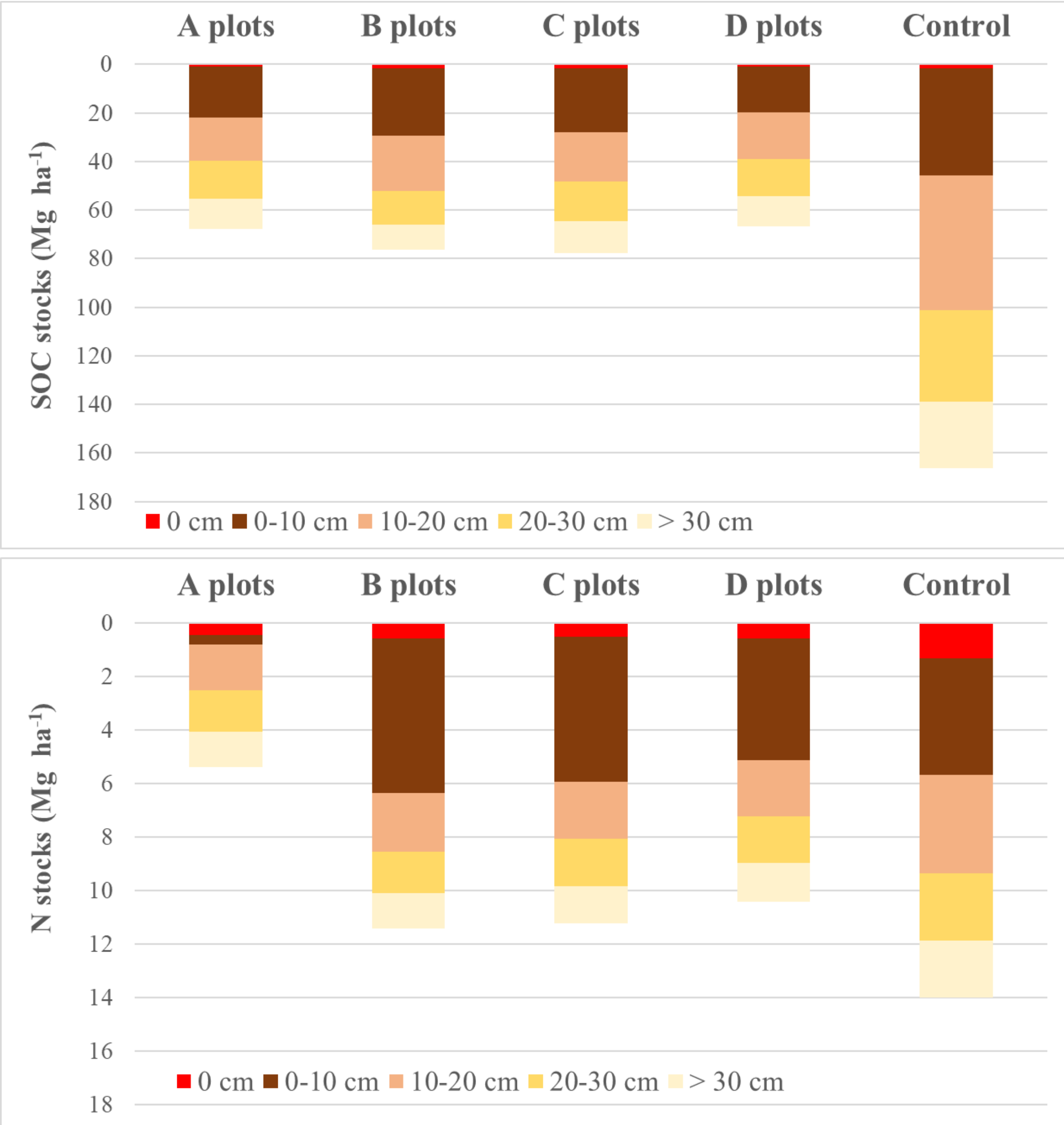


Figure 29. Soil organic carbon (SOC) and nitrogen (N) stocks of soil samples at four depths (0-10, 10-20, 20-30 and 30-40 cm) and in the different plots (A, B, C and D and control plots).

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 30).

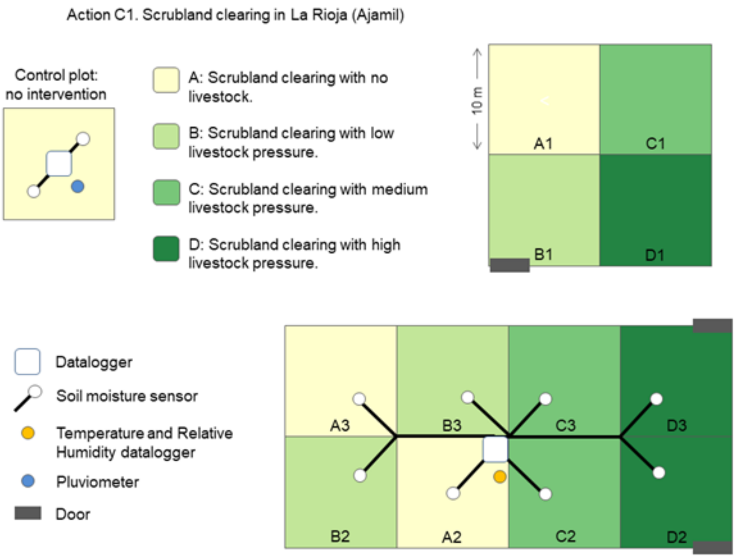


Figure 30. Diagram of the livestock and monitoring subplots.

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 San Román 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.

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. However, as we present the first period of data, statistical analyses have not been carried out. Note that next year, when more results will be available, conclusions regarding the comparison among treatments will be drawn.

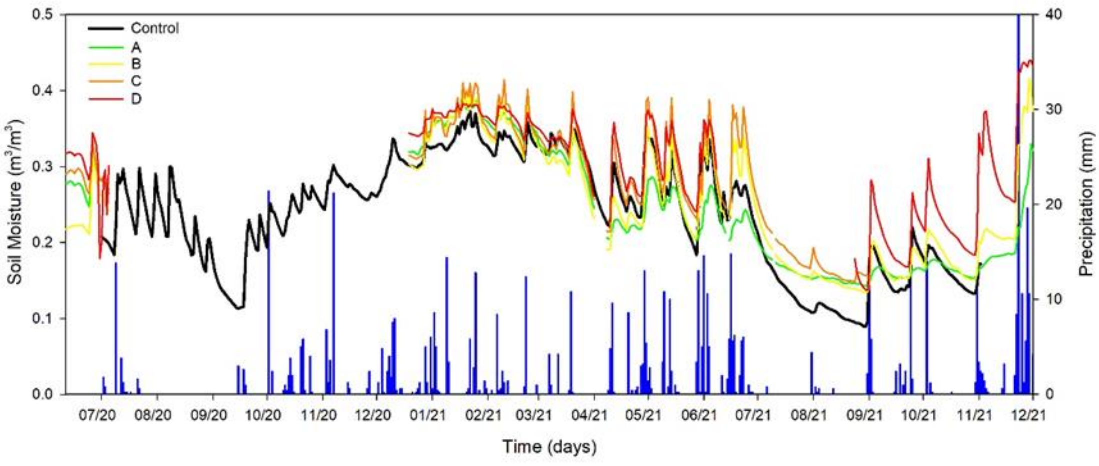


Figure 31. Soil humidity and precipitation in scrubland cleared experimental plot (Ajamil).

5.2. Monitoring results of the Pastures

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

5.2.1. Biodiversity

Vegetation surveys are carried out in late spring or early summer (May-June). 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 done in June 2022 in order to record the intermediate status of the pastures.

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. Although we did not find significant differences between treatments neither in the Shannon diversity index nor in the total herbaceous richness, we found significantly higher chamaephyte richness and relative cover in the control areas than in the scrubland clearing subplots (Table 18). Regarding functional types, we found significantly more legume species in the control area than in the scrubland clearing subplots.

Variables		Control Mean ± SE	Scrubland clearing Mean ± SE	F	p-value
Shannon index		2.50 ± 0.05	2.49 ± 0.06	0.0367	0.8505
Total herbaceous richness		19.33 ± 1.03	18.67 ± 0.90	0.2388	0.6317
Chamaephytes	Richness (n)	0.56 ± 0.18	0.11 ± 0.11	4.5714	**<0.05***
	Relative cover (%)	0.54 ± 0.20	0.07 ± 0.07	4.9266	**<0.05***
Hemichryptophytes	Richness (n)	13.56 ± 0.77	12.44 ± 0.91	0.8677	0.3654
	Relative cover (%)	68.24 ± 3.70	59.75 ± 3.21	3.006	0.1022
Geophytes	Richness (n)	0.22 ± 0.15	0.56 ± 0.24	1.3846	0.2565
	Relative cover (%)	0.62 ± 0.42	0.80 ± 0.40	0.095	0.7618
Therophytes	Richness (n)	4.89 ± 0.39	5.56 ± 0.50	1.0992	0.31
	Relative cover (%)	29.61 ± 4.28	39.38 ± 3.13	3.3899	0.0842
Legumes	Richness (n)	5.11 ± 0.42	4.11 ± 0.20	4.5634	**<0.05***
	Relative cover (%)	34.09 ± 4.34	34.81 ± 4.10	0.0146	0.9052
Grasses	Richness (n)	6.33 ± 0.53	6.44 ± 0.34	0.0315	0.8614
	Relative cover (%)	40.12 ± 3.43	45.11 ± 3.66	0.9918	0.3341
Forbs	Richness (n)	7.78 ± 0.74	8.11 ± 0.73	0.102	0.7536
	Relative cover (%)	24.80 ± 3.81	20.08 ± 1.73	1.2792	0.2747

Table 18. Effect of the AFM (scrubland clearing) in biodiversity variables: Shannon index, herbaceous species richness and in the richness and relative cover of the different Raunkiaer lifeforms (chamaephytes, hemichryptophytes, geophytes and therophytes) and in the different functional types (legumes, grasses and other forbs).

On the other hand, we expected not to find any effects of the livestock treatments since in the first year (2020) vegetation surveys were set previous to sheep entry in the plots. As expected, we did not find significant differences between livestock treatments in none of the variables studied (Table 19). In the following vegetation samplings (intermediate and final), we expect to find more diversity in the plots submitted to low and medium grazing intensity than in the plots not submitted to livestock and submitted to high grazing intensity.

		No livestock	Low	Medium	High		
Variables		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	F	p-value
Shannon index		2.49 ± 0.06	2.43 ± 0.04	2.46 ± 0.05	2.36 ± 0.04	1.2048	0.3238
Total herbaceous richness		18.67 ± 0.90	19.11 ± 0.68	18.11 ± 0.45	18.56 ± 0.65	0.3573	0.7842
Chamaephytes	Richness (n)	0.11 ± 0.11	0.33± 0.17	0 ± 0	0.11 ± 0.11	1.4902	0.2359
	Relative cover (%)	0.07 ± 0.07	0.16 ± 0.08	0 ± 0	0.05 ± 0.05	1.2943	0.2932
Hemichryptophytes	Richness (n)	12.44 ± 0.91	12.78 ± 0.52	12.44 ± 0.47	12 ± 0.58	0.2444	0.8647
	Relative cover (%)	59.75 ± 3.21	56.67 ± 1.93	51.29 ± 3.01	54.17 ± 1.78	1.977	0.1372
Geophytes	Richness (n)	0.56 ± 0.24	0.67 ± 0.17	0.33 ± 0.17	0.67 ± 0.17	0.6957	0.5615
	Relative cover (%)	0.80 ± 0.40	0.53 ± 0.15	0.58 ± 0.36	1.54 ± 0.57	1.3618	0.2721
Therophytes	Richness (n)	5.56 ± 0.50	5.33 ± 0.44	5.33 ± 0.29	5.78 ± 0.28	0.2978	0.8267
	Relative cover (%)	39.38 ± 3.13	42.63 ± 1.91	48.13 ± 3.15	44.24 ± 1.78	1.9953	0.1345
Legumes	Richness (n)	4.11 ± 0.20	4.33 ± 0.29	4.44 ± 0.18	4.22 ± 0.28	0.3556	0.7854
	Relative cover (%)	34.81 ± 4.10	39 ± 3.28	41.56 ± 2.64	47.66 ± 2.98	2.6618	0.0647
Grasses	Richness (n)	6.44 ± 0.34	6.67 ± 0.44	6.56 ± 0.38	6.67 ± 0.29	0.0848	0.9679
	Relative cover (%)	45.11 ± 3.66	41.55 ± 4.05	41.07 ± 3.13	35.61 ± 2.22	1.3846	0.2653
Forbs	Richness (n)	8.11 ± 0.73	8.11 ± 0.54	7.11 ± 0.59	7.67 ± 0.58	0.5971	0.6215
	Relative cover (%)	20.08 ± 1.73	19.45 ± 1.38	17.38 ± 3.12	16.73 ± 1.38	0.6251	0.604

Table 19. Livestock effect on the scrubland cleared areas in biodiversity variables: Shannon index, herbaceous species richness and in the richness and relative cover of the different Raunkiaer lifeforms (chamaephytes, hemichryptophytes, geophytes and therophytes) and in the different functional types (legumes, grasses and other forbs).

5.2.2. Pasture production and quality

Pasture production and quality samplings are carried out in late spring or early summer (May-June). We aim to record the pasture production and quality in an initial status and in a final status (intermediate status is not recorded since cumulative effects on the pastures are not significant after one year, only). The first sampling was done in June 2021, since in June 2020 we were not able to collect the samples. Samples are still being processed and analysed in the laboratory. Therefore, we do not show the results regarding nutritive quality.

As we expected, biomass production of the herbaceous pasture is significantly higher in the scrubland clearing area than in the control area (Figure 32). Contrary to what expected, we found significant differences between grazing treatments in biomass production, being significantly lower in the subplots submitted to high grazing than in the subplots with no sheep (Figure 33). These samples were collected in 2021 (after one year of sheep entering the plots).

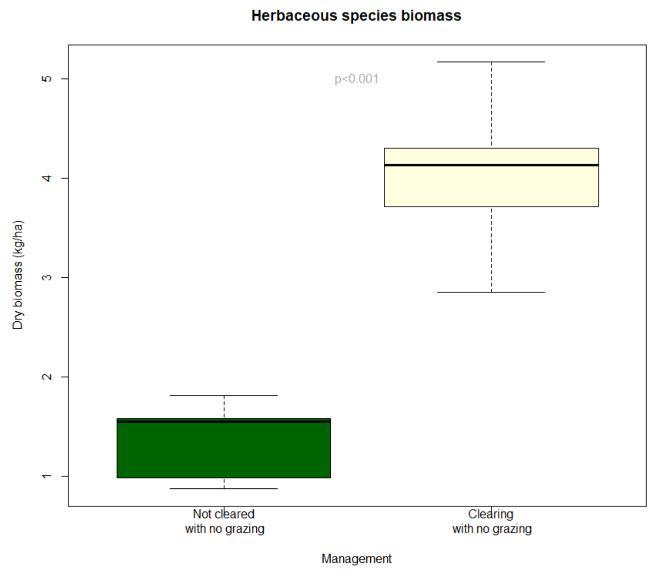


Figure 32. Biomass production in the herbaceous pasture in scrubland clearing area and in the non-managed area (control).

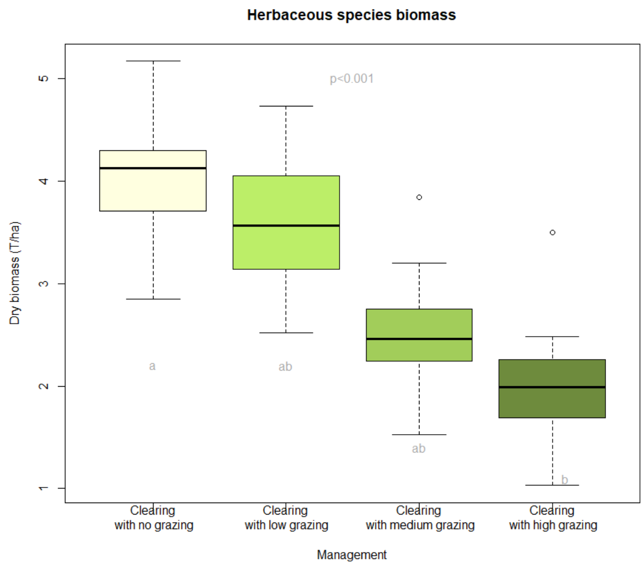


Figure 33. Biomass production in each of the livestock treatments (low, medium, high grazing) in the scrubland clearing area

5.3. Monitoring results of Rainfall simulations

In La Rioja, the first experiments were carried in July 2020 in order to monitor the initial conditions, i.e., in the cleared subplots without grazing and in the control subplots. In November and December 2020, after the livestock grazed for the third time within the year, new rainfall simulations were performed in all the subplots and the control subplots.

Under initial conditions, the hydrological response was higher in the cleared subplot without grazing (A) than in the scrubland (control) subplot, which did not produce any runoff nor sediment (Table 21). The sediment response (SC, SP and SD) in the cleared subplot was very low. At the end of the year, after the livestock has grazed for the third time within the year (results of the first campaign 2020, Table 23), the hydrological response was much higher, probably due to higher soil moisture conditions. RC clearly increased and TR clearly decreased with increasing livestock density, from 0.33 to 0.76 and 6.3 to 3.1 min, respectively. The sediment response was in this case very variable, with highest SC, SP and SD in the control and the A and C subplots.

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
Ajamil	Control	0.00	7.40	NA	5	0.00	0.00	0.00
		0.00	11.50	NA	5	0.00	0.00	0.00
	Cleared without livestock (A)	0.50	27.00	3.7	4	0.15	0.11	2.32
		0.00	22.35	NA	7	0.00	0.00	0.00

Table 20. All hydrogeological and sedimentological variables extracted from rainfall simulations in La Rioja in July 2020 (initial conditions). Simulations without runoff are represented in Time to runoff variable with a NA and with a 0 value in Sediment concentration, production, and detachment. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
Ajamil	Control	0.00±0.00	9.45±2.90	NA	5±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	Cleared without livestock (A)	0.25±0.35	24.68±3.29	3.7	6±2.12	0.08±0.11	0.05±0.07	1.16±1.63

Table 21. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in simulations in July 2020 (initial conditions). All values have a n=2. All values represent mean ± standard error. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
Ajamil	Control	0.71	22.61	5.1	4	0.36	0.20	7.86
		0.05	31.20	8.1	NA	0.01	0.09	0.19
	Cleared without livestock (A)	0.78	36.08	4.9	10	0.32	0.21	6.95
		0.00	36.68	NA	10	0.00	0.00	0.00
	Cleared with low pressure (B)	0.00	21.64	NA	10	0.00	0.00	0.00
		0.47	21.71	5.8	10	0.08	0.07	1.71
		0.53	26.14	6.7	10	0.19	0.19	4.03
	Cleared with medium pressure (C)	0.53	13.99	4.8	10	0.13	0.11	2.90
		0.43	13.99	6.7	10	0.08	0.08	1.75
		0.52	9.45	3.7	10	0.26	0.17	5.65
	Cleared with high pressure (D)	0.56	11.85	4.6	3	0.16	0.13	3.36
		0.97	12.04	1.7	NA	0.10	0.04	2.19

Table 22. All hydrogeological and sedimentological variables extracted from rainfall simulations in La Rioja in November and December 2020. Simulations without runoff are represented in Time to runoff variable with a NA and with a 0 value in Sediment concentration, production, and detachment. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

Site	Land management	RC (-)	IR (mm h^{-1})	TR (min)	WF (cm)	SC (g L^{-1})	SP (g)	SD (g m^{-2} h^{-1})
Ajamil	Control	0.38±0.47	26.91±6.07	6.6±2.14	4±0.00	0.19±0.25	0.15±0.08	4.03±5.42
	Cleared without livestock (A)	0.39±0.55	36.38±0.42	4.9±0.00	10±0.00	0.16±0.23	0.11±0.15	3.48±4.92
	Cleared with low pressure (B)	0.33±0.29	23.16±2.58	6.3±0.59	10±0.00	0.09±0.09	0.09±0.10	1.91±2.02
	Cleared with medium pressure (C)	0.49±0.06	12.48±2.62	5.0±1.52	10±0.00	0.16±0.09	0.12±0.04	3.44±2.00
	Cleared with high pressure (D)	0.76±0.30	11.94±0.13	3.1±2.04	3±0.00	0.13±0.04	0.09±0.06	2.77±0.83

Table 23. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in simulations in November and December 2020. All values have a n=3, except in Ajamil A and B with n=2. All values represent mean ± standard error. 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) and SD: Sediment detachment (g m^{-2} h^{-1}).

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 34). 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 SAHI-Ebro (Sistema Automático de Información Hidrológica) P007 in Ajamil and at a rainfall gauge datalogger installed at the control plot.

In this period, until 02-11-2021, 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).

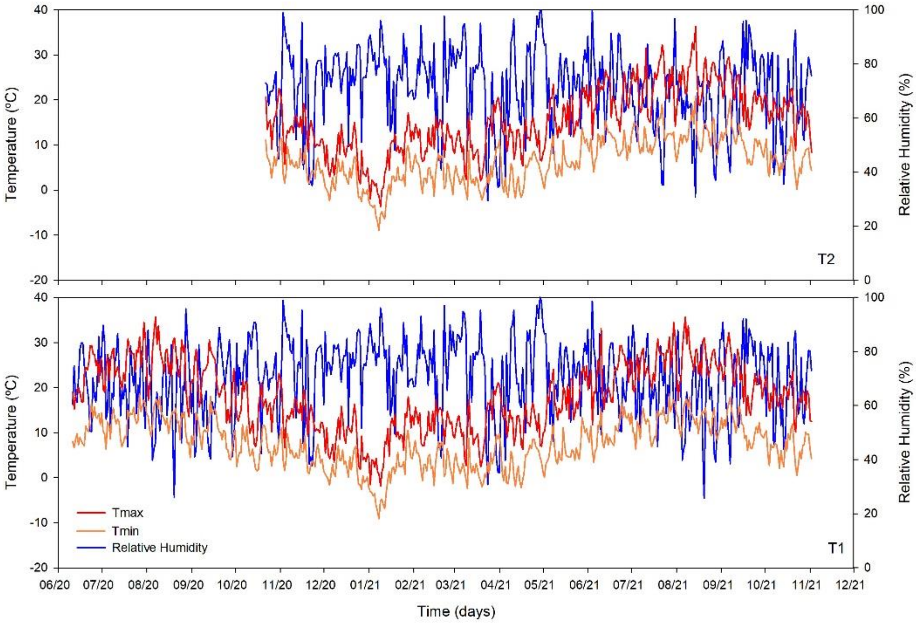


Figure 34. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plot in Ajamil. T1: in the A2 experimental subplot; T2: under a tree. *It starts in October because the data logger was stolen.*

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 02-11-2021, the maximum temperature has been 36.3 ºC (14-08-2021) and the minimum -9.3 ºC (08-01-2021) (Figure 35).

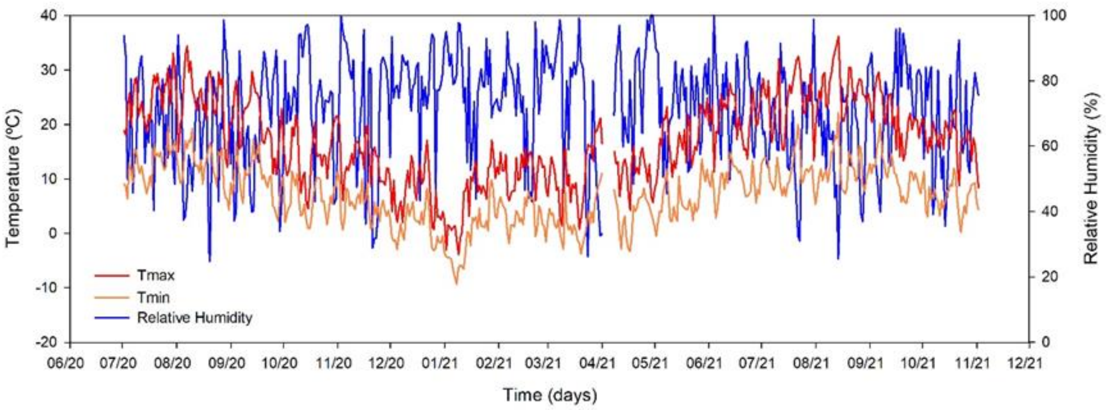


Figure 35. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental Control plot in Ajamil.

Figure 36 shows monthly averages of maximum temperature, minimum temperature and mean monthly precipitation for the period 06-2020 to 12-2021 (19 months) recorded in the experimental plots located in Ajamil (management and control plots). High rainfall values were recorded in spring (between April and June in both locations). 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.

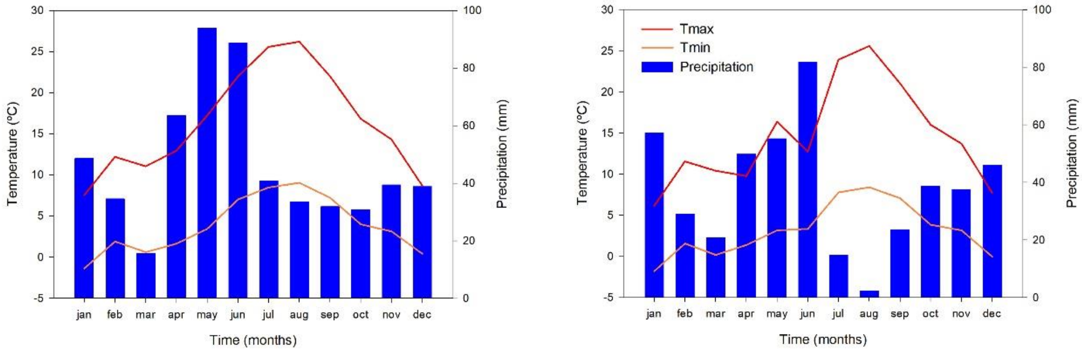


Figure 36. Climogram registered in the scrubland cleared experimental plot (Ajamil). Left: in the subplot A2, right: in the control plot.

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*.

Related to the soil characterization and soil monitoring, it can be highlighted that the first soil sampling campaigns were carried out during 2020, and all the proposed physic and chemical soil properties were measured and analysed in in the laboratory from the Pyrenean Institute of Ecology (IPE-CSIC) (225 samples were analysed in total). **Significant differences between topsoil and depth soils were found in all the different sites**. **No significant differences were found between the different treatments and control plots**, **except in the case of Ajamil**, where some differences were recorded related probably to different geographical conditions due to the locations of the plots (i.e. higher altitude in the control plot area).

Soil moisture content and site meteorological conditions are being measured in all the sites since spring 2020, although with some data gaps due to technical malfunction of some probes and thefts. All the variables will continue measuring and they will be used to establish relationships with the other environmental variables measured in the project: biodiversity, pasture production, hydrological response.

Pasture monitoring through biodiversity, production and quality analyses were measured at the beginning of the monitoring period to check initial conditions ant **the first results showed a general positive effect of the scrubland clearing in biodiversity** (regarding functional types, we found significantly more forbs species in the cleared subplots than in the control subplot). Regarding **pasture production, we did not find a significant effect of the scrubland clearing in biomass**. In the following vegetation samplings (intermediate in 2022, and final in 2023) we expect to obtain significant results of the effects of scrubland clearing in pasture production and quality and biodiversity.

Related to the hydrological and sedimentological response, in general under initial conditions, **the scrubland control subplot showed lower hydrological response and longer time to runoff than the cleared subplots**. Differences related to sediment response and sediment production was also observed between the plots, observing and **increase in sedimentological response with an increase in the livestock density.**

It should be highlighted that the monitoring network has been successfully implemented and that **all the monitoring variables are being measured,** related to soil characteristics, soil moisture, biodiversity, pasture production and quality, hydrological and erosion response, and the meteorological conditions of the different sites (temperature, precipitation and relative humidity). In addition, soil sampling and rainfalls simulation campaigns are going to be carried out at the beginning of the next year and data are going to be analysed by different project partners. Consequently, **all the activities and the periodicity defined in the proposal have been successfully completed** and continuous information is being recorded being a successful process for the future monitoring network defined in the LIFE MIDMACC project.

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.

8. Supplementary material

	Depth (cm)	A	B	C	D	Control
pH	0-10	8.0 ± 0.2	8.1 ± 0.1	7.9 ± 0.2	8.0 ± 0.1	8.0 ± 0.1
	10-20	8.3 ± 0.1	8.2 ± 0.1	8.2 ± 0.1	8.1 ± 0.1	8.1 ± 0.1
	20-30	8.3 ± 0.1	8.2 ± 0.1	8.3 ± 0.1	8.3 ± 0.1	8.3 ± 0.1
	30-40	8.3 ± 0.1	8.2 ± 0.1	8.5 ± 0.1	8.3 ± 0.1	8.3 ± 0.1
Conductivity (µs/cm)	0-10	203.7 ± 52.8	163.9 ± 8.0	206.0 ± 44.1	168.3 ± 13.6	203.7 ± 10.0
	10-20	142.0 ± 23.9	156.6 ± 7.6	139.6 ± 11.3	159.4 ± 5.60	202.6 ± 11.0
	20-30	136.3 ± 3.1	145.0 ± 13.2	145.9 ± 8.5	142.5 ± 12.6	159.3 ± 10.0
	30-40	134.9 ± 16.6	178.1 ± 9.3	118.0 ± 4.4	147.8 ± 19.5	162.9 ± 11.0
$CaCo_3$ (%)	0-10	39.7 ± 5.5	42.3 ± 2.6	41.5 ± 1.9	46.9 ± 1.4	43.8 ± 1.1
	10-20	44.4 ± 3.1	43.4 ± 1.9	45.2 ± 2.7	46.2 ± 1.6	41.9 ± 1.0
	20-30	44.4 ± 0.4	45.5 ± 2.4	44.2 ± 3.6	45.5 ± 1.6	44.90 ± 2.0
	30-40	44.3 ± 3.3	44.9 ± 3.0	44.2 ± 4.7	45.1 ± 6.3	49.8 ± 1.3
OC (%)	0-10	3.8 ± 1.3	3.3 ± 0.8	3.7 ± 1.1	2.9 ± 0.0	3.3 ± 0.1
	10-20	2.3 ± 0.3	2.5 ± 0.4	2.8 ± 0.4	2.6 ± 0.2	2.2 ± 0.1
	20-30	1.8 ± 0.3	2.2 ± 0.4	2.0 ± 0.2	2.1 ± 0.2	1.8 ± 0.1
	30-40	1.7 ± 0.3	1.9 ± 0.2	1.5 ± 0.2	1.8 ± 0.2	1.8 ± 0.0
N (%)	0-10	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0
	10-20	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0
	20-30	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0
	30-40	0.2 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.2 ± 0.0
SOC stock (Mg ha^{-1})	0-10	44.9 ± 11.0	40.6 ± 7.1	43.7 ± 9.1	36.5 ± 0.3	41.2 ± 0.5
	10-20	30.4 ± 2.7	32.9 ± 4.3	35.9 ± 3.6	33.4 ± 2.0	29.9 ± 1.1
	20-30	25.4 ± 3.2	29.6 ± 4.0	26.8 ± 2.7	28.7 ± 2.0	25.3 ± 1.5
	30-40	23.3 ± 3.2	25.8 ± 2.2	20.1 ± 3.2	24.4 ± 2.3	24.6 ± 0.4
N stock (Mg ha^{-1})	0-10	3.7 ± 1.1	3.6 ± 0.4	3.7 ± 0.8	3.3 ± 0.2	3.3. ± 0.1
	10-20	2.7 ± 0.3	3.0 ± 0.3	3.1 ± 0.3	3.0 ± 0.1	2.8 ± 0.1
	20-30	2.4 ± 0.3	2.7 ± 0.2	2.5 ± 0.2	2.5 ± 0.1	2.4 ± 0.1
	30-40	2.3 ± 0.3	2.4 ± 0.2	2.1 ± 0.1	2.2. ± 0.3	2.3 ± 0.1
CN ratio	0-10	12.1 ± 0.6	11.3 ± 0.8	11.7 ± 0.1	11.2 ± 0.7	12.4 ± 0.2
	10-20	11.4 ± 0.9	11.1 ± 0.4	11.6 ± 0.4	11.2 ± 0.6	10.9 ± 0.5

	20-30	10.5 ± 0.4	11.0 ± 0.9	10.8 ± 0.6	11.3 ± 0.4	10.4 ± 0.8
	30-40	10.4 ± 0.5	11.0 ± 0.5	9.9 ± 0.9	11.0 ± 0.3	11.0 ± 0.1
BD ($g\ cm^{-3}$)	0-10	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	1.3 ± 0.0	1.2 ± 0.0
	10-20	1.3 ± 0.0	1.3 ± 0.0	1.3 ± 0.0	1.3 ± 0.0	1.3 ± 0.0
	20-30	1.4 ± 0.0	1.4 ± 0.0	1.4 ± 0.0	1.4 ± 0.0	1.3 ± 0.0
	30-40	1.4 ± 0.0	1.4 ± 0.0	1.4 ± 0.0	1.4 ± 0.0	1.3 ± 0.0
P (mg/Kg)	0-10	3.9 ± 2.0	2.2. ± 0.6	4.9 ± 3.1	3.6 ± 0.6	2.8 ± 0.6
	10-20	2.0 ± 1.1	1.4 ± 0.8	2.6 ± 0.5	2.8 ± 0.6	2.2. ± 0.6
	20-30	1.6 ± 0.8	0.7 ± 0.4	1.7 ± 0.9	1.8 ± 0.5	1.6 ± 0.5
	30-40	1.4 ± 0.6	1.4 ± 1.0	1.2 ± 0.6	1.4 ± 0.6	1.4 ± 0.6
Clay (%)	0-10	39.0 ± 6.4	35.2 ± 11.1	43.9 ± 1.1	40.5 ± 6.4	45.9 ± 1.0
	10-20	38.3 ± 2.9	41.4 ± 5.9	40.5 ± 6.5	36.4 ± 2.1	51.9 ± 1.1
	20-30	44.4 ± 9.0	38.8 ± 3.4	46.5 ± 6.1	46.2 ± 2.8	23.3 ± 2.0
	30-40	45.6 ± 4.5	43.4 ± 3.1	42.5 ± 6.3	45.3 ± 7.5	30.0 ± 1.1
Silt (%)	0-10	29.9 ± 1.8	27.4 ± 1.0	30.2 ± 2.6	31.7 ± 2.4	31.6 ± 1.1
	10-20	28.0 ± 1.7	27.5 ± 2.9	29.1 ± 3.2	32.0 ± 6.9	30.1 ± 1.4
	20-30	27.6 ± 4.3	25.5 ± 2.0	30.5 ± 3.6	32.1 ± 3.2	12.5 ± 1.3
	30-40	27.3 ± 0.7	26.2 ± 2.0	27.7 ± 5.1	26.2 ± 0.5	15.9 ± 1.8
Sand (%)	0-10	31.1 ± 5.3	37.4 ± 10.5	25.9 ± 2.9	27.8 ± 8-4	22.5 ± 2.4
	10-20	33.7 ± 1.7	31.2 ± 3.0	30.5 ± 5.9	31.6 ± 7.2	18.0 ± 1.2
	20-30	28.0 ± 12.5	36.0 ± 3.2	23.1 ± 8.8	21.8 ± 5.9	64.2 ± 6.9
	30-40	27.3 ± 4.0	30.5 ± 4.2	29.8 ± 10.0	28.6 ± 7.2	54.1 ± 2.0
Field Capacity	0-10	0.1 ± 0.0	0.2 ± 0.1	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
	10-20	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
	20-30	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.0
	30-40	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.2 ± 0.0
Wilting point	0-10	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.1
	10-20	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.1 ± 0.0
	20-30	0.2 ± 0.1	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.3 ± 0.1
	30-40	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.3 ± 0.0

Table 24 Supplementary material. Mean values and standard deviation recorded in La Garcipollera.

	Depth (cm)	A	B	C	D	Control
pH	0-10	7.5 ± 0.2	7.4 ± 0.2	7.7 ± 0.2	7.9 ± 0.3	7.6 ± 0.1
	10-20	8.0 ± 0.3	7.9 ± 0.1	8.1 ± 0.1	8.2 ± 0.1	8.1 ± 0.1
	20-30	8.3 ± 0.1	8.2 ± 0.1	8.3 ± 0.1	8.4 ± 0.1	8.4 ± 0.1
	30-40	8.5 ± 0.1	8.4 ± 0.1	8.5 ± 0.1	8.5 ± 0.0	8.4 ± 0.1
Conductivity (µs/cm)	0-10	356.4 ± 70.8	464.3 ± 205.4	294.8 ± 54.7	277.1 ± 44.7	339.2 ± 30.0
	10-20	235.1 ± 69.4	216.9 ± 34.4	204.2 ± 29.5	186.4 ± 44.6	225.3 ± 11.0
	20-30	199.7 ± 39.8	188.5 ± 8.4	172.0 ± 33.9	187.3 ± 61.1	162.6 ± 20.0
	30-40	162.2 ± 23.5	151.2 ± 3.6	150.7 ± 26.7	161.3 ± 34.9	173.2 ± 21.0
$CaCo_3$ (%)	0-10	24.8 ± 7.0	25.6 ± 11.6	23.9 ± 13.0	31.3 ± 7.3	28.6 ± 3.1
	10-20	28.4 ± 9.1	31.9 ± 10.3	32.9 ± 6.2	32.1 ± 8.7	38.8 ± 4.0
	20-30	30.5 ± 8.1	32.2 ± 7.3	33.3 ± 6.2	34.7 ± 9.2	38.6 ± 7.0
	30-40	31.0 ± 9.2	29.6 ± 7.8	27.6 ± 15.1	34.0 ± 9.4	35.5 ± 5.3
OC (%)	0-10	6.3 ± 1.2	7.0. ± 3.7	5.9 ± 1.1	4.6 ± 0.5	4.8. ± 0.1
	10-20	3.6 ± 1.0	2.9 ± 0.4	3.2 ± 0.4	2.9 ± 0.1	2.6. ± 0.1
	20-30	2.2 ± 0.4	2.0 ± 0.2	2.2 ± 0.2	2.1 ± 0.4	2.0 ± 0.1
	30-40	1.7 ± 0.3	1.6 ± 0.1	1.6 ± 0.2	1.6 ± 0.2	1.5 ± 0.0
N (%)	0-10	0.6 ± 0.1	0.6 ± 0.3	0.5 ± 0.1	0.4 ± 0.1	0.4 ± 0.0
	10-20	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.0	0.3 ± 0.0	0.2 ± 0.0
	20-30	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0
	30-40	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.1 ± 0.0
SOC stock (Mg ha^{-1})	0-10	63.2 ± 8.2	65.0 ± 20.3	61.1 ± 5.1	51.4 ± 3.5	53.6 ± 1.6
	10-20	42.8 ± 9.6	37.2 ± 4.3	40.1 ± 3.7	36.8 ± 1.2	33.6 ± 1.0
	20-30	30.0 ± 4.7	27.5 ± 2.6	29.2 ± 2.6	27.9 ± 4.1	26.9 ± 0.2
	30-40	24.1 ± 2.9	22.5 ± 1.2	22.5 ± 1.8	22.7 ± 1.8	20.9 ± 0.8
N stock (Mg ha^{-1})	0-10	5.6 ± 0.7	5.7 ± 1.7	5.4 ± 0.4	4.5 ± 0.5	4.4 ± 0.1
	10-20	3.6 ± 0.8	3.5 ± 0.8	3.8 ± 0.3	3.4 ± 0.2	2.6 ± 0.1
	20-30	2.6 ± 0.3	2.9 ± 0.2	2.8 ± 0.4	2.6 ± 0.4	2.4 ± 0.1
	30-40	2.3 ± 0.3	2.3 ± 0.2	2.1 ± 0.2	2.0 ± 0.1	1.8 ± 0.2
CN ratio	0-10	11.2 ± 0.4	11.5 ± 0.2	11.2 ± 0.6	11.4 ± 0.4	12.2 ± 0.0
	10-20	11.8 ± 0.2	10.8 ± 1.0	10.5 ± 0.3	11.0 ± 0.4	12.9 ± 0.3
	20-30	11.8 ± 1.0	9.6 ± 1.4	10.4 ± 0.7	10.8 ± 0.3	11.4 ± 0.3
	30-40	10.8 ± 1.3	10.0 ± 1.4	11.0 ± 1.1	11.5 ± 0.5	11.4 ± 0.5

BD (g cm^{-3})	0-10	1.0 ± 0.1	1.0 ± 0.2	1.0 ± 0.1	1.1 ± 0.0	1.2 ± 0.0
	10-20	1.2 ± 0.1	1.3 ± 0.0	1.2 ± 0.0	1.3 ± 0.0	1.3 ± 0.0
	20-30	1.3 ± 0.1	1.4 ± 0.0	1.4 ± 0.0	1.4 ± 0.0	1.3 ± 0.0
	30-40	1.4 ± 0.0	1.4 ± 0.0	1.4 ± 0.0	1.4 ± 0.0	1.3 ± 0.0
P (mg/Kg)	0-10	15.7 ± 4.9	16.9. ± 7.1	14.2 ± 3.8	9.2 ± 2.8	8.2 ± 1.6
	10-20	6.7 ± 4.2	7.0 ± 3.5	5.6 ± 0.3	5.3 ± 1.4	3.3 ± 0.5
	20-30	3.8 ± 2.0	5.6 ± 2.3	3.6 ± 1.5	3.1 ± 1.1	1.1 ± 0.5
	30-40	2.6 ± 2.0	2.3 ± 2.2	2.2 ± 0.6	2.1 ± 0.4	2.1 ± 0.8
Clay (%)	0-10	39.0 ± 7.2	38.9 ± 11.9	32.7 ± 14.3	42.1 ± 16.4	26.2 ± 1.0
	10-20	40.3 ± 11.8	38.3 ± 8.3	39.8 ± 17.4	36.9 ± 9.6	33.0 ± 1.1
	20-30	39.6 ± 8.5	43.3 ± 14.5	37.0 ± 19.1	43.1 ± 17.5	39.7 ± 2.0
	30-40	40.0 ± 8.6	43.6 ± 12.8	43.1 ± 13.9	42.1 ± 20.2	34.5 ± 1.1
Silt (%)	0-10	37.8 ± 2.3	30.7 ± 2.3	34.2 ± 6.6	39.0 ± 6.0	22.6 ± 1.1
	10-20	39.0 ± 4.9	31.3 ± 13.7	33.1 ± 9.4	35.1 ± 10.6	25.0 ± 1.4
	20-30	35.9 ± 3.9	31.9 ± 5.2	28.4 ± 4.4	29.7 ± 1.6	19.7 ± 1.3
	30-40	28.9 ± 2.5	35.5 ± 7.2	33.2 ± 2.5	32.3 ± 2.3	24.7 ± 1.8
Sand (%)	0-10	23.3 ± 8.2	30.4 ± 10.7	33.2 ± 9.4	18.9 ± 16.8	51.2 ± 12.4
	10-20	20.7 ± 8.6	30.3 ± 12.4	27.1 ± 19.7	28.1 ± 11.5	42.0 ± 11.2
	20-30	24.5 ± 11.5	24.8 ± 18.0	34.7 ± 16.9	27.2 ± 17.1	40.6 ± 9.9
	30-40	28.9 ± 6.1	20.9 ± 12.8	23.7 ± 15.8	25.6 ± 18.0	40.8 ± 12.0
Field Capacity	0-10	0.1 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.0
	10-20	0.1 ± 0.1	0.1 ± 0.0	0.1 ± 0.1	0.1 ± 0.0	0.1 ± 0.0
	20-30	0.1 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.0
	30-40	0.1 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.0
Wilting point	0-10	0.2 ± 0.0	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.2 ± 0.1
	10-20	0.2 ± 0.1	0.2 ± 0.0	0.2 ± 0.1	0.2 ± 0.0	0.2 ± 0.0
	20-30	0.2 ± 0.0	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1
	30-40	0.2 ± 0.0	0.3 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.0

Table 25. Supplementary material. Mean values and standard deviation recorded in San Román.

	Depth (cm)	A	B	C	D	Control
pH	0-10	5.7 ± 0.2	5.7 ± 0.1	5.5 ± 0.1	5.8 ± 0.3	5.6 ± 0.1
	10-20	6.1 ± 0.4	5.8 ± 0.2	5.8 ± 0.2	6.0 ± 0.6	5.6 ± 0.1
	20-30	6.4 ± 0.3	6.2 ± 0.4	6.0 ± 0.3	6.3 ± 0.3	5.5 ± 0.1
	30-40	6.7 ± 0.2	6.6 ± 0.2	6.5 ± 0.3	6.6 ± 0.6	5.2 ± 0.1
Conductivity (µs/cm)	0-10	119.2 ± 66.1	130.5 ± 17.8	153.3 ± 100.0	117.4 ± 37.3	152.4 ± 10.0
	10-20	68.2 ± 17.9	98.0 ± 20.0	79.0 ± 22.6	85.6 ± 35.0	113.1 ± 11.0
	20-30	80.4 ± 18.7	82.7 ± 44.2	66.2 ± 6.0	64.3 ± 11.2	86.9 ± 10.0
	30-40	74.1 ± 23.1	65.7 ± 16.7	56.3 ± 4.0	92.8 ± 55.7	77.7 ± 11.0
$CaCo_3$ (%)	0-10	-	-	-	-	-
	10-20	-	-	-	-	-
	20-30	-	-	-	-	-
	30-40	-	-	-	-	-
OC (%)	0-10	1.5 ± 0.3	2.1 ± 0.7	1.9 ± 0.5	1.3 ± 0.4	3.7. ± 0.5
	10-20	1.2 ± 0.2	1.6 ± 0.3	1.4 ± 0.1	0.8 ± 0.1	5.1. ± 0.2
	20-30	1.1 ± 0.3	0.9 ± 0.1	1.1 ± 0.1	1.0 ± 0.2	3.0 ± 0.1
	30-40	0.8 ± 0.2	0.7 ± 0.2	0.9 ± 0.2	0.8 ± 0.1	2.0 ± 0.1
N (%)	0-10	0.2 ± 0.1	0.3 ± 0.1	0.3 ± 0.2	0.3 ± 0.2	0.4 ± 0.0
	10-20	0.1 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.3 ± 0.0
	20-30	0.1 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.2 ± 0.0
	30-40	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.2 ± 0.0
SOC stock (Mg ha^{-1})	0-10	20.7 ± 4.3	27.6 ± 8.1	26.3 ± 6.0	18.6 ± 5.5	44.1 ± 4.1
	10-20	17.9 ± 2.9	22.8 ± 4.1	20.5 ± 1.2	19.5 ± 1.6	55.7 ± 1.2
	20-30	15.7 ± 3.5	14.1 ± 1.1	16.4 ± 0.7	15.3 ± 2.6	37.6 ± 0.5
	30-40	12.6 ± 3.2	10.3 ± 2.4	13.0 ± 2.0	12.3 ± 1.5	27.2 ± 1.1
N stock (Mg ha^{-1})	0-10	3.4 ± 0.6	4.4 ± 0.4	4.2 ± 0.7	3.9 ± 2.1	5.1. ± 0.3
	10-20	1.7 ± 0.2	2.2 ± 0.3	2.1 ± 0.1	2.1 ± 0.4	3.7 ± 0.1
	20-30	1.6 ± 0.1	1.5 ± 0.2	1.8 ± 0.2	1.7 ± 0.2	2.5 ± 0.1
	30-40	1.3 ± 0.1	1.3 ± 0.2	1.4 ± 0.2	1.5. ± 0.1	2.1 ± 0.0
C/N ratio	0-10	6.0 ± 0.3	6.3 ± 0.2	6.2 ± 0.5	5.2 ± 1.2	8.7 ± 0.4
	10-20	10.5 ± 0.9	10.4 ± 0.5	9.8 ± 0.9	7.0 ± 1.4	15.2 ± 0.7

	20-30	10.1 ± 2.2	9.1 ± 0.2	9.3 ± 0.7	8.8 ± 1.6	14.9 ± 0.5
	30-40	9.4 ± 2.3	7.6 ± 1.3	9.4 ± 0.9	8.7 ± 1.8	12.7 ± 0.5
BD (g cm^{-3})	0-10	1.4 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	1.5 ± 0.0	1.2 ± 0.0
	10-20	1.5 ± 0.0	1.4 ± 0.0	1.4 ± 0.0	1.5 ± 0.0	1.1 ± 0.0
	20-30	1.5 ± 0.0	1.5 ± 0.0	1.5 ± 0.0	1.5 ± 0.0	1.3 ± 0.0
	30-40	1.5 ± 0.0	1.5 ± 0.0	1.5 ± 0.0	1.5 ± 0.0	1.4 ± 0.0
P (mg/Kg)	0-10	4.2 ± 1.5	5.5. ± 2.5	7.0 ± 0.1	5.8 ± 5.5	6.3 ± 0.6
	10-20	2.3 ± 0.7	2.9 ± 1.5	2.5 ± 0.5	5.0 ± 0.8	4.2 ± 0.6
	20-30	1.3 ± 0.4	1.4 ± 0.6	1.8 ± 1.1	1.3 ± 0.5	2.5 ± 0.5
	30-40	1.1 ± 0.6	1.1 ± 0.3	1.0 ± 0.4	0.9 ± 0.6	1.8 ± 0.6
Clay (%)	0-10	22.8 ± 0.9	23.5 ± 0.4	23.7 ± 1.4	23.2 ± 1.1	38.1 ± 1.0
	10-20	24.1 ± 1.7	22.9 ± 0.9	23.9 ± 1.0	15.8 ± 0.5	36.1 ± 1.1
	20-30	26.5 ± 1.4	26.5 ± 2.2	24.6 ± 2.5	25.0 ± 1.9	32.7 ± 2.0
	30-40	26.0 ± 3.1	24.2 ± 2.0	25.9 ± 1.2	24.9 ± 4.2	28.7 ± 1.1
Silt (%)	0-10	62.0 ± 1.6	62.3 ± 1.4	62.3 ± 0.5	62.4 ± 0.7	43.7 ± 1.1
	10-20	67.0 ± 1.8	63.7 ± 3.5	61.0 ± 2.6	48.1 ± 4.0	43.4 ± 1.4
	20-30	62.3 ± 1.7	60.2 ± 5.7	60.9 ± 4.5	62.6 ± 2.2	51.2 ± 1.3
	30-40	61.1 ± 1.6	62.3 ± 5.5	65.2 ± 3.7	64.0 ± 6.1	59.3 ± 1.8
Sand (%)	0-10	15.2 ± 1.7	14.3 ± 1.1	14.0 ± 1.1	14.4 ± 0.6	18.3 ± 2.4
	10-20	8.9 ± 2.5	13.4 ± 2.9	15.1 ± 2.7	15.8 ± 4.4	20.5 ± 1.2
	20-30	11.2 ± 3.0	13.3 ± 4.2	14.6 ± 2.2	14.6 ± 3.1	16.0 ± 6.9
	30-40	12.9 ± 3.5	13.5 ± 4.7	8.9 ± 2.7	8.9 ± 2.4	12.0 ± 2.0
Field Capacity	0-10	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0
	10-20	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0
	20-30	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	30-40	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0
Wilting point	0-10	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0
	10-20	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0
	20-30	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0
	30-40	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0

Table 26. Supplementary material. Mean values and standard deviation recorded in Ajamil.