LIFE MIDMACC

Mid-mountain adaptation to climate change

LIFE18 CCA/ES/001099

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Duration of project: 5 years

Deliverable 5

Implementation of the forest management pilot experiences

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Executive summary

This deliverable gives an in deep description of one of the climate change adaptation measures applied in the project: forest management for fire risk prevention and maintenance with extensive livestock farming. These measures, designed and deployed together with local stakeholders, were implemented by the end of 2019 and beginning 2020 in Aragón and Catalonia. An in deep description of the location of the experiences and the initial planned actions can be consulted at Nadal-Romero et al (2019, Deliverable 1).

The first section is a short introduction to the deliverable. The second section describes the forest management activity in Aragon, with a briefly description of the proposed pilot experience in the project and a detailed description of the implemented pilot experience. This section also includes a short summary of the monitoring in the forest management experiences in Aragon. The third section reproduce the same information from the forest management experiences plots in Catalonia. Finally, the fourth section summarizes all the implementation activities related to the forest management pilot experiences.

This deliverable presents the activities carried out to implement the action C2, fundamental in the LIFE MIDMACC project. We have tried to define, from the global to the concise, all the activities that have been carried out, up to now, and those that are going to be carried out with more detailed in the next months, and where and how they are going to be done.

This deliverable is finished with a delay of four months regarding the initial date of delivery (June 2020). The main cause of this delay is attributable to the COVID19 pandemic that provoked a retard of about four months in all the field work needed to finish implementation tasks, to perform all the inventories (forest, vegetation, soil …) and to conclude with the installation of the instruments needed for the monitoring tasks (sensors, dataloggers …).

This deliverable was reviewed in December 2021, in order to include the description of the second pilot experience in Aragon, in a *Populus* forest, that was not implemented in 2020 due to the COVID pandemic.

Content

1. Introduction

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

The demonstrative activities have been performed in different pilot sites representative of Mediterranean mid-mountain areas. In that report, we present the implementation actions related to **forest management activities** to diminish forest fire risk and improve livestock grazing, carried out in **Aragón and Catalonia**. The thinning of trees and scrubland clearing in wooded areas (as the main activity), will be carried out in Aragon (La Garcipollera) and Catalonia (Requesens-l'Albera). In both cases, the selected areas are representative of the study cases to be upscaled to the regional level and also replicable to other areas, with two main objectives: to **analyse the environmental implications for the climate change conditions** (water resources, soil erosion, soil quality and soil organic stocks, soil moisture and air moisture and temperature, pasture quality and biodiversity) and to **evaluate the socio-economic impacts on the economy of extensive farms**.

Forest management: This measure is based on the thinning of trees and scrubland clearing in wooded areas to **reduce fire risk** whereas **stimulating pasture regeneration and extensive livestock farming**. In Aragon, two pilots have been carried out in two different forests: *a Pinus nigra* forest and a *Populus* forest, both as part of La Garcipollera Research Station. In Catalonia, the pilots have been implemented in a Holm oak forest located in the Requesens state (Empordà).

This report presents the implementation action, the description and methods employed (what, how, where and when) in both regions (Aragon and Catalonia) and briefly presents the monitoring program.

2. Forest management pilot experience in Aragon

2.1. The pilot experience in the project proposal

Following, a description of the pilot experience as it was included in the proposal is shown, in order to better explain the final pilot experience implemented.

Sub-action C2.2 Forest management in Aragon

Two pilot experiences will be carried out in Aragon. The first experience will be implemented in La Garcipollera experimental site under logistic help of CITA. La Garcipollera was in general reforested in the decade of 1950 by *Pinus sylvestris*, but it also maintains some naturally regenerated forests of *Quercus faginea*.

The second experience will be implemented in Aísa sub-basin (9600 ha) in the Central Pyrenees, where there are 174 cows and 3119 sheep. The plots will be located in an oak forest in the lower part of the sub-basin (sunny parts), which is replaced with the Mediterranean scrub of *Buxus sempervirens*.

The pilot experiences will mainly consist of:

- Forest management in plots of 1-2 ha in each forest type (*Pinus sylvestris* and *Quercus faginea* in La Garcipollera and oak forest in Aísa). In these forests, the undergrowth vegetation will be removed to promote fuel discontinuity, with the purpose of reducing the forest fire risk and to increase the pasture production and reduce water stress within the forest.
- Control plots (one for each forest type) with no intervention to monitor the site evolution, and with no actuation (around 1-2 ha). These plots will be also monitored following the same experimental design than what developed in the forest management plots.

2.2. The implemented pilot experience

The pilot experience has been implemented in La Garcipollera Research Station (Central Pyrenees, Huesca). This experimental farm is dedicated to the study of mountain agriculture and livestock. It has about 14 hectares of meadow, and all kinds of livestock facilities, as well as two experimental herds, one of about 200 heads (cows) and the second one about 300 sheep.

The final choice of the plots has been subject to the needs of the experimental farm. For this reason, two plots (Figure 1) of **0.58 ha and 0.86 ha** respectively were finally selected to carry out action C2. One of the plots was selected on a reforestation forest of *Pinus nigra* while the other was selected on a forest of *Populus sp*. Both decisions imply changes with respect to the initial proposal. In first place, there was a wrong identification of the pinewood forest during the project proposal, because the common specie in La Garcipollera is *Pinus nigra*, whereas *Pinus sylvestris*, the forest mentioned in the proposal, is minority in the area of study. In second place, the initial planned plot of oak (*Quercus*) was inaccessible, due to the lamentable state of conservation of the access track. The Government of Aragon was predisposed to its arrangement but finally its short-term conditioning was not possible. For this reason, the second study area has been localized in a *Populus* forest. Despite this, the objectives, area of study (number of plots and surface), methodology and monitoring remain the same as those included in the proposal.

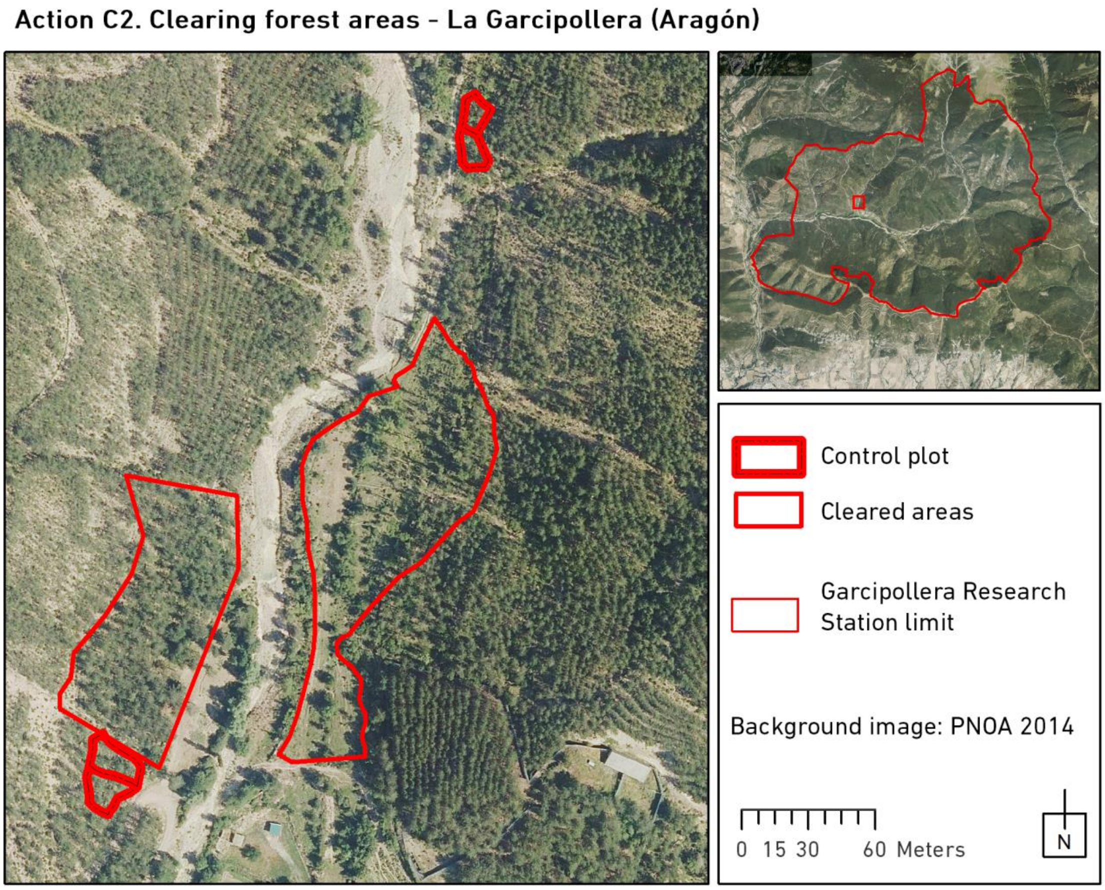


Figure 1. Location of the forest management pilot experience in Aragón

The forest management pilot experience in Aragon has consisted of:

1. The application of scrubland clearing in a *Pinus nigra* forest area of **0.58 ha**. The main objective of this management has been to promote fuel discontinuity, with the purpose of reducing the forest fire risk and to increase the pasture production and reduce water stress within the forest. Adaptive management practice has mainly consisted of **high intensity scrubland clearing,** leaving the

grass generated underneath. The practice was applied on January 2020 and the area was subsequently fenced off (February 2020) to prevent the entry of wild animals and from the farm's own livestock.

2. An area with no actuation of **554 m^2** of *Pinus nigra* forest. This area is close by the managed area and shows similar condition in location, altitude and orientation. This area will not be neither managed nor pastured, with the objective to monitor the site evolution with no actuation.
3. The application of scrubland clearing in a *Populus* forest area of **0.86 ha**. The main objective of this management is to promote fuel discontinuity, with the purpose of reducing the forest fire risk and to increase the pasture production and reduce water stress within the forest. Adaptive management practice has mainly consisted of **high intensity scrubland clearing,** leaving the grass generated underneath. The practice was applied on February 2021 and the area was subsequently fenced off to prevent the entry of wild animals and from the farm's own livestock.
4. An area with no actuation of **554 m^2** of *Populus* forest. This area is close by the managed area and shows similar condition in location, altitude and orientation. This area will not be neither managed nor pastured, with the objective to monitor the site evolution with no actuation

2.3. The *Pinus nigra* forest before the application of adaptive forest management

The forest where the adaptive management has been applied, is a pine forest where ***Pinus nigra* is the dominant species** in the area (98% of basal area), with some minority escort species: ash tree (*Fraxinus* sp.) and some isolated individuals of pear tree (*Pyrus cordata*). In Aragon, the adaptive practice has affected to the understorey, but not to the trees structure. For this reason, in the following paragraphs, we include a description of the forest structure which is similar in all the area (managed and control). The changes in the understorey between the non-managed (control) and the managed area are described in the following chapter.

A **forest inventory** was performed in **June 2020 to characterise the initial conditions of the forest stand**. The inventory was realized **in eight rectangular sub-plots** with an area of 400 m^2, uniformly distributed. In each plot, the following variables were taken to characterise the stand:

- Forest structure: the number of trees of each species is counted and the diameter at breast height (DBH), the height of each tree and the canopy cover is measured.
- Understorey biovolume: two strip biomass transects (10 m) to estimate understorey biovolume are defined in each plot. In each transect, the maximum height and cover of scrubland species are measured in 50x50 cm quadrat plots.
- Forest fuel continuity: the crown fire hazard is assessed following the methodology of the CVFoC Manual (Piqué et al. 2011), by taking the following measures: Aerial cover (%), ladder cover (%), surface cover (%), height of surface fuel (m), distance between surface and ladder/aerial fuels (m), distance between ladder and aerial fuels (m). Using a crown fire hazard chart, the crown fire hazard of each plot is assessed.

- Forest health status: Forest decline status is assessed through visual estimation of tree mortality percentage (dried crowns), defoliation percentage (non-present leaves in relation of leaves present on a healthy tree) and foliage discoloration percentage (non-green leaves in relation of green leaves on a healthy tree) in 10 trees per forest inventory plot.

Figure 2 shows the location of the subplots in each area. There are two subplots in the control area (BC1 and BC2), three in the managed area with livestock (B1S, B3S and B5S) and three in the managed area without livestock (B2N, B4N and B6N).

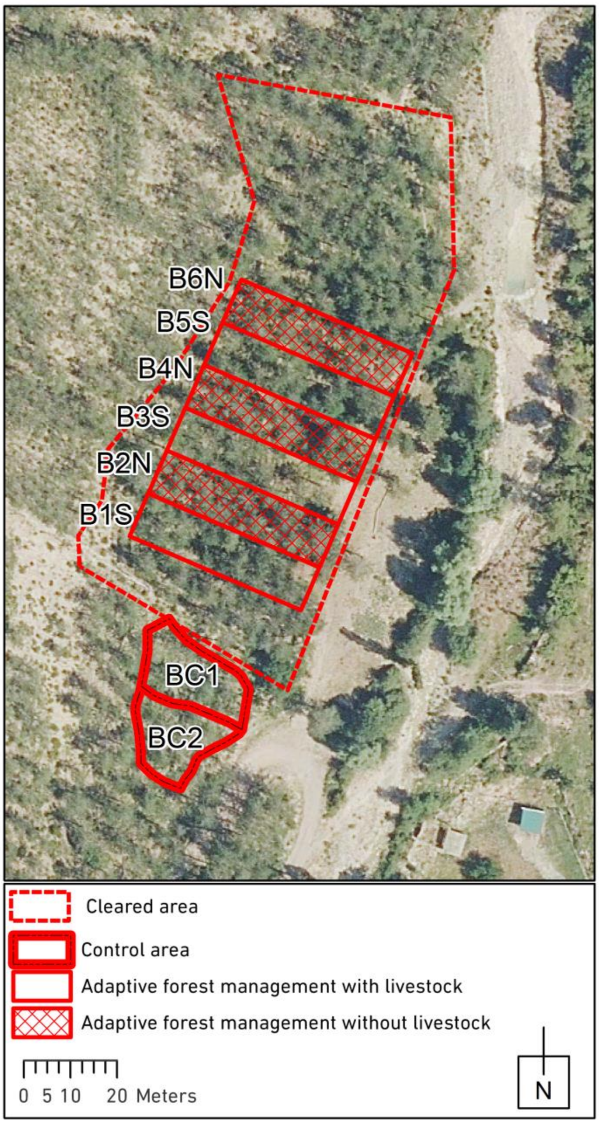


Figure 2. Subplot's location for the forest inventory.

The initial inventory determined that this forest is a **low dense forest** (about 470 trees/ha) with a mean **basal area about 24.2 m^2/ha** and an **even-aged stand planted in the 60's** (Table 1, Figure 3). Mean diameter at breast height oscillates between 21.8 and 28 cm and mean height between 13.7 and 20.7 m. The plots show a similar crown fire hazard, identified as the structure type C which means a low hazard (Figure 3, Figure 4). This type of structures is characterized by almost always presenting vertical discontinuity between some of the strata, being the ladder cover variable. The fire spreads below the aerial cover. Surface cover, and ladder cover if any, are consumed, but given the vertical discontinuity with the aerial cover, the fire does not pass to the crowns and remains on the surface. The forest structures affected by this type of fire typically respond to low mortality; occasionally a tree dies.

Forest inventory subplot	Canopy cover (%)	Number of trees / ha	Basal area (m^2/ha)	Mean diameter at breast height (cm)	Mean tree's height (m)	Forest fuel continuity model	Crown fire hazard
BC1	55	450	17.7	21.8	13.7	B13	Moderate
BC2	60	400	18.8	24.2	14.4	C12	Low
B1S	75	625	33.5	26.5	16.3	C9	Low
B3S	50	475	28.7	28.0	17.6	C12	Low
B5S	65	475	22.8	26.2	17.9		
B2N	70	425	25.1	26.9	18.9	C10	Low
B4N	65	450	21.7	26.0	20.7	C12	Low
B6N	50	450	25.2	26.9	18.9	C10	Low

Table 1. Resume of the inventory variables per forest inventory subplots measured on June 2020. The data of B5S referred to forest fuel continuity model has been lost and will be measured again as soon as possible.

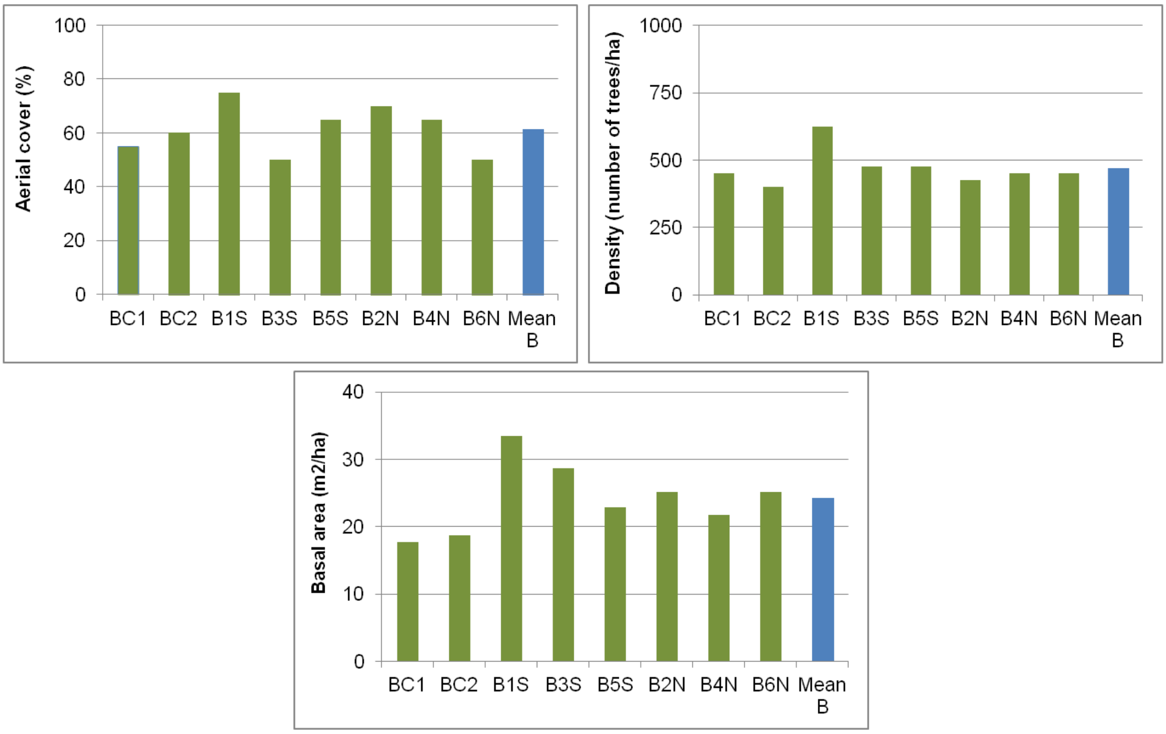


Figure 3. Distribution of aerial cover (%), density (number of trees per ha) and basal area (m^2/ha) per forest inventory subplot.

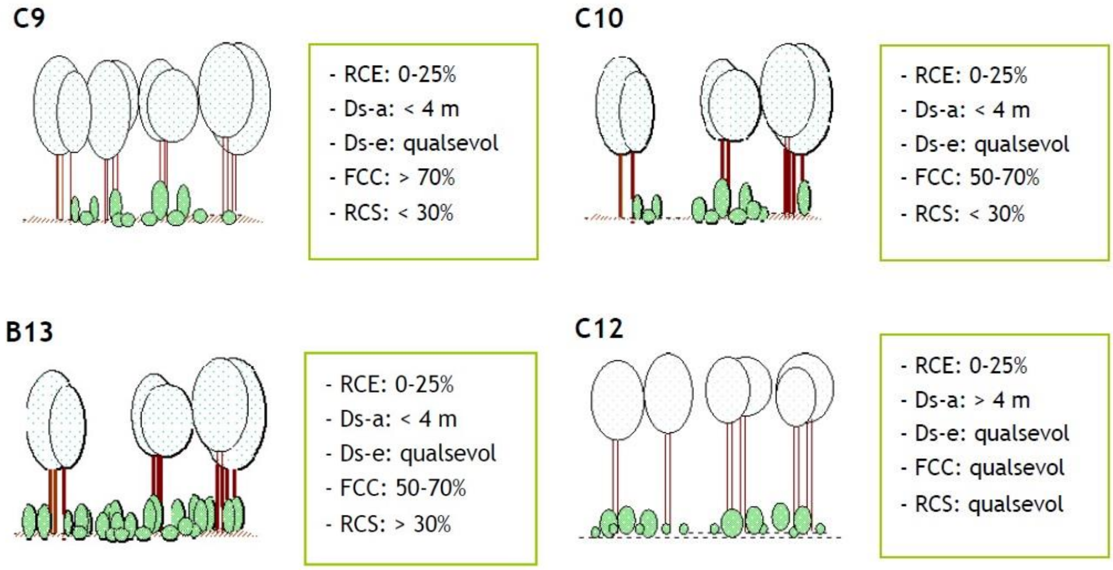


Figure 4. Description of the structure type B13, C9, C10 and C12 with moderate and low crown fire hazard following Piqué et al. 2011.

We have applied some statistics to compare among cleared subplots and with the control subplots (ANOVA and Tukey test). We have observed that **there are not significant differences in the basal area between the managed and the control subplots**. So we can conclude that the forest strucuture in all the subplots is quite similar and non significant differences are found (Figure 5, Annex 1).

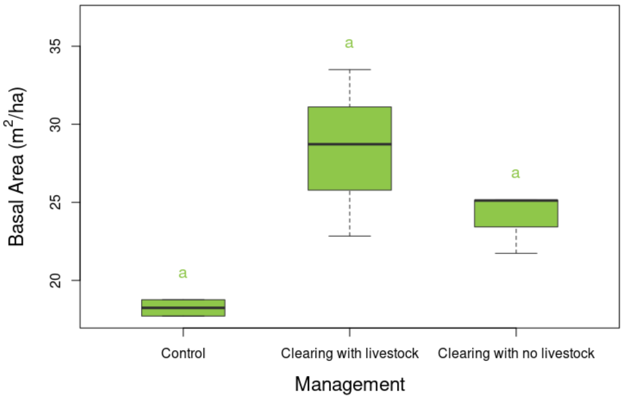


Figure 5. Differences in basal area (m^2/ha) among forest inventory subplots.

Figure 6 shows the average diametric class distribution for the forest. As explained before, the forest is an **even-aged stand** planted in the 60's. For this reason, there is a **predominance of individuals in the middle diametric classes** (between class 20: diameter between 17.5 and 22.5 cm; and class 30: between 27.5 and 32.5). The escort species (ash and pear trees) are residual and located in an extreme of the plot. The distribution of the basal area per diametric class follows the same structure than the distribution of diameter (Figure 7).

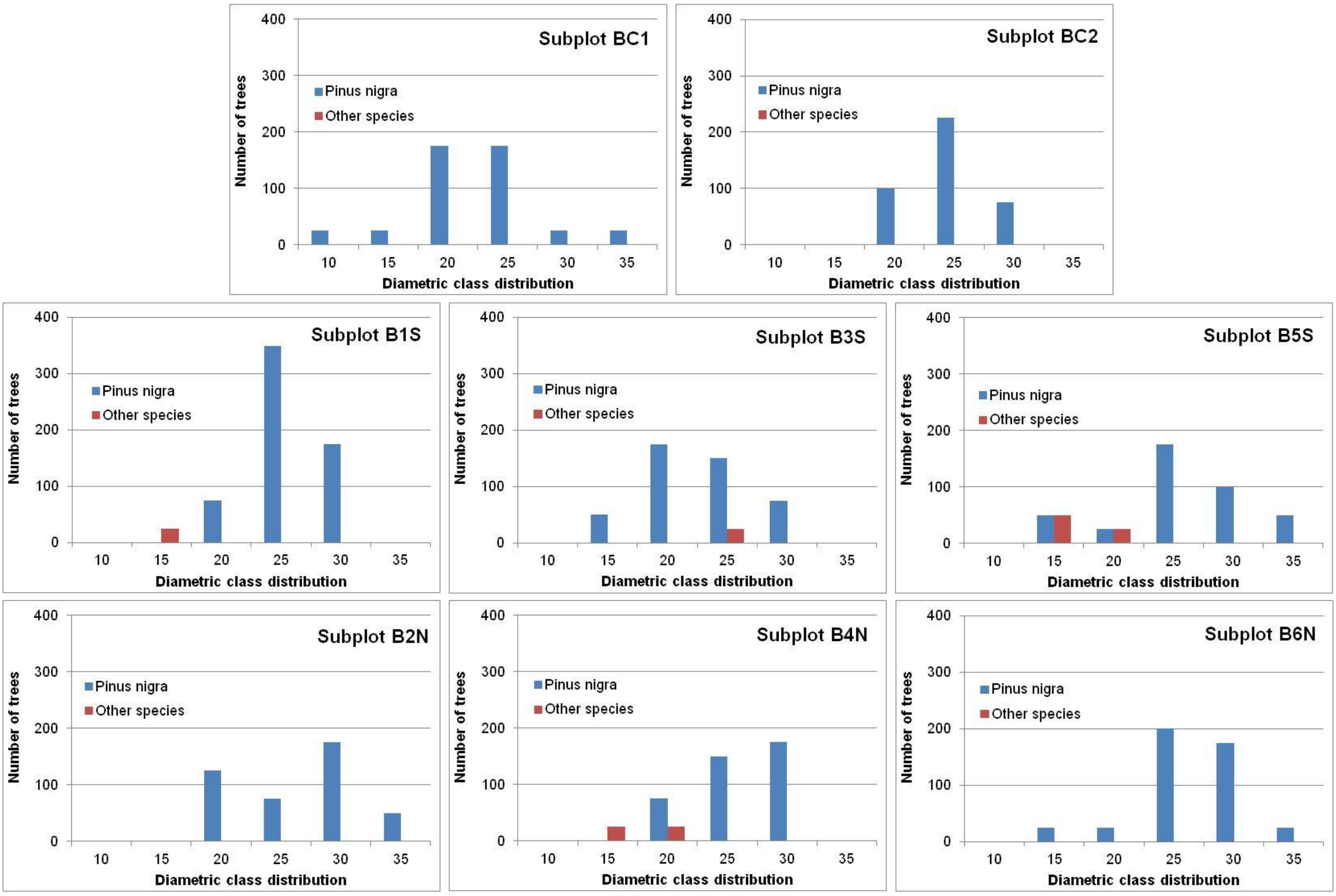
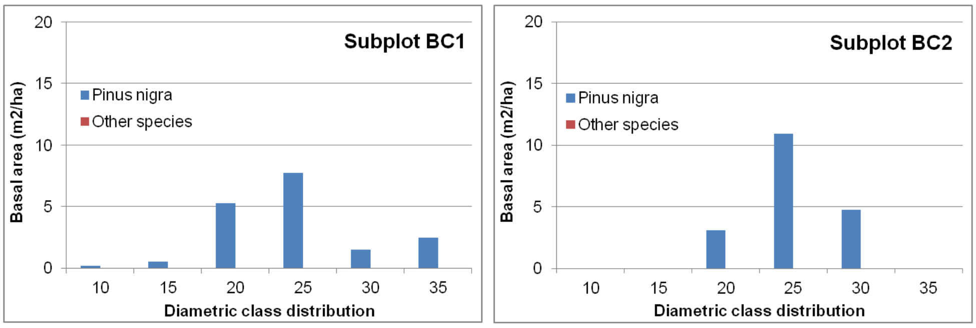


Figure 6. Number of trees per diametric class of the Pinus nigra forest in the forest inventory subplots.



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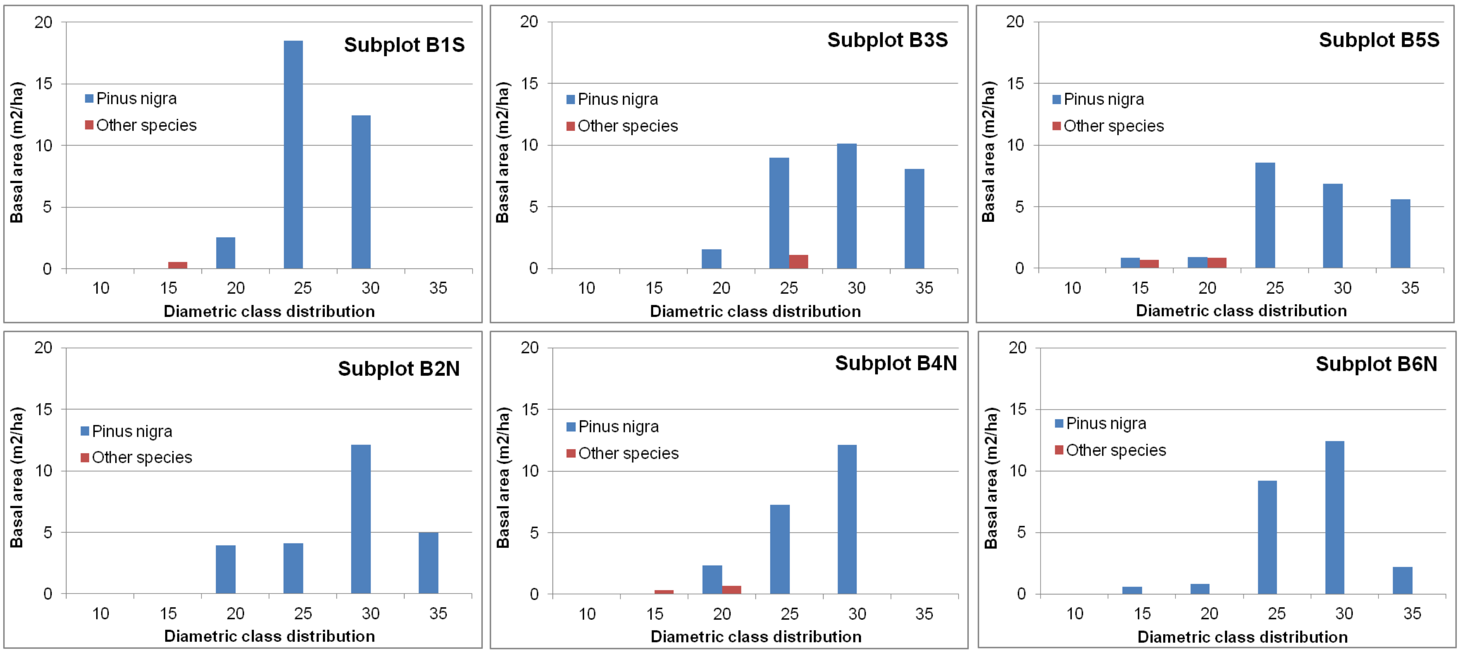


Figure 7. Distribution of basal area per diametric class of the Pinus nigra forest in the forest inventory subplots.

Figure 8 shows the forest's initial appearance in the forest inventory subplots.

Figure 8. Initial structure of the Pinus nigra forest

2.4. The adaptive forest management implemented in the *Pinus nigra* forest

Forest adaptive management has been applied in an area of 0.58 ha of *Pinus nigra* forest. The management practice has mainly consisted of **high intensity scrubland clearing** in order to promote fuel discontinuity, with the purpose of reducing the forest fire risk and to increase the pasture production and reduce water stress within the forest. The practice was applied on January 2020 and the area was subsequently fenced off (February 2020) to prevent the entry of wild animals and from the farm's own livestock.

In order to **characterise the treatment applied**, we have analysed the data related with the **understorey in the forest inventories** performed in June 2020. In this case, the data of the **two-control** rectangular forest inventory **subplots** (BC1-2) has been compared with the data of the **six managed subplots:** three subplots are located in the area where the livestock will enter (B1-3-5S), and the other three in the area where livestock will not enter (B2-4-6N).

Figure 9 shows the main changes in forest structure after the treatment, through changes in understorey cover and biovolume. The **treatment implied about 95%-reduction of understorey cover and 96%-reduction of understorey biovolume** (m^3), **in order to stimulate pasture production and regeneration** (Table 2). We have applied some statistics to compare between the cleared the control subplots (ANOVA and Tukey test). We have observed that there are significant differences in the understorey cover between the cleared and the control subplots: **the cleared area has a significant less understorey cover than the control subplots** and there are not differences between the cleared subplots with livestock (B1-3-5S) and without livestock (B2-4-6N) (Figure 10 Left, Annex 1).

Regarding **forest decay** (assessed as a combination of leaf discoloration and tree defoliation) **no significant initial differences among treatments are observed**, but we expect some divergent trends during the monitoring period (Figure 10 Right, Table 2, Annex 1).

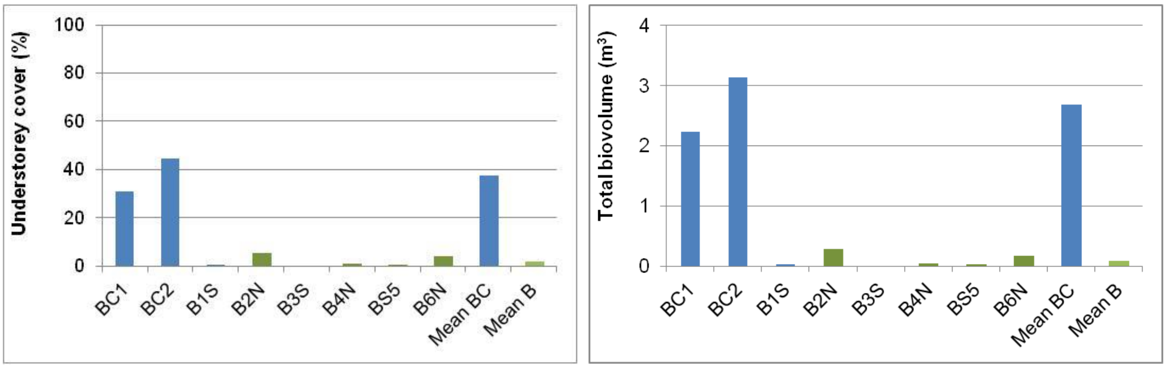


Figure 9. Distribution of understorey cover (%) and total biovolume (m^3/ha) per circular forest inventory subplot.

Forest inventory subplot	Understorey							Forest decay		
	Cover (%)	Mean height. (m)	Total biovolume (m^3)	Mean biovolume (cm)	Logging residues (%)	Herbaceous cover (%)	Litter (%)	Tree defoliation (%)	Leaf discoloration (%)	Mean forest decay (%)
BC1	30.9	0.6	2.2	0.056	0.0	51.6	25.0	0.0	4.5	4.5
BC2	44.4	0.6	3.1	0.078	0.0	35.8	24.3	0.0	5.0	5.0
B1S	0.6	0.2	0.0	0.001	0.0	42.2	32.8	1.5	4.0	5.5
B2N	5.3	0.5	0.3	0.007	2.3	70.0	33.2	0.0	9.5	9.5
B3S	0.0	0.0	0.0	0.000	0.5	20.4	55.8	0.0	12.0	12.0
B4N	1.0	0.4	0.0	0.001	1.5	57.5	41.8	1.5	7.0	8.5
BS5	0.5	0.3	0.0	0.001	0.8	17.1	59.9	0.5	8.5	9.0
B6N	4.0	0.4	0.2	0.004	0.0	59.0	53.9	2.0	9.0	11.0

Table 2. Resume of the inventory variables related with understorey and forest decay per forest inventory subplots measured on Juny 2020.

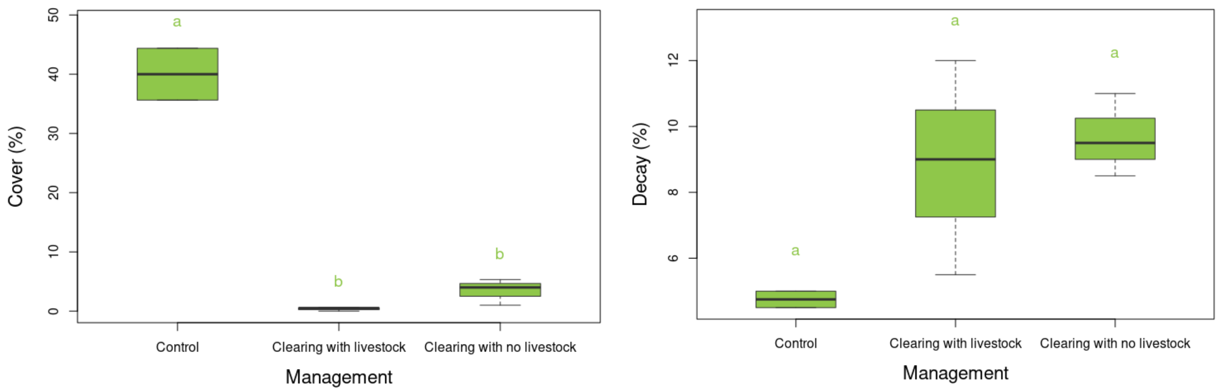


Figure 10. Left: Differences in understory cover (%) among forest inventory subplots. Right: Differences in forest decay (%) among forest inventory subplots.

Together with the forest inventories, we have performed **vegetation inventories** to analyse **pasture production and quality and vegetation biodiversity**. The details of the sampling can be consulted in Annex 2. To assess the **pasture's biodiversity**, we sampled the vegetation growing inside three sub-plots with no livestock and in three sub-plots submitted to livestock by cows (B) in the area submitted to clearing. As a control, we also sampled the vegetation growing in an area with the same environmental conditions and vegetation structure but with no clearing intervention and no livestock. We recorded the surface covered by every species found inside 1*1 m quadrats at each sub-plot in the clearing area (n= 3 sub-plots per livestock treatment * 4 quadrats= 36 quadrats) and in the control area (n=12 quadrats). **We found a total of 118 species, being 93 herbaceous and 25 woody species** (Table 1 in Annex 2). We also tested for differences per management treatment in the number of species and the area covered by each lifeform.

To assess the **pasture production and quality,** we collected systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats (n=36 samples). Samples were divided into herbaceous and woody species separately. Samples were cleaned (discarding the litter), and dried in a stove at 65ºC during 48 hours. Then, they were weighed to estimate the dry biomass production (T/ha). The sample processing is still in progress. All the samples will be grinded to a particle size of <1 mm to assess the pasture quality by analysing the content of proteins and fibers. **We found significantly more herbaceous species in the areas submitted to clearing than in the non-managed area (control).** Contrarily, **richness of woody species was significantly larger in the control area than in the clearing area**. We did not find significant differences in species richness (neither herbaceous nor woody species) between the plots submitted to livestock and not submitted to livestock within the clearing area.

2.5. The livestock management and monitoring subplots in the *Pinus nigra* forest

In previous sections, we have already explained the two areas where the pilot experience has been implemented: a control area, with no action, and a cleared area, where adaptive forest management has been applied. Our **experimental design** consists on creating **three typologies of plots**: 1) **control plots**, without neither forest management nor the entry of livestock (BC); 2) **cleared plots with livestock** (BS); 3) **cleared plots without livestock** (BN). For each of the plots, we have performed **three replicates** (B1-3-5S and B2-4-6N), except in the control area where only two plots have been possible (BC1-2). With three replicates we can perform statistical analysis to confirm if differences among the plots are significant.

The experimental design includes three plots of 400 m^2 with its replicates, **eight subplots of 400 m^2** in total. The surface of the subplots has been defined based on: a) the surface available in the area; and b) the conditions imposed by the property about the livestock management. In this case, the stockbreeder has facilitated the access of the cows to the plots during a concrete number of days. The proposal of livestock management has been to **introduce 2 cows during 72 hours, at least 2 times per year**, but the number can increase based on the pasture recover. In order to control the livestock, we fenced all the plots. The two **cows entered for first time on 8th June 2020** during 72 hours in each of the three subplots with livestock (B1S, B3S and B5S).

Figure 11. Cows grazing the livestock subplots on 8th of June 2020 (left) and subplots after grazing on the 10th of June 2020.

Those **eight subplots (plots and replicate) coincide with the monitoring subplots of the project**. In those subplots, all the monitoring tasks defined in the project proposal will be performed during four years.

Figure 12 shows the eight subplots defined for the livestock management and monitoring tasks. In each of these subplots we have located a forest inventory subplot.

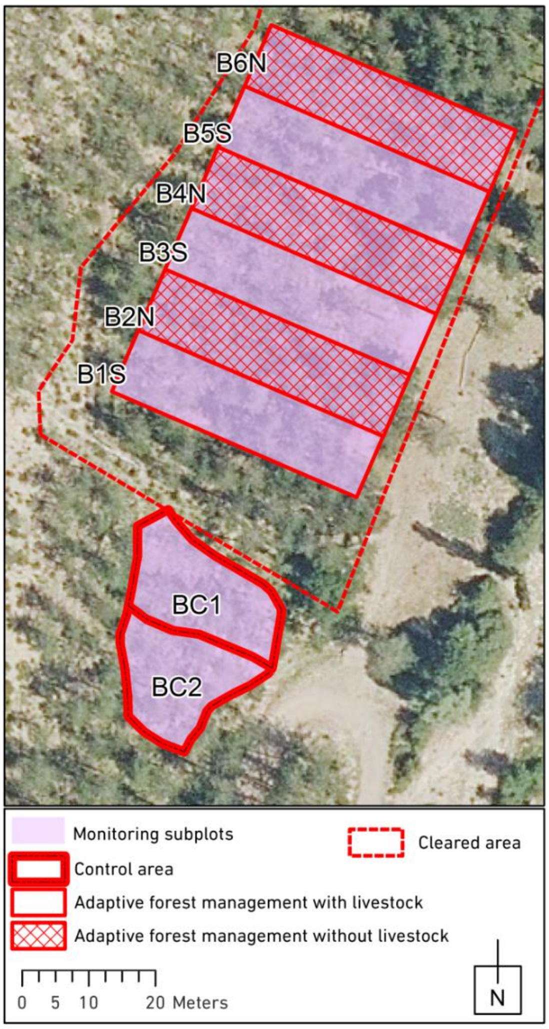


Figure 12. Location of the plots and replicates of the experimental design. Those subplots coincide with the monitoring subplots.

The **monitoring variables and protocols** will be defined in Deliverable 9, foreseen on December 2020. Nevertheless, here there is a short resume of the typology of variables followed in the monitoring subplots. Besides, Figure 13 shows a diagram of the livestock and monitoring plots, together with the distribution and location of the different monitoring tools.

- Soil analysis: The first sample of soils were taken along January and June 2020. At each monitoring subplot, three soil samples were sampled at 10 cm increments: 0 cm, 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. We collected systematically 3 soil samples per plot and depth. Subsamples (n=195) were combined into one soil composite sample per plot and depth. In total 65 composite samples were collected (n=650). In addition, bulk soil samples were collected to test soil moisture and bulk density values. Those analyses will allow to set the initial conditions of the soil. Before the end of the project, a sample of the same subplots will be taken to know the effect of the different treatments on the following soil variables: Field bulk density (BD), pH and electrical conductivity (EC), total carbon concentration (Ctotal), total nitrogen concentration (N), carbonate content ($CaCO_3$), 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).

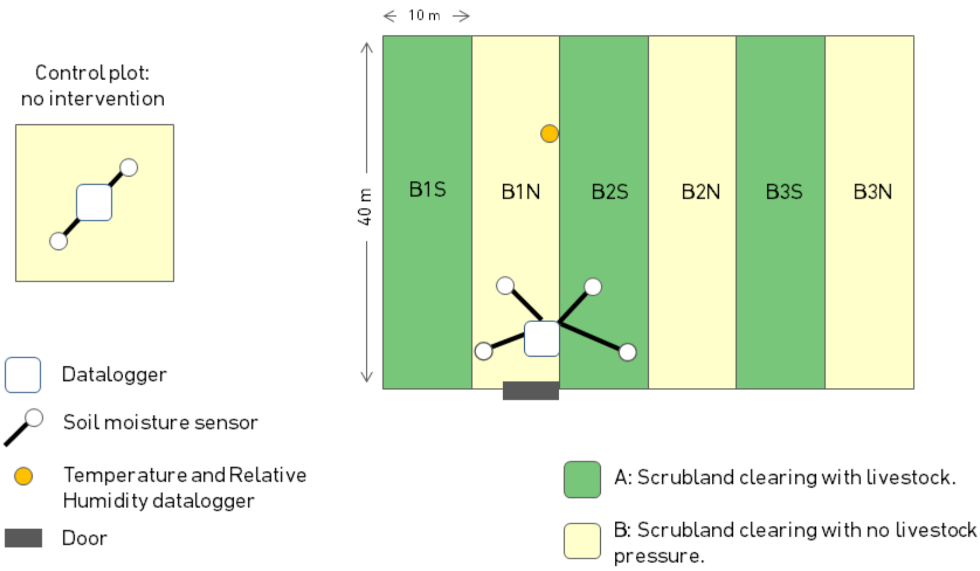


Figure 13. Diagram of the livestock and monitoring subplots.

- Installation of the instrumentation to control environmental variables: soil moisture sensors, pluviometers and air moisture and temperature sensors. Two sensors were installed for each plot (control, clearing with and without livestock) to obtain two replicas. A U30-NRC Meteorological Station HOBO USB datalogger was installed and the soil moisture data from 4 plots (2 experiments with their two replicas) were installed. Likewise, one datalogger was installed in the control area with two soil moisture sensors. The soil humidity probes are S-SMC M 005. These probes, buried at 20 cm depth, are inserted in a corrugated tube for protection, mainly to avoid being bitten by livestock. The sensors are nailed in a vertical position at 20 cm depth, as recommended in the installation manual. We have also installed air temperature and relative humidity sensors (Tinytag Plus 2 - TGP-4500) with measurement ranges of -25ºC-85ºC and 0-100%, respectively. In order to have different replicas of both measurements, they were installed inside the experimental plots, control plots and outside them, in shady and well-ventilated sites (Figure 15).
- Forest inventory: Forest inventory will be done in all monitoring subplots several times along project duration. The inventory is carried out in rectangular subplots with an area of 400 m^2, distributed within the monitoring subplots. A first forest

inventory was carried out on June 2020 to set the initial conditions of the stand, as previously explained. Along the summer of 2020, the first monitoring campaign was carried out every 15 days to collect forest fuel samples. The variables monitored are: forest structure; understorey biovolume; regeneration; forest fuel continuity; and forest health status.

- Vegetation inventory (pasture production and quality and biodiversity): A vegetation inventory will be done in all monitoring subplots several times along project duration. We sample the vegetation growing inside each of the sub-plots, recording every species found inside 1*1 m quadrats. Likewise, to assess the pasture production and quality, we collected systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats. The variables monitored are: pasture production and quality; pastoral value; pasture nutritive quality (protein and fibre content) and biomass productivity (Figure 16). Results of the species composition and richness recorded in the first inventory, and biomass productivity of the pasture are specified in Annex 2.
- Rain simulation: Rainfall experimental generation will be done in all monitoring subplots several times along project duration. The variables monitored are: runoff coefficient, delay time, depth of infiltration, sediments. First rainfall simulations will be performed on October 2020 and second sets of experiments are planned to be carried out in winter 2020-2021.

Figure 14. Soil sampling in forest inventory control subplots carried out in June 2020.

Figure 15. Instrumentation in the subplots: soil moisture datalogger.

Figure 16. First vegetation samplings in La Garcipollera carried out in July 2020.

2.6. The *Populus* forest before the application of adaptive forest management

The forest where the adaptive management has been applied, is a *Populus* forest where ***Populus nigra* is the dominant species** in the area (98% of basal area), with some minority escort species: ash tree (*Fraxinus* sp.), hawthorn (*Crataegus monogyna*) and some isolated individuals of quince tree (*Cydonia oblonga*) and European plum (*Prunus domestica*). In Aragon, the adaptive practice has affected to the understorey, but not to the trees structure. For this reason, in the following paragraphs, we include a description of the forest structure which is similar in all the area (managed and control). The changes in the understorey between the non-managed (control) and the managed area are described in the following chapter.

A **forest inventory** was performed in **May 2021 to characterise the initial conditions of the forest stand**. The inventory was realized **in eight rectangular sub-plots** with an area of 400 m^2, uniformly distributed. In each plot, the same variables as in the *Pinus nigra* forest were taken.

Figure 17 shows the location of the subplots in each area. There are two subplots in the control area (CC1 and CC2), three in the managed area with livestock (C2S, C4S and C6S) and three in the managed area without livestock (C1N, C3N and C5N).

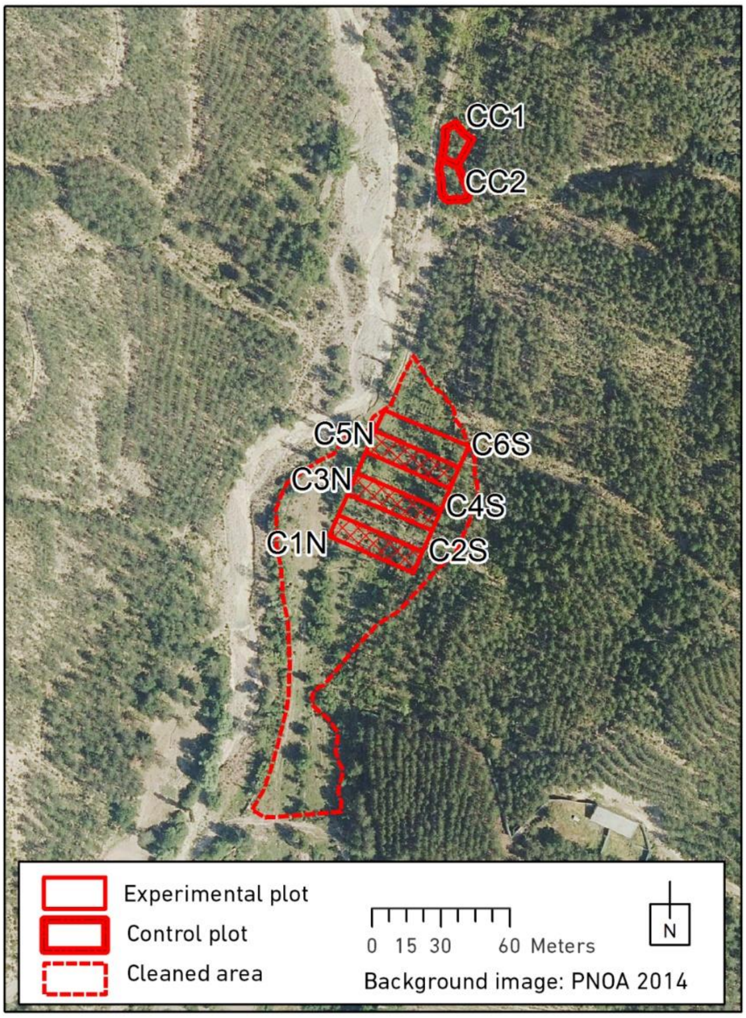


Figure 17. Subplot's location for the forest inventory.

The initial inventory determined that this forest is a **very low dense forest** (between 75 and 175 trees/ha) with a mean **basal area about 9.5 m^2/ha** (Table 1, Figure 3). Mean diameter at breast height oscillates between 29.3 and 33.9 cm and mean height between 13.3 and 25.0 m. The crown fire hazard was estimated using the manual of Piqué et al. (2011) for *Quercus* species, since there is not hazard estimation for *Populus* ones. Control subplots have a moderate hazard, with a structure type B16 (Table 3, Figure 19). On the other hand, the managed areas have mainly a low crown fire hazard after the implementation.

Forest inventory subplot	Canopy cover (%)	Number of trees / ha	Basal area (m^2/ha)	Mean diameter at breast height (cm)	Mean tree's height (m)	Forest fuel continuity model	Crown fire hazard
CC1	10	75	5.1	29.3	25.0	B16	Moderate
CC2	15	125	7.4	29.7	24.3	B16	Moderate
C2S	15	150	10.9	32.8	23.4	C13	Low
C4S	40	175	13.0	33.9	22.0	B16	Moderate
C6S	20	150	13.8	33.8	24.5	C13	Low
C1N	5	75	6.3	31.9	13.3	C13	Low
C3N	20	150	13.7	33.7	20.7	C13	Low
C5N	5	75	5.7	30.6	18.7	C13	Low

Table 3. Resume of the inventory variables per forest inventory subplots measured on May 2021.

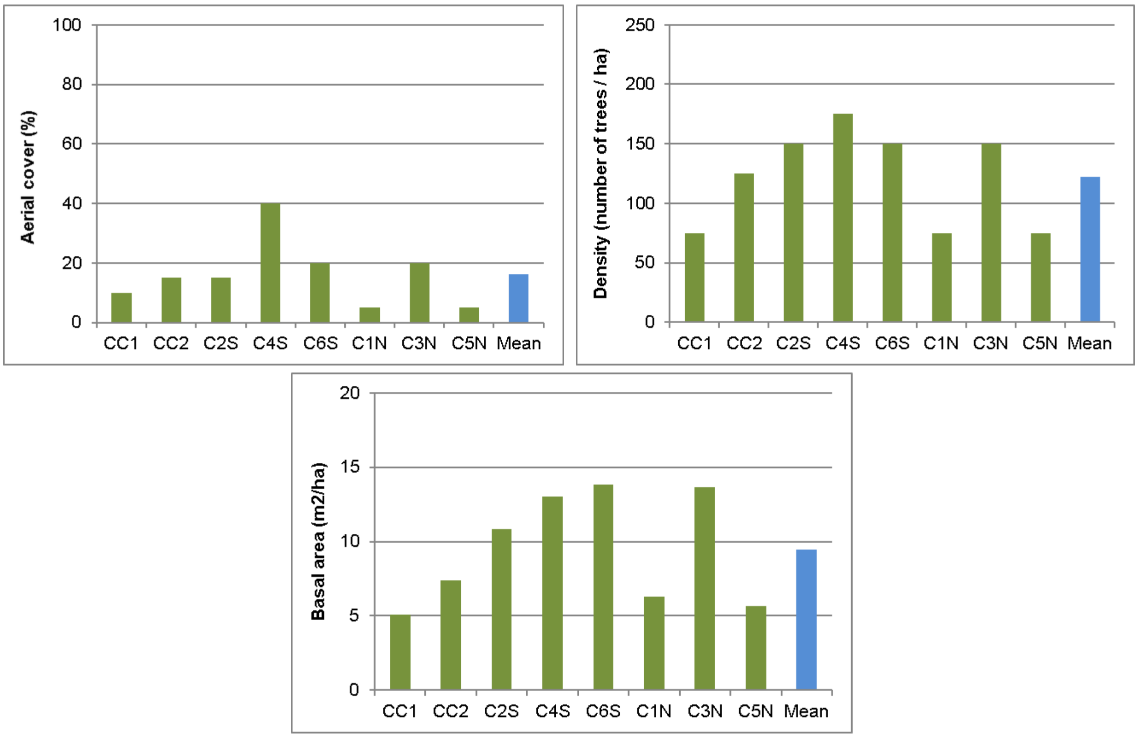


Figure 18. Distribution of aerial cover (%), density (number of trees per ha) and basal area (m^2/ha) per forest inventory subplot.

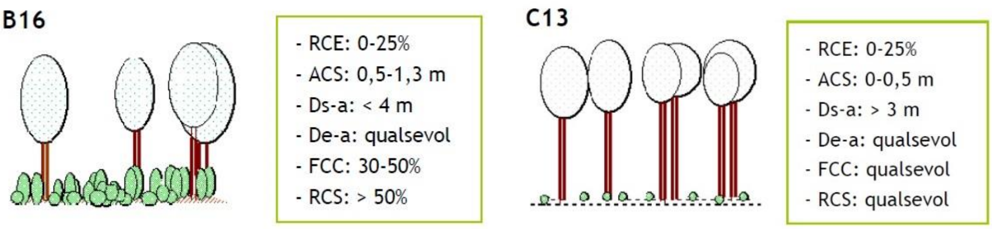


Figure 19. Description of the structure type B16 and C13 with moderate and low crown fire hazard following Piqué et al. 2011.

We have applied some statistics to compare among cleared subplots and with the control subplots (ANOVA and Tukey test). We have observed that **there are not significant differences in the basal area between the managed and the control subplots**. So we can conclude that the forest strucuture in all the subplots is quite similar and non significant differences are found (Figure 20, Annex 1).

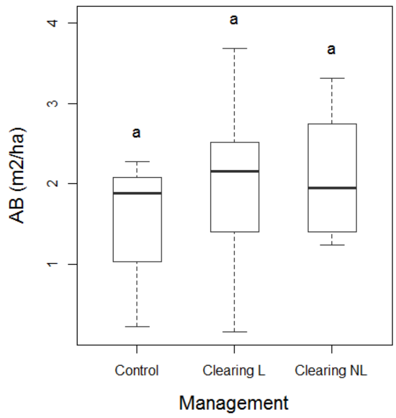


Figure 20. Differences in basal area (m^2/ha) among forest inventory subplots.

Figure 21 shows the average diametric class distribution for the forest. As explained before, the forest has a very low density with a **predominance of individuals in the higher diametric classes** (between class 25: diameter between 22.5 and 27.5 cm; and class 40: between 37.5 and 42.5). The escort species are a minority and spread along the area. The distribution of the basal area per diametric class follows the same structure than the distribution of diameter (Figure 22).

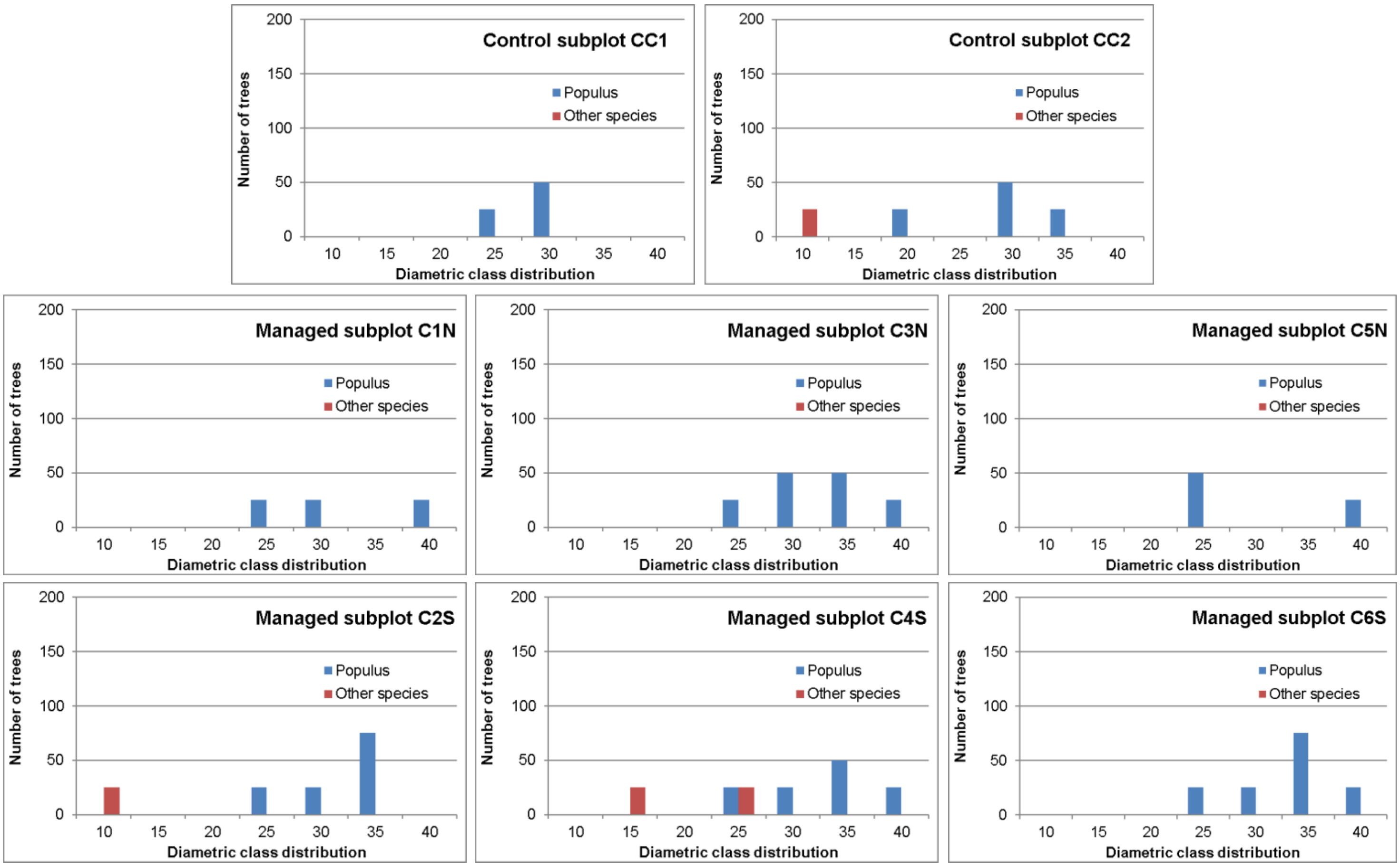
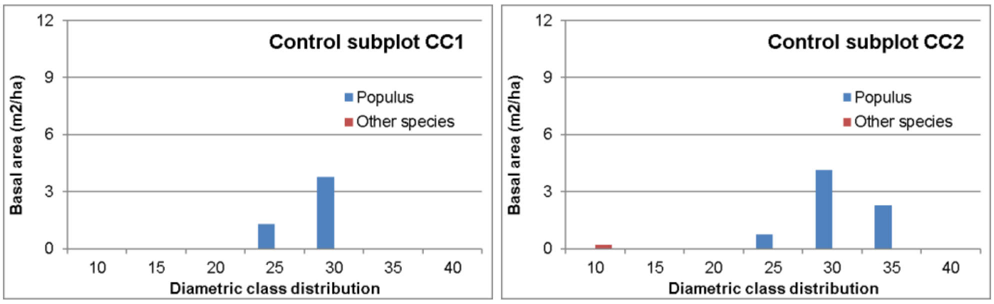


Figure 21. Number of trees per diametric class of the Populus forest in the inventory subplots.



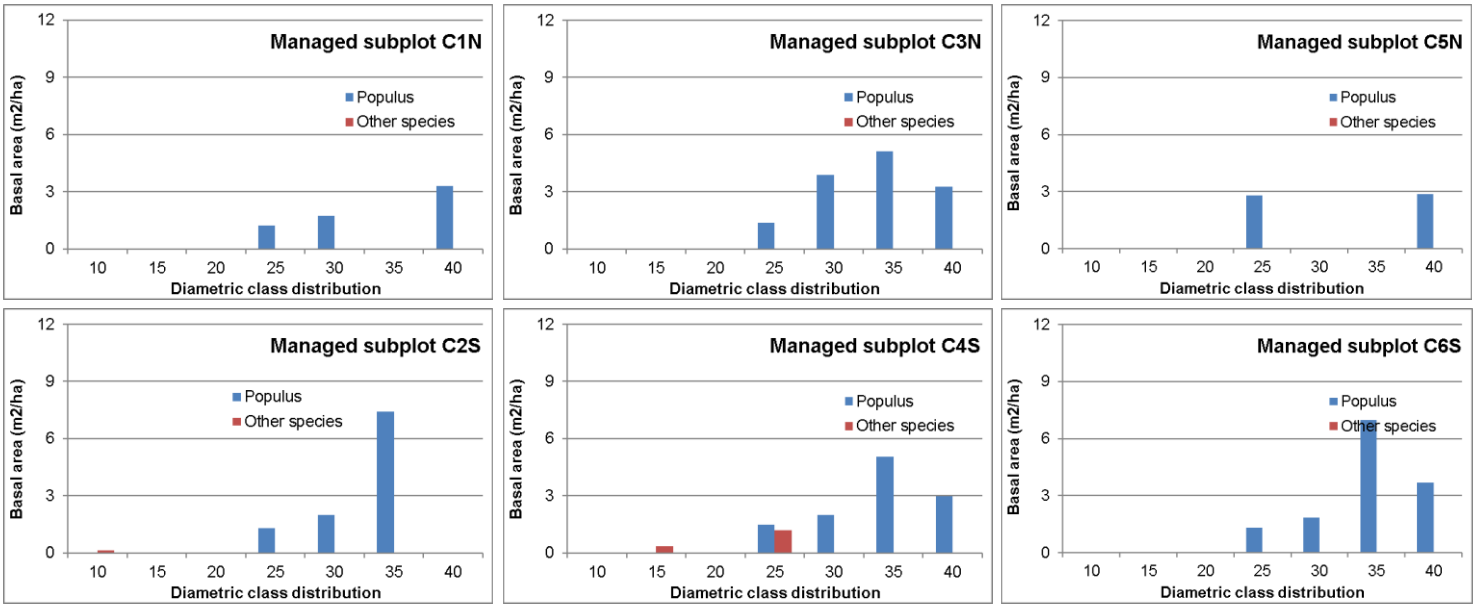


Figure 22. Distribution of basal area per diametric class of the Populus forest in the forest inventory subplots.

Figure 23 shows the forest's initial appearance in the forest inventory subplots.

Figure 23. Initial structure of the Populus forest

2.7. The adaptive forest management implemented in the *Populus* forest

Forest adaptive management has been applied in an area of 0.86 ha of *Populus* forest. The management practice has mainly consisted of **high intensity scrubland clearing** in order to promote fuel discontinuity, with the purpose of reducing the forest fire risk and to increase the pasture production and reduce water stress within the forest. The practice was applied on February 2021 and the area was subsequently fenced off to prevent the entry of wild animals and from the farm's own livestock.

In order to **characterise the treatment applied**, we have analysed the data related with the **understorey in the forest inventories** performed in May 2021. In this case, the data of the **two control** rectangular forest inventory **subplots** (CC1-2) has been compared with the data of the **six managed subplots:** three subplots are located in the area where the livestock will enter (C2-4-6S), and the other three in the area where livestock will not enter (C1-3-5N).

Figure 24 shows the main changes in forest structure after the treatment, through changes in understorey cover and biovolume. The **treatment implied about 84%-reduction of understorey cover and 97%-reduction of understorey biovolume** (m^3), **in order to stimulate pasture production and regeneration** (Table 4). We have applied some statistics to compare between the cleared the control subplots (ANOVA and Tukey test). We have observed that there are significant differences in the understorey cover between the cleared and the control subplots: **the cleared area has a significant less understorey cover than the control subplots** and there are not differences between the cleared subplots with livestock (B1-3-5S) and without livestock (B2-4-6N) (Figure 25 Left, Annex 1).

Regarding **forest decay** (assessed as a combination of leaf discoloration and tree defoliation) **no significant differences among treatments are observed** for 2021, but we expect some divergent trends during the monitoring period (Figure 25 Right, Table 4, Annex 1).

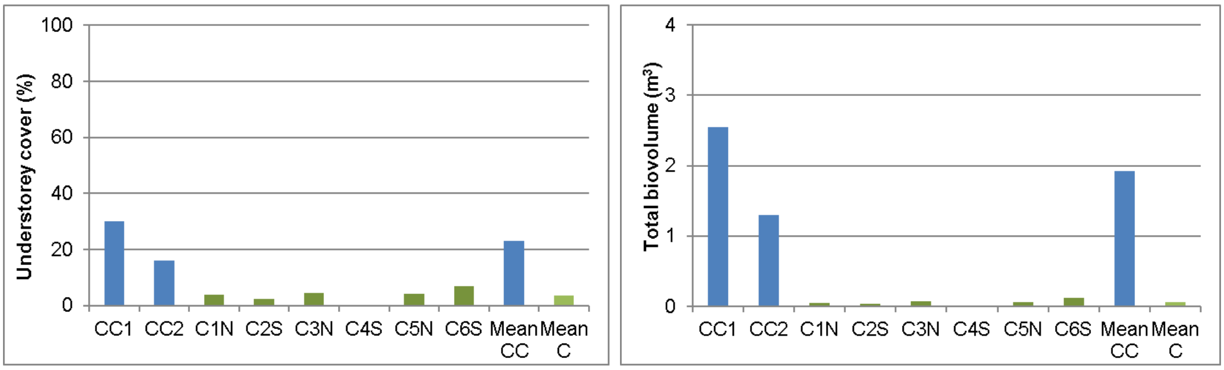


Figure 24. Distribution of understorey cover (%) and total biovolume (m^3/ha) per forest inventory subplot.

Forest inventory subplot	Understorey							Forest decay		
	Cover (%)	Mean height. (m)	Total biovolume (m^3)	Mean biovolume (cm)	Logging residues (%)	Herbaceous cover (%)	Litter (%)	Tree defoliation (%)	Leaf discoloration (%)	Mean forest decay (%)
CC1	30.3	0.7	2.5	0.064	9.1	79.6	20.1	18.3	0.0	18.3
CC2	16.0	0.7	1.3	0.033	8.4	77.1	10.5	24.0	0.0	24.0
C1N	3.9	0.1	0.0	0.002	7.4	78.8	3.3	27.0	0.0	27.0
C2S	2.5	0.1	0.0	0.001	7.5	62.0	8.6	39.2	0.0	39.2
C3N	4.5	0.1	0.1	0.002	5.1	61.5	8.5	20.7	0.0	20.7
C4S	0.1	0.1	0.0	0.000	4.4	81.8	2.4	13.8	0.0	13.8
C5N	4.3	0.1	0.1	0.001	7.4	69.3	6.9	16.7	0.0	16.7
C6S	7.0	0.1	0.1	0.003	8.3	77.1	12.0	16.4	0.0	16.4

Table 4. Resume of the inventory variables related with understorey and forest decay per forest inventory subplots measured on May 2021.

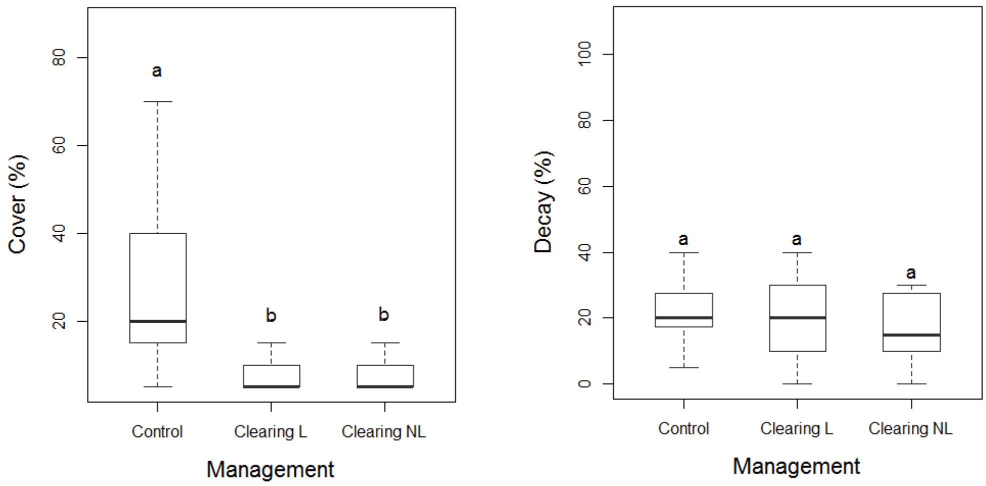


Figure 25. Left: Differences in understory cover (%) among forest inventory subplots. Right: Differences in forest decay (%) among forest inventory subplots.

Together with the forest inventories, we have performed **vegetation inventories** to analyse **pasture production and quality and vegetation biodiversity**. The details of the sampling can be consulted in Annex 2. To assess the **pasture's biodiversity**, we sampled the vegetation growing inside three sub-plots with no livestock and in three sub-plots submitted to livestock by cows in the area submitted to clearing. As a control, we also sampled the vegetation growing in an area with the same environmental conditions and vegetation structure but with no clearing intervention and no livestock. We recorded the surface covered by every species found inside 1*1 m quadrats at each sub-plot in the clearing area (n= 3 sub-plots per livestock treatment * 4 quadrats= 36 quadrats) and in the control area (n=12 quadrats). **We found a total of 88 species, being 72 herbaceous and 16 woody species** (Table 2 in Annex 2).

To assess the **pasture production and quality,** we collected systematically the plants growing in 50 x 50 cm areas close to each of the previously surveyed quadrats (n=36 samples). Samples were divided into herbaceous and woody species separately. Samples were cleaned (discarding the litter), and dried in a stove at 65ºC during 48 hours. Then, they were weighed to estimate the dry biomass production (T/ha). The sample processing is still in progress. All the samples will be grinded to a particle size of <1 mm to assess the pasture quality by analysing the content of proteins and fibers.

We found significantly more herbaceous species in the areas submitted to clearing than in the non-managed area (control). Contrarily, **richness of woody species was significantly larger in the control area than in the clearing area**. We did not find significant differences in species richness (neither herbaceous nor woody species) between the plots submitted to livestock and not submitted to livestock within the clearing area.

2.8. The livestock management and monitoring subplots in the *Populus* forest

In previous sections, we have already explained the two areas where the pilot experience has been implemented: a control area, with no action, and a cleared area, where adaptive forest management has been applied. Our **experimental design** consists on creating **three typologies of plots**: 1) **control plots**, without neither forest management nor the entry of livestock (CC); 2) **cleared plots with livestock** (CS); 3) **cleared plots without livestock** (CN). For each of the plots, we have performed **three replicates** (C1-3-5N and C2-4-6S), except in the control area where only two plots have been possible (CC1-2). With three replicates we can perform statistical analysis to confirm if differences among the plots are significant.

The experimental design includes three plots of 400 m^2 with its replicates, **eight subplots of 400 m^2** in total. The surface of the subplots has been defined based on: a) the surface available in the area; and b) the conditions imposed by the property about the livestock management. In this case, the stockbreeder has facilitated the access of the cows to the plots during a concrete number of days. The proposal of livestock management has been to **introduce 2 cows during 72 hours, at least 2 times per year**, but the number can increase based on the pasture recover. In order to control the livestock, we fenced all the plots. The two **cows entered for first time on 18th June 2021** during 72 hours in each of the three subplots with livestock (C2S, C3S and C5S).

Figure 26. Cows grazing the livestock subplots on 18th of June 2021.

Those **eight subplots (plots and replicate) coincide with the monitoring subplots of the project**. In those subplots, all the monitoring tasks defined in the project proposal will be performed during four years.

Figure 27 shows the eight subplots defined for the livestock management and monitoring tasks. In each of these subplots we have located a forest inventory subplot.

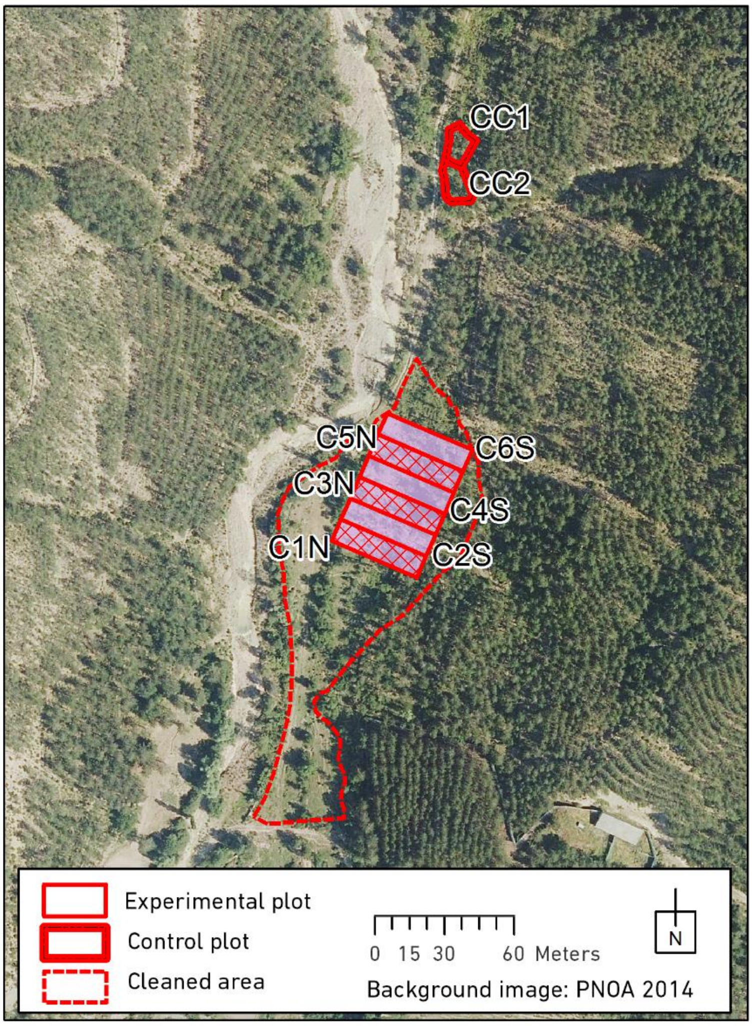


Figure 27. Location of the plots and replicates of the experimental design. Those subplots coincide with the monitoring subplots.

The **monitoring variables and protocols** will be defined in Deliverable 9, foreseen on December 2020. Nevertheless, here there is a short resume of the typology of variables followed in the monitoring subplots. Besides,

Figure *28* shows a diagram of the livestock and monitoring plots, together with the distribution and location of the different monitoring tools.

- Soil analysis: The first sample of soils were taken along May 2021. At each monitoring subplot, three soil samples were sampled at 10 cm increments: 0 cm, 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. We collected systematically 3 soil samples per plot and depth. Subsamples (n=120) were combined into one soil composite sample per plot and depth. In total 40 composite samples were collected (n=650). In addition, bulk soil samples were collected to test soil moisture and bulk density values. Those analysis will allow to set the initial conditions of the soil. Before the end of the project, a sample of the same subplots will be taken to know the effect of the different treatments on the following soil variables: Field bulk density (BD), pH and electrical conductivity (EC), total carbon concentration (Ctotal), total nitrogen concentration (N), carbonate content (CaCO3), organic carbon (Corg), soil organic carbon (SOC) and nitrogen (TN) stocks, organic matter (OM), grain size distribution, organic phosphorus (P), saturated soil moisture (SAT), field capacity (FC), wilting point (WP) and CN ratio (Figure 29).

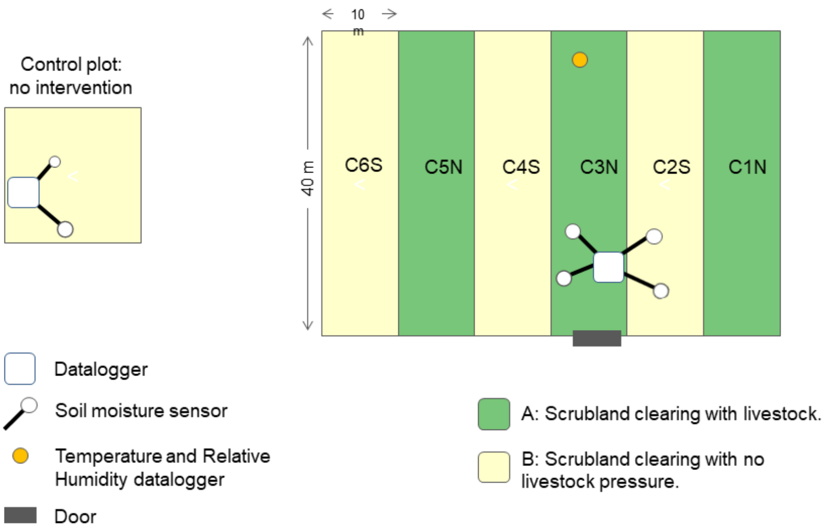


Figure 28. Diagram of the livestock and monitoring subplots.

- Installation of the instrumentation to control environmental variables: soil moisture sensors, pluviometers and air moisture and temperature sensors. Two sensors were installed for each plot (control, clearing with and without livestock) to obtain two replicas. A U30-NRC Meteorological Station HOBO USB datalogger was installed and the soil moisture data from 4 plots (2 experiments with their two replicas) were installed. Likewise, one datalogger was installed in the control area with two soil moisture sensors. The soil humidity probes are S-SMC M 005. These probes, buried at 20 cm depth, are inserted in a corrugated tube for protection, mainly to avoid being bitten by livestock. The sensors are nailed in a vertical position at 20 cm depth, as recommended in the installation manual. We have also installed air temperature and relative humidity sensors (Tinytag Plus 2 - TGP-4500) with measurement ranges of -25ºC-85ºC and 0-100%, respectively. In order to have different replicas of both measurements, they were installed inside the experimental plots, control plots and outside them, in shady and well-ventilated sites (Figure 30).
- Forest inventory: Forest inventory will be done in all monitoring subplots several times along project duration. The inventory is carried out in rectangular subplots with an area of 400 m^2, distributed within the monitoring subplots. A first forest inventory was carried out on May 2021 to set the initial conditions of the stand, as previously explained. Along the summer of 2021, the first monitoring campaign was carried out every 15 days to collect forest fuel samples. The

variables monitored are: forest structure; understorey biovolume; regeneration; forest fuel continuity; and forest health status.

- Vegetation inventory (pasture production and quality and biodiversity): A vegetation inventory will be done in all monitoring subplots several times along project duration. We sample the vegetation growing inside each of the sub-plots, recording every species found inside 1*1 m quadrats. Likewise, to assess the pasture production and quality, we collected systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats. The variables monitored are: pasture production and quality; pastoral value; pasture nutritive quality (protein and fibre content) and biomass productivity (Figure 31). Results of the species composition and richness recorded in the first inventory, and biomass productivity of the pasture are specified in Annex 2.
- Rain simulation: Rainfall experimental generation will be done in all monitoring subplots several times along project duration. The variables monitored are: runoff coefficient, delay time, depth of infiltration, sediments. First rainfall simulations will be performed on November 2021.

Figure 29. Soil sampling in forest inventory control subplots carried out in May 2021.

Figure 30. Installation of the instrumentation in the subplots: soil moisture datalogger.

Figure 31. First vegetation samplings in La Garcipollera carried out in May 2021.

3. Forest management pilot experience in Catalonia

3.1. The pilot experience in the project proposal

Following, a description of the pilot experience as it was included in the proposal is shown, in order to better explain the final pilot experience implemented.

Sub-action C2.1 Forest management in Catalonia

Two pilot experiences will be carried out in Catalonia. The plots will be located in a holm oak forest in the lower part of the Eastern Pyrenees (Albera Massif), in the Requesens private estate (Fig. C2.1). The criteria used to select this forest are included in Table C2.2.

The Requesens estate has 2.230 ha and is currently grazed by about 300 Albera cows, an endangered breed. Previous actions have been taken by the owners to promote pastures, albeit with some obstacles impeded it:

- The constant graze of the cattle along the year, especially in spring when herbs sprout, leading to high pressure on the pastures.
- Recent owner's experiences to create open areas, without forest, for pasture lands production have failed, due to the quickly colonization of the area by the invasive ragwort (*Senecio inaequidens*), that impedes the settle of pastures.

The pilot experiences will mainly consist of:

1. Forest management interventions in plots of around 1-2 ha. Combining tree thinning and undergrowth clearing we will promote mature structures with bigger trees (more resistant to water stress), fuel discontinuity (to reduce forest risk) and small open areas (to avoid ragwort colonization in Requesens).
2. A plot with no intervention to monitor the site evolution with no actuation (around 1-2 ha).
3. Provide the area with livestock infrastructure, including drinking trough, fodder trough, and covered site, among others. In Requesens, the construction of a fenced enclosure to contain the cattle during herb regeneration and fodder feeding period.

3.2. The implemented pilot experience

The forest management pilot experience in Catalonia is located in a **Holm oak forest** in the lower part of the Eastern Pyrenees (Protected Natural Area of l'Albera), specifically, in the Requesens estate (Figure 32).

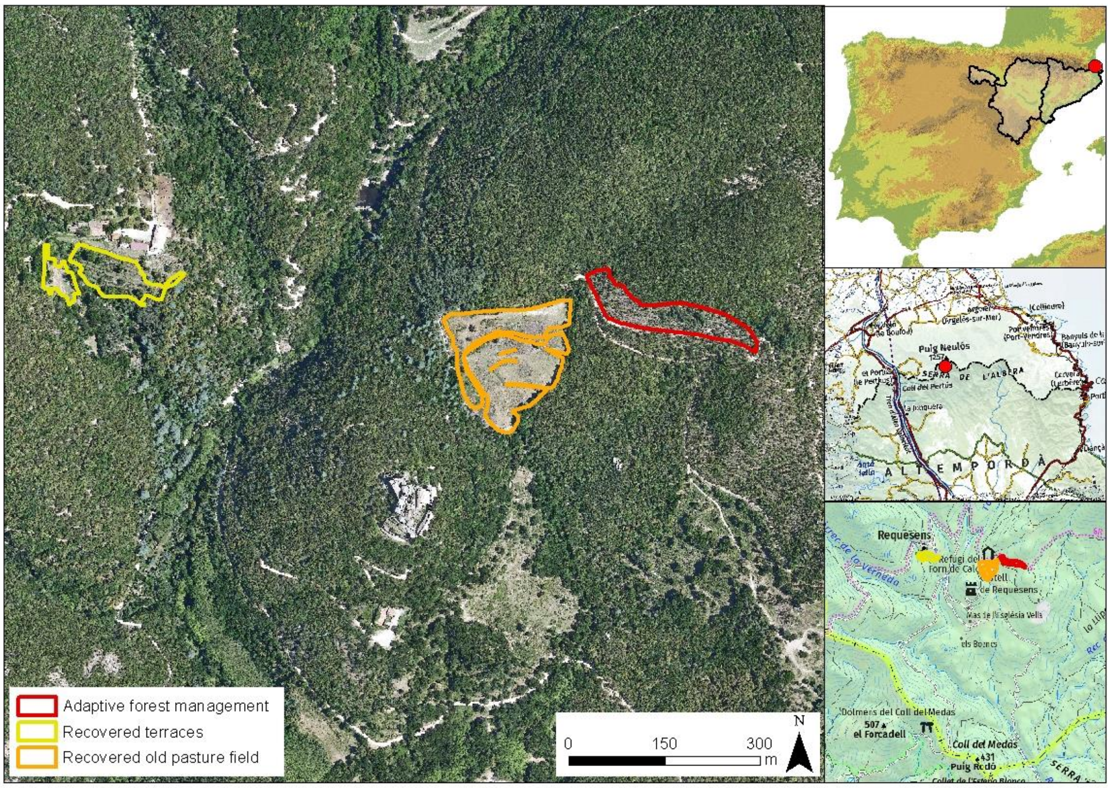


Figure 32. Location of the forest management pilot experience in Catalonia

The forest management pilot experience in Catalonia has consisted of:

1. The application of adaptive forest management in a Holm oak forest area of **1.15 ha** (Figure 33). The main objective of this management has been to address two main challenges: 1) to reduce the forest vulnerability to climate change by reducing fire risk and forest water stress and increasing wood production/carbon sequestration; and 2) to improve the socioeconomic development of the farming activity to favour its sustainability. Adaptive management practice has mainly consisted of **selective thinning and scrubland clearing** in order to reduce tree density, reduce fuel continuity and promote mature structures with bigger trees and fuel discontinuity.

   Along 2019, the Requesens' property was implementing forest management in several hectares of Holm oak in the estate, following the guidelines of the Management and Forest Improvement Technical Plan (PTGMF) and the guidelines of the Protected Natural Area of l'Albera to reduce fire risk. As the criteria and objective of the forest management were the same than in LIFE MIDMACC project, we decided to use one of the areas already managed as forest pilot experience.

   This area has been divided in **two different pilot experiences**, depending on the livestock management:

   a. A **sub-area of 5,520 m^2** where **livestock will enter**. When visiting the plot, it was found that the natural recuperation of the pasture under the forest was a difficult issue since the livestock management for the last years in the estate have favoured the compress of soil and the disappearance of the herbaceous vegetation. Then, some actions were needed in order to recover the pastures under the forest (explained in chapter 3.4). The objective of this sub-area is to monitor the evolution of the adaptive forest management regarding climate change vulnerability when extensive livestock farming is use to maintain the effects of the management treatment.

b. A **sub-area of 5,978 m^2** where **livestock will not enter**. In this sub-area, the logging residues has been left in the soil. The objective of this sub-area is to monitor the evolution of the adaptive forest management regarding climate change vulnerability as traditionally applied, without neither logging residues elimination nor extensive livestock farming.

2. An <u>area with **no actuation of 1.47 ha**</u>. This area is close by the managed area and show similar condition in location, altitude and orientation. This area will not be neither managed nor pastured, with the objective to monitor the site evolution with no actuation.

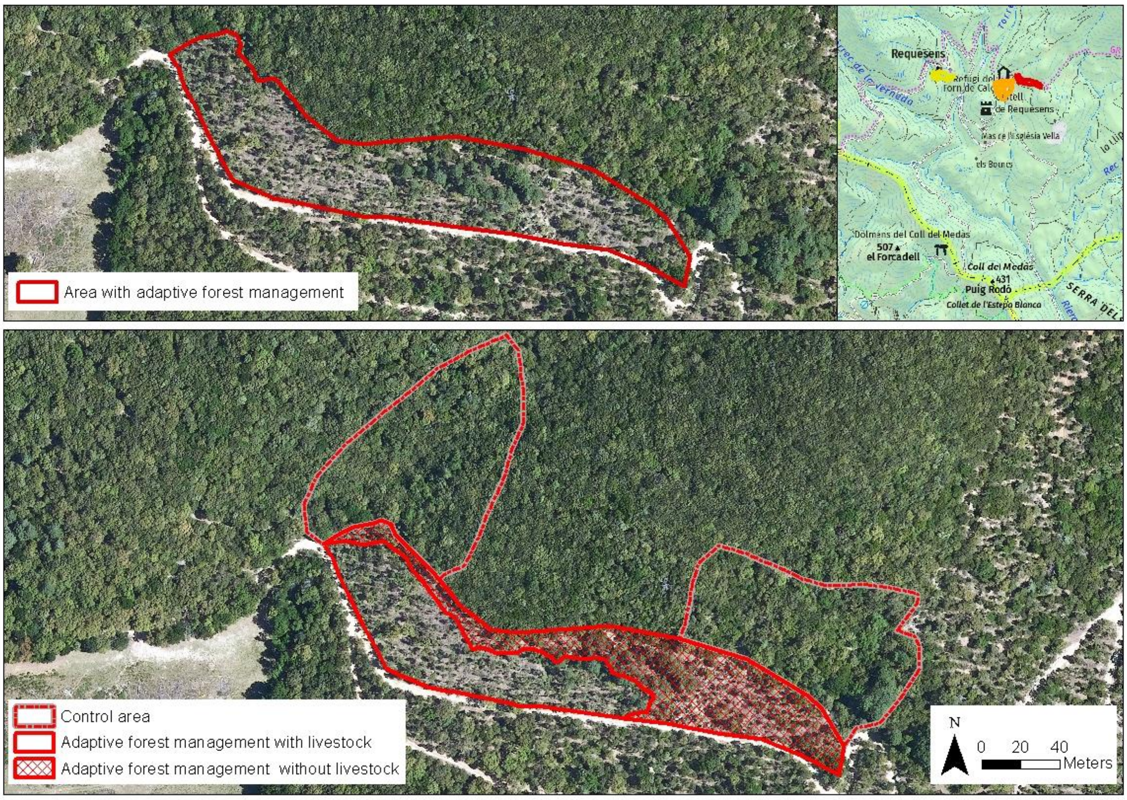


Figure 33. Location of the areas with adaptive forest management (with and without livestock) and the control area.

3. The <u>improvement of the livestock infrastructure</u>, including drinking trough, fodder trough, and covered and enclosed site, containing the cattle during herb regeneration and fodder feeding period, among others. These actions were designed during the proposal formulation (along summer 2018), in order to improve the sustainability of the extensive livestock farm. Nevertheless, when the project started (July 2019), the situation of the farming activity had changed, as is explained in Nadal-Romero et al (2019) (Deliverable 1). Two main changes

were introduced by the property in that year: 1) the reduction of the cattle from the 300 cows farming in end-2018 to the current 130 cows; and 2) the creation of four big fences where enclosing and controlling the cattle. Those actions improved the activity of the livestock farming, but the **lack of pastures** inside the fences forced to feed the animals with fodder with an important economic expenditure, creating an **unsustainable situation for the economic viability** of the farm.

Thus, to pursue the second objective of the pilot experience and improve the socioeconomic development of the farming activity to favour its sustainability, some changes needed to be included in the pilot experience design. The construction of a fence enclosure for winter pastures was not necessary at that moment but some other interventions were needed to improve the exploitation feasibility. In particular, there is an **urgent necessity to recover pastures in the area**. Given the present deterioration state, a **natural recuperation is complicated**. The proposal is to select the areas where the pasture recovery will be promoted, to fence it to avoid cattle pressure and to sow a mix of seeds well adapted to the area, in order to increase as first step the pasture production and as second step in the future the pasture biodiversity. Once the pastures are recovered, the management needs to be planned to have a high animal pressure during a short time period.

Within these new guidelines, the **following activities were performed to increase the sustainability of the farm**:

- The **recuperation of an old pasture field of about 2.47 ha** (Figure 34). The recuperation consisted of the elimination of scattered scrubland and isolated trees, recuperation of terraces, construction of interior fences, shallow soil plough and mechanical direct seed sowing with a seed mixture of P3 type (dactyl, English ryegrass, Italian ryegrass, white clover), along with tall pistachio. This activity will favour both the improvement of the socioeconomic development of the farming activity and its sustainability and the reduction of fire risk through the recuperation of the agro-silvo-pastoral mosaic.
- The **recuperation of abandoned pasture terraces of about 0.97 ha** (Figure 34). The terraces were cleared by the Protected Natural Area of l'Albera to establish a firebreak point according to firefighters' criteria and to reduce fire risk of Requesens neighbourhood. The recuperation consisted on manually sowing of a specific mixture of pasture seeds, including ryegrass, dactyl and alfalfa. This activity will favour both the improvement of the socioeconomic development of the farming activity and its sustainability and the reduction of fire risk through the creation of a firebreak point.
- In the future, similar activities will be implemented in order to improve the socioeconomic development of the farming activity and its sustainability.

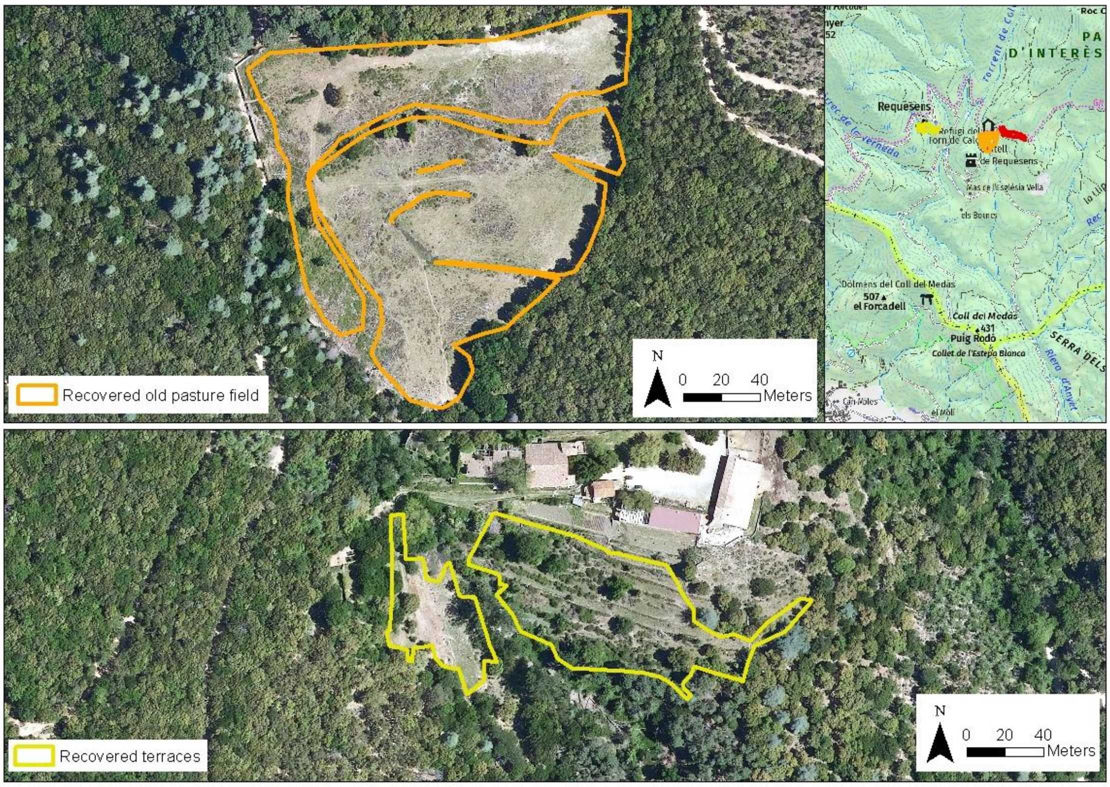


Figure 34. Location of the recovered old pasture field and recovered terraces.

3.3. The Holm oak forest before the application of adaptive forest management

The forest where the adaptive management has been applied, is an Holm oak forest (*Quercus ilex*) where **Holm oak is the dominant species** in the area (50% of basal area), with some escort species: cork oak (*Quercus suber*), oak (*Quercus humilis*), strawberry tree (*Arbutus unedo*), and some isolated individuals of Scots pine (*Pinus sylvestris*) and maritime pine (*Pinus pinaster*). The initial situation of the forest before management is unknown for the project, since we have used an area that was already managed when the project started. In order to monitor starting conditions, we have assumed that previous forest situation was similar to the control area selected in the project. Actually, this similarity has been confirmed by the property, the Natural Park and the aerial image (Figure 35).

A **forest inventory** was performed in the **control area in May 2020 to characterise the initial conditions of the forest stand**. The inventory was realized **in three circular sub-plots** with a radius of 10 m, uniformly distributed and preassigned in a map. The central point of these plots was marked for future periodic surveys. In each plot, the following variables were taken to characterise the stand:

- Forest structure: the number of trees/resprouts of each species is counted and the diameter at breast height (DBH), the height of each tree and the canopy cover is measured.
- Understorey biovolume: two strip biomass transects (10 m) to estimate understorey biovolume are defined in each plot. In each transect, the maximum height and cover of scrubland species are measured in 50x50 cm quadrat plots.

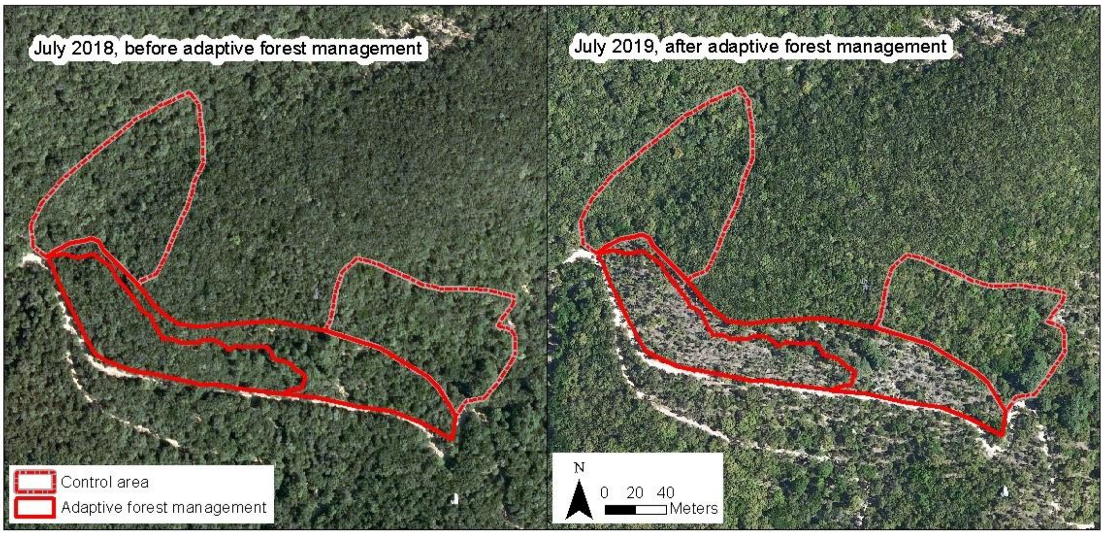


Figure 35. Comparison of the aerial image before and after the application of adaptive forest management.

- Regeneration: three Holm oak stumps recently cut are selected and the number of sprouts is counted.
- Forest fuel continuity: the crown fire hazard is assessed following the methodology of the CVFoC Manual (Piqué et al. 2011), by taking the following measures: Aerial cover (%), ladder cover (%), surface cover (%), height of surface fuel (m), distance between surface and ladder/aerial fuels (m), distance between ladder and aerial fuels (m). Using a crown fire hazard chart, the crown fire hazard of each plot is assessed.
- Forest health status: Forest decline status is assessed through visual estimation of tree mortality percentage (dried crowns), defoliation percentage (non-present leaves in relation of leaves present on a healthy tree) and foliage discoloration percentage (non-green leaves in relation of green leaves on a healthy tree) in 10 trees per forest inventory plot.

Figure 36 shows the location of the circular subplots in each area. There are three subplots in the control area (BC7, BC8 and BC9), three in the managed area with livestock (BTAR1, BTAR2 and BTAR3) and three in the managed area without livestock (BTSR4, BTSR5 and BTSR6).

The initial inventory in the control area determined that this **forest is highly dense** (over 1,700 trees/ha) with a **basal area over 30 m^2/ha and an irregular coppice forest structure** (Table 5). Mean diameter at breast height oscillate between 11.6 and 13.1 cm, meanwhile mean height are very similar between plots (7.3-7.6 m). The three plots show a **similar crown fire hazard**, identified as the structure type B9 which means a **moderate hazard** (

Figure *37*). This type of structures are characterized to present indistinctly vertical continuity or discontinuity, being the ladder cover and the aerial cover variable. These typologies generate torches and secondary foci that passively burn from crowns, whereas small groups of trees become inflamed but the spread between crowns is not maintained continuously. The structures affected by this type of fire usually respond to lower mortality than the highly vulnerable structures. The existence of a mixture of fully burnt trees and others with a high percentage of green canopy are characteristic of these stands.

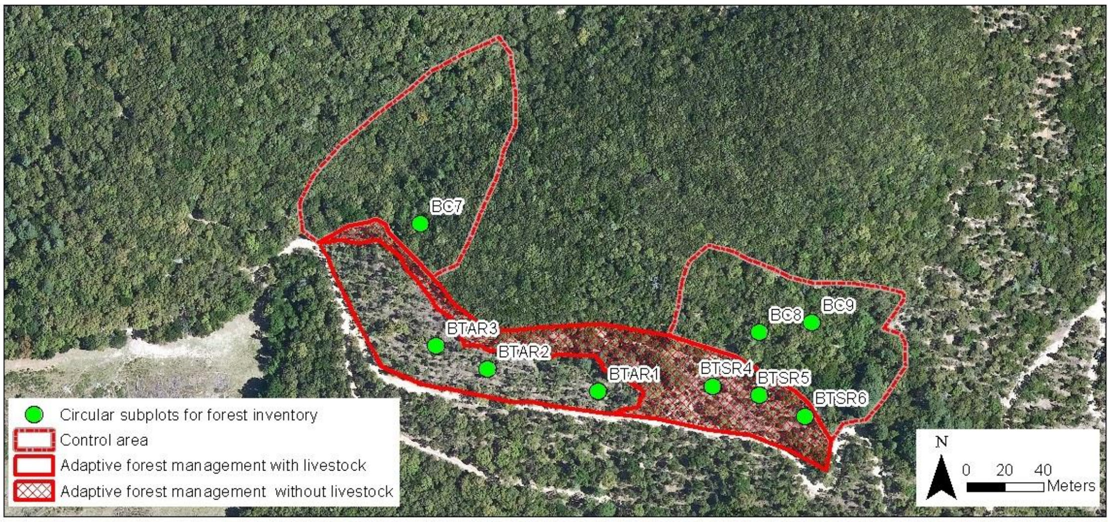


Figure 36. Location of the circular subplots for the forest inventory.

Forest inventory subplot	Canopy cover (%)	Number of trees / ha	Basal area (m2/ha)	Mean diameter at breast height (cm)	Mean tree's height (m)	Forest fuel continuity model	Crown fire hazard
BC7	80	1783	29.5	13.1	7.6	B9	Moderate
BC8	90	1974	40.7	12.6	7.4	B9	Moderate
BC9	90	2515	38.3	11.6	7.3	B9	Moderate

Table 5. Resume of the inventory variables per inventory subplots measured on May 2020.

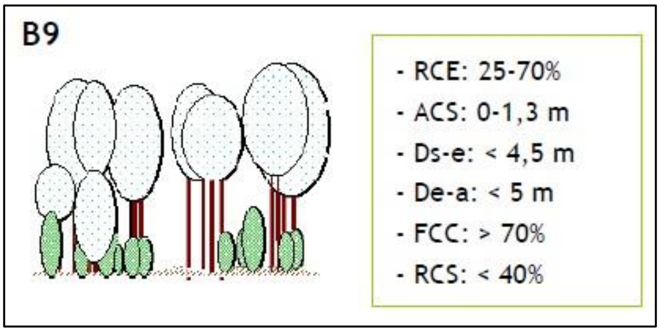


Figure 37. Structure type B9 with moderate crown fire hazard following Piqué et al. 2011.

Figure 38 shows the average diametric class distribution for the forest in the control area. There is a **predominance of individuals in the lower diametric classes** (Class 10: diameter between 7.5 and 12.5 cm; and class 15: between 12.5 and 17.5), characteristic of irregular coppice forests. In this case, **past forest management** has favoured the **production of sprouts** to provide firewood. Other escort species, such as cork oak (*Quercus suber*) and oak (*Quercus humilis*), have not been managed, showing larger trees with higher diameter and larger basal area (Figure 39).

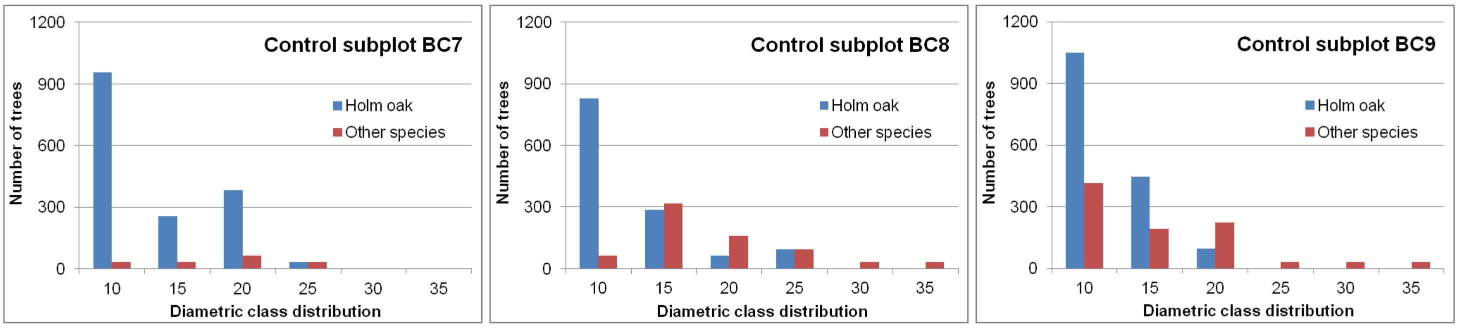


Figure 38. Number of trees per diametric class of the Holm oak forest and escort species in the three control subplots.

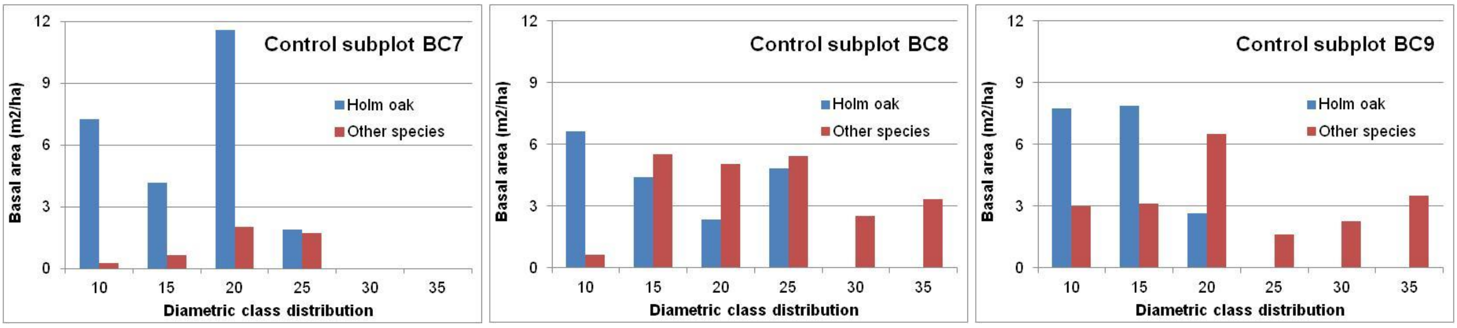


Figure 39. Distribution of basal area per diametric class of the Holm oak forest and escort species in the three control subplots.

Figure 40 shows the forest's initial appearance in the control subplots.

Figure 40. Initial structure of the Holm oak forest

3.4. The adaptive forest management implemented

Forest adaptive management has been applied in an area of 1.15 ha of Holm oak forest. The management practice has mainly consisted of **selective thinning and scrubland clearing** in order to reduce tree density, reduce fuel continuity and promote mature structures with bigger trees and fuel discontinuity. Figure 41 shows an explanatory diagram of the treatment applied; the management allows that a higher radiation arrives to the soil, to favour the development of pastures. Through monitoring, our objective is to see how are the differences in the water content of the soil (HS), the air humidity (HR) and the fire risk, among other variables.

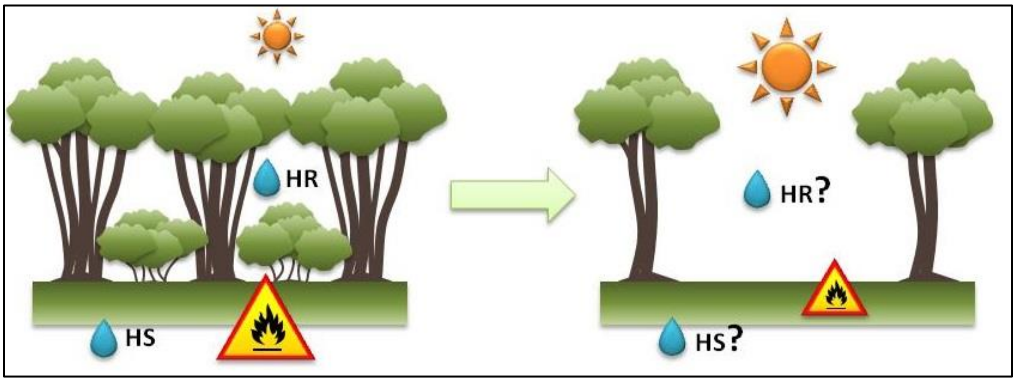


Figure 41. Diagram with a graphical explanation of the treatment applied.

In the managed area, a **forest inventory** has been also performed in **May 2020 to characterise the treatment** and to compare with the initial conditions of the forest stand. In this area, **six circular forest inventory subplots** with a radius of 10 m have been uniformly distributed and preassigned in a map. Three of the circular subplots are located in the area where the livestock will enter (BTAR1-2-3), and the other three in the area where livestock will not enter (BTSR4-5-6) (Figure 5). In the inventory of these subplots, we measured the same variables as in the control subplots.

The characterization of the treatment has been done by comparing the control subplots (BC7-8-9) with the treatment ones (BT1-2-3-4-5-6). Figure 42 shows the main changes in forest structure after the treatment, through changes in stem density and basal area. The treatment implied about **60%-reduction of aerial cover, 62%-reduction of basal area and 66%-reduction of density** (number of trees per ha), causing a **higher opening of the forest canopy in order to stimulate pasture production and regeneration**. We have applied some statistics to compare among treatments and with the control subplots (ANOVA and Tukey test). We have observed that there are **significant differences in the basal area between the managed and the control subplots**. Although the managed subplots without livestock (BTSR4-5-6) has a lower basal area than the managed ones with livestock (BTAR1-2-3), there are not significant differences among them, so we can conclude that the management applied in all the area is quite similar, but the differences are significant when comparing with the control area (Figure 43, Annex 1).

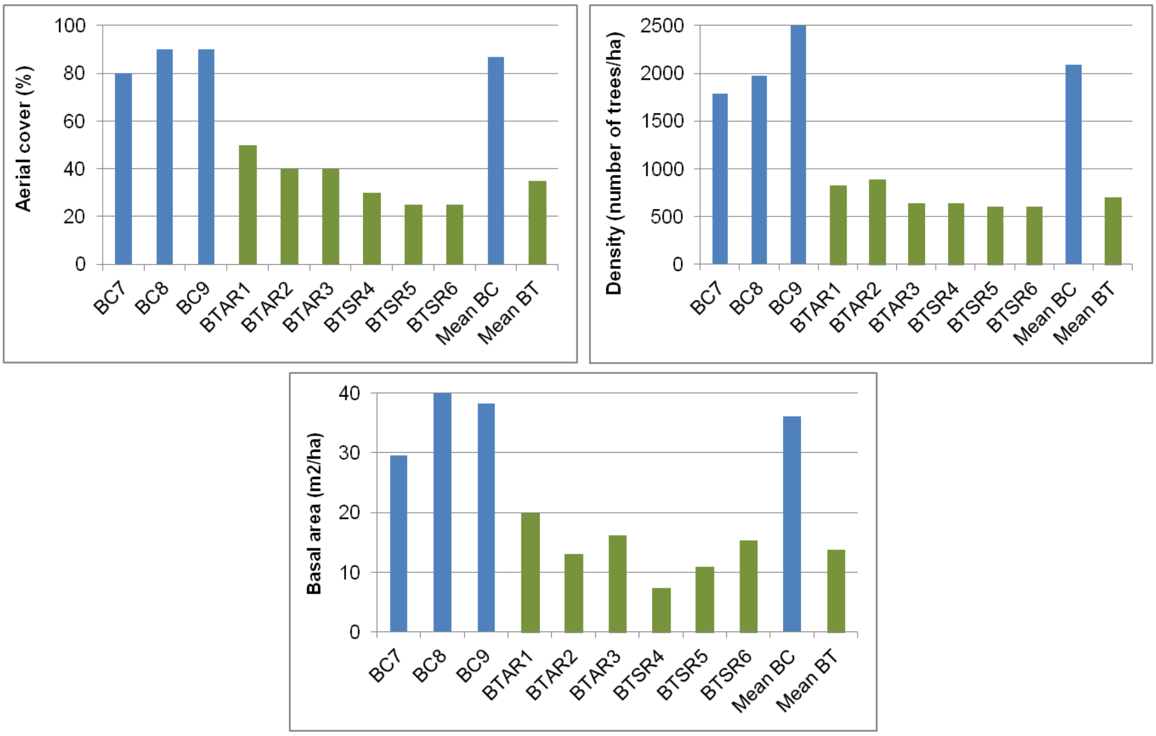


Figure 42. Distribution of aerial cover (%), density (number of trees per ha) and basal area (m2/ha) per circular forest inventory subplot.

The initial inventory in the managed area determined a mean density around 700 trees/ha, with a mean basal area about 13.8 m^2/ha and a 35% of mean aerial cover (Table 6). Mean diameter at breast height oscillates between 11.6 and 17.3 cm, meanwhile mean height is between 4.9 and 9.8 m. The six plots show a similar crown fire hazard, identified as the structure type B16 which means a moderate hazard (Figure 44). The description of the type of structure is similar to the control subplots.

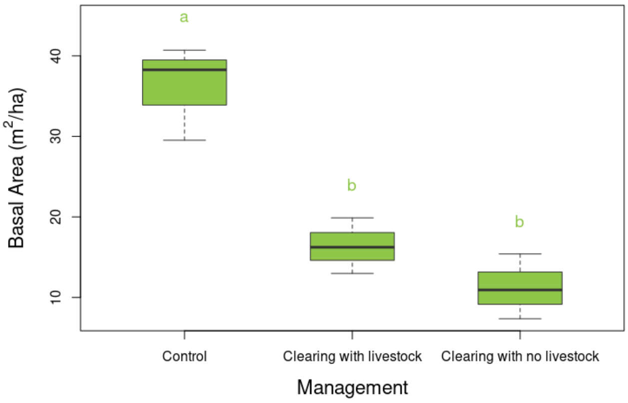


Figure 43. Differences in basal area (m²/ha) among forest inventory subplots.

Forest inventory subplot	Canopy cover (%)	Number of trees	Basal area (m2/ha)	Mean diameter at breast height (cm)	Mean tree's height (m)	Forest fuel continuity model	Crown fire hazard
BTAR1	50	828	19.9	11.6	7.8	B16	Moderate
BTAR2	40	891	13.0	13.4	9.8	B16	Moderate
BTAR3	40	637	16.2	17.3	8.6	B16	Moderate
BTSR4	30	637	7.4	11.9	4.9	B16	Moderate
BTSR5	25	605	10.9	14.2	6.7	B16	Moderate
BTSR6	25	605	15.4	16.4	6.5	B16	Moderate

Table 6. Resume of the inventory variables per forest inventory subplots measured on May 2020

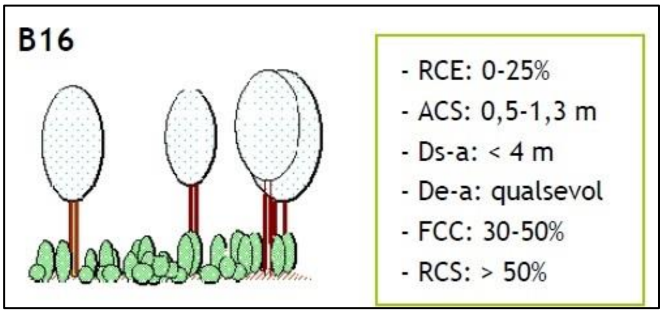


Figure 44. Description of the structure type B16 with moderate crown fire hazard following Piqué et al. 2011.

Figure 45 shows the average diametric class distribution for the forest in the managed subplots. There is still a predominance of individuals in the lower diametric classes (class 10, 15 and 20), although there has been a clear selection of cutting small diameter trees, leaving big trees of Holm oak and other escort species (Figure 46).

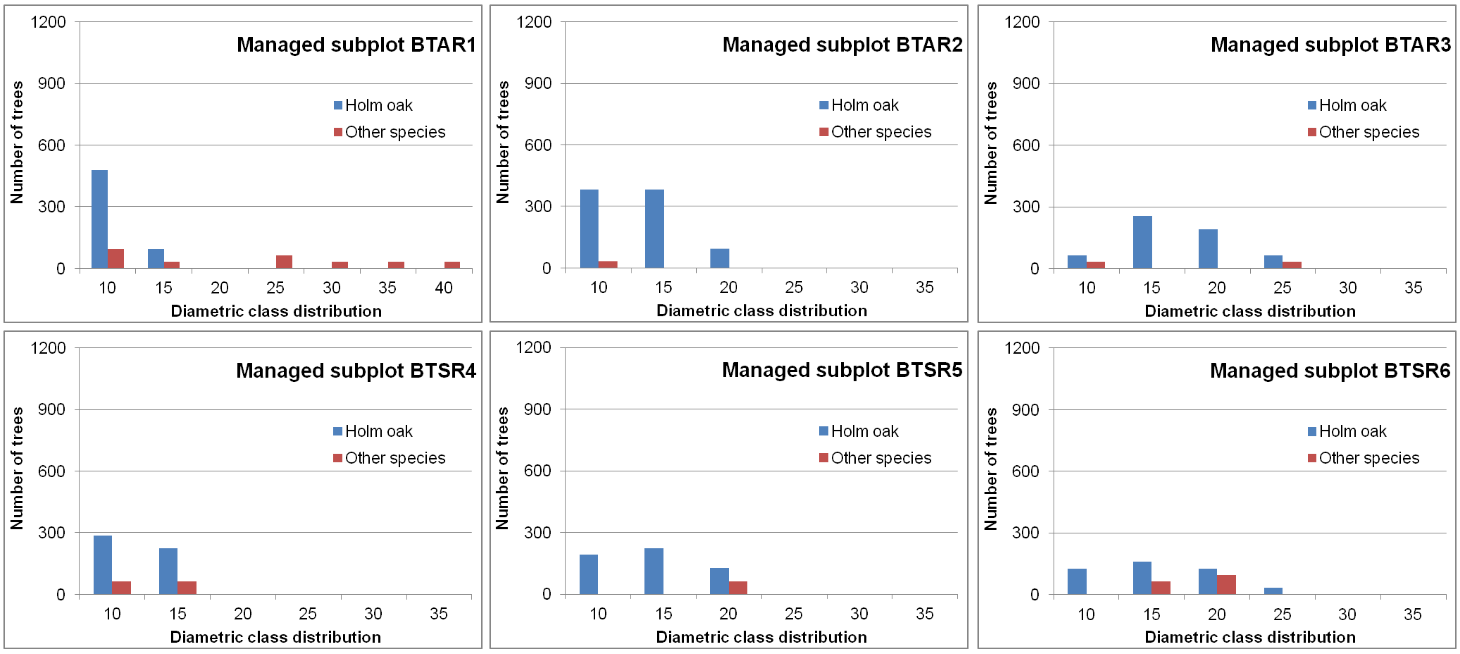


Figure 45. Number of trees per diametric class of the Holm oak forest and escort species in the six managed plots.

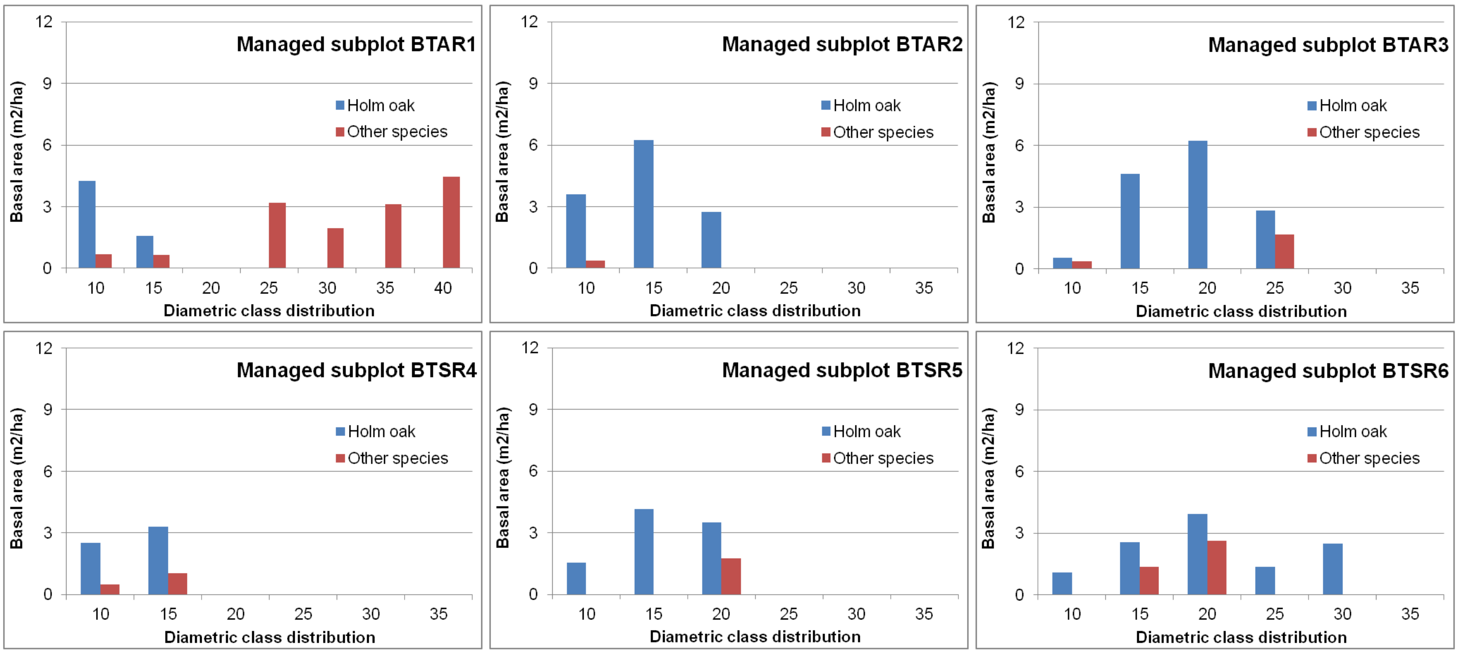


Figure 46. Distribution of basal area per diametric class of the Holm oak forest and escort species in the six managed subplots.

The managed area has been divided in **two different pilot experiences**, depending on the livestock management:

1. The **first sub-area** has been prepared for the **entrance of the livestock**, with a surface of 5,520 m^2. It was fenced and prepared following the next steps:
    - The removal of all gross logging residues. The removal was done manually, and had an economical cost of 1,500 €. The residues were sold as firewood.
    - The entrance of the cows for a couple of days to eat the oak and heather sprouts.
    - The randomly and manually sowing of a specific mixture of pasture seeds. The sowing was performed on November 18th, 2019. The seeds included a mixture of ryegrass (50%) of weight, dactyl (30%) and alfalfa (20%). The economical cost of the seeds was 835€.

    Figure 47 shows the different steps in the preparation of the sub-area.

Figure 47. (Left) Managed area with logging residues; (Middle) Managed area after the removal of logging residues; (Right) Managed area after three months of seed sowing.

2. The **second sub-area** has been left with the **logging residues** and has a surface of 5,978 m^2.

Figure 48 and Figure 49 and shows the forest's appearance in the managed area in May 2020, depending on the sub-area.

Figure 48. Forest appearance in the managed area with pasture recuperation (BTAR).

Figure 49. Forest appearance in the managed area without pasture recuperation (BTSR).

Using the data of the forest inventories in the circular monitoring subplots, an initial **assessment** of the **understory biovolume and forest decay** has been performed. Figure 50 (Left) and Table 7 shows the initial structure of the understory biovolume after the management in relation with the control subplots. The understory cover performs a coherent initial situation, where control subplots show the higher coverage, following by subplots without livestock where logging residues have been left, and a lower cover in subplots with livestock where logging residues have been eliminated and only grass is growing. The statistical analysis show that only the last subplots, **managed area with livestock, has a significant less cover than the control subplots** (Annex 1). Regarding **forest decay** (assessed as a combination of leaf discoloration and tree defoliation) **no significant initial differences among treatments are observed**, but we expect some divergent trends during the monitoring period (Figure 50 Right, Table 7, Annex 1).

Forest inventory subplot	Understorey							Forest decay		
	Cover (%)	Mean height. (m)	Total biovolume (m^3)	Mean biovolume (cm)	Logging residues (%)	Herbaceous cover (%)	Litter (%)	Tree defoliation (%)	Leaf discoloration (%)	Mean forest decay (%)
BC7	19.0	1.2	3.8	0.1		1.5	46.5	13.0	1.0	14.0
BC8	51.3	2.4	14.7	0.4		0.4	92.8	12.5	2.0	14.5
BC9	24.5	1.8	4.2	0.1		6.6	85.8	10.0	0.5	10.5
BTAR1	3.6	0.3	0.1	0.003		57.8	15.6	0.5	4.0	4.5
BTAR2	3.5	0.4	0.1	0.003		55.0	27.4	0.5	4.7	5.2
BTAR3	2.5	0.3	0.1	0.002		60.4	18.8	8.5	14.5	23.0
BTSR4	19.3	0.4	0.9	0.03	38.9	8.3	1.1	10.5	1.5	12.0
BTSR5	28.0	0.4	1.2	0.04	44.0	14.0		8.0	1.5	9.5
BTSR6	30.4	0.4	1.5	0.02	28.1	25.8		18.5	1.0	19.5

Table 7. Resume of the inventory variables related with understorey and forest decay per forest inventory subplots measured on May 2020.

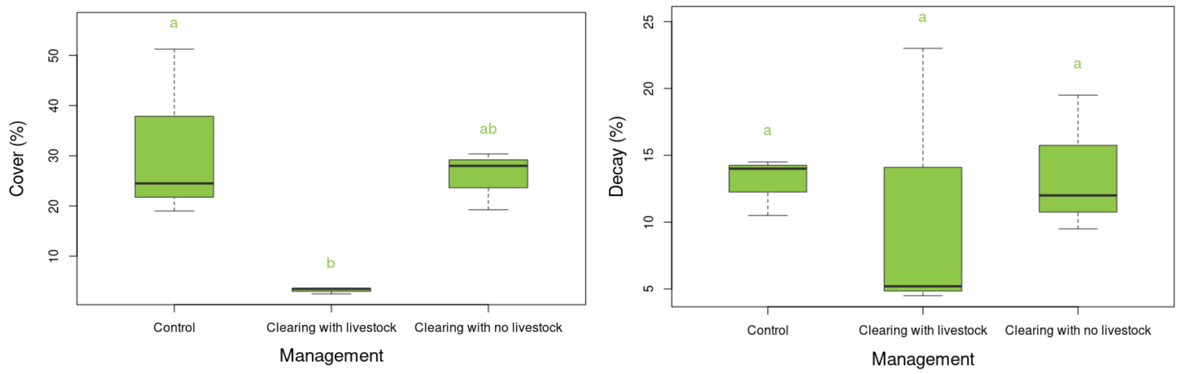


Figure 50. Left: Differences in understory cover (%) among forest inventory subplots. Right: Differences in forest decay (%) among forest inventory subplots.

Together with the forest inventories, we have performed **vegetation inventories** to analyse **pasture production and quality and vegetation biodiversity**. The details of the sampling can be consulted in Annex 2. To assess the **pasture's biodiversity**, in an area submitted to forest management (thinning and clearing), we sampled the vegetation growing inside three sub-plots with experimental seeding and submitted to livestock by cows (BTAR1-2-3) and inside three subplots with no experimental seeding and no livestock activity (BTSR4-5-6). As a control, we also sampled the vegetation growing in three sub-plots within an area with the same environmental conditions and vegetation structure but with no management intervention, no seeding and no livestock activity (BC7-8-9). We recorded the surface covered by every species found inside four 1*1 m quadrats at each sub-plot per forest management and livestock treatment (n= 3 treatments * 3 sub-plots * 4 quadrats= 36 quadrats). **We found a total of 80 species, being 56 herbaceous and 24 woody species** (Table 2 in Annex 2). We also tested for differences per management treatment (control, managed with livestock, managed with no livestock) in the number of species and the area covered by each lifeform.

To assess the **pasture production and quality**, we were planning to collect systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats (n=36 samples). However, during this field campaign, **vegetation sampling was not feasible because the plants were parched**. In future field campaigns, samples will be collected, weighed and analysed for the content of proteins and fibers.

3.5. The livestock management and monitoring subplots

In previous sections, we have already explained the two areas where the pilot experience has been implemented: a control area, with no action, and a managed area, where adaptive forest management has been applied. Within the managed area, we have identified two different sub-areas: a sub-area of 5,520 m^2 prepared for the entrance of the livestock and a sub-area of 5,978 m^2 where no preparation has been applied.

Within these three areas/sub-areas of work, we have performed three replicates of our experimental design. Our **experimental design** consists on creating **three typologies of plots**: 1) **control plots**, without neither forest management nor the entry of livestock (BC); 2) **managed plots with livestock** (BTAR); 3) **managed plots without livestock** (BTSR). For each of the plots, we have performed **three replicates**

(BC7-8-9; BTAR1-2-3 and BTSR4-5-6). With three replicates we can perform statistical analysis to confirm if differences among the plots are significant.

The experimental design includes three plots of 1,000 m^2 with its replicates, **nine subplots of 1,000 m^2** in total. The surface of the subplots has been defined based on: a) the surface available in each area and sub-area; and b) the conditions imposed by the property about the livestock management. The second condition is the reason why the size of the subplots in Catalonia (1,000 m^2) differs from the subplots in Aragon (400 m^2). In Aragon, the stockbreeder could easily move two cows from one subplot to each replicate in a concrete number of days. However, in Catalonia, the stockbreeder needed to move a higher number of cows during a shorter period, in order to correctly attend the whole exploitation. The stockbreeder proposed to introduce **20 cows per subplot and day**. Taking the reference that one cow needs 50 m^2/day of pasture to properly feed, the surface of the plot needed to be 1,000 m^2. In order to control the livestock, we fenced with three electric shepherd threads the managed subplots with livestock. The **cows entered for first time by the middle of May 2020**: 16 cows, 2 bulls and 8 calves, during one day and a half in each of the three subplots with livestock (BTAR1-2-3).

Figure 51. Cows grazing the livestock subplots (BTAR1-2-3) between the 13th and the 17th of May 2020.

Those **nine subplots (plots and replicate) coincide with the monitoring subplots of the project**. In those subplots, all the monitoring tasks defined in the project proposal will be performed during four years. Figure 52 shows the nine subplots defined for the livestock management and monitoring tasks. In each of these subplots we have located a forest inventory circular subplot.

The **monitoring variables and protocols** will be defined in Deliverable 9, foreseen on December 2020. Nevertheless, here there is a short resume of the typology of variables followed in the monitoring subplots. Besides, Figure 53 shows a diagram of the livestock and monitoring plots, together with the distribution and location of the different monitoring tools.

- <u>Soil analysis</u>: The first sample of soils were taken along June 2020. We have taken two sample per monitoring subplot, at two different depths: 0-10 cm and >10cm. Those analysis will allow to set the initial conditions of the soil. Before the end of the project, a sample of the same subplots will be taken to know the effect of the different treatments on the following soil variables: Field bulk density (BD), pH and electrical conductivity (EC), total carbon concentration (Ctotal), total nitrogen concentration (N), carbonate content ($CaCO_3$), 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 54).

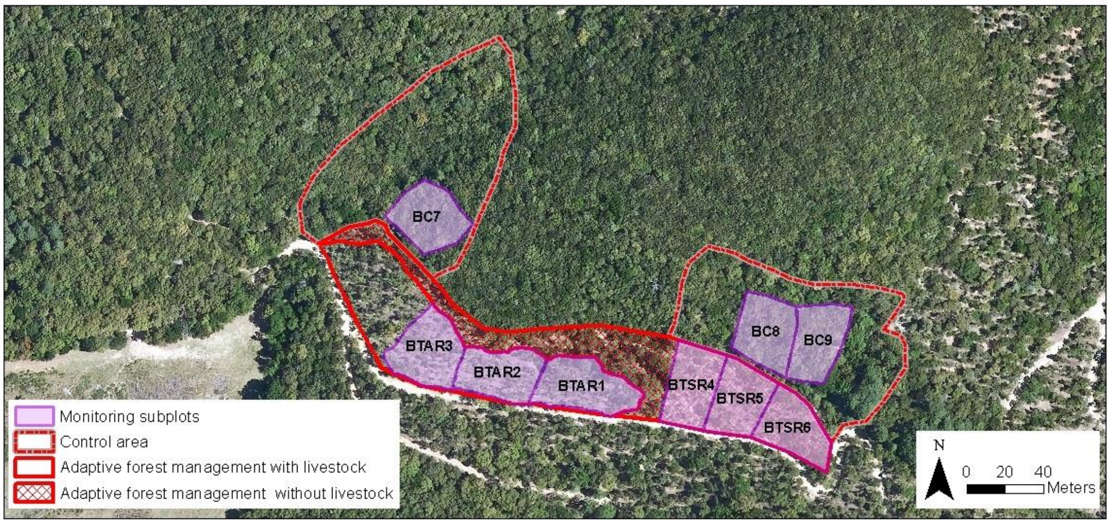


Figure 52. Location of the plots and replicates of the experimental design. Those subplots coincide with the monitoring subplots.

- Installation of the instrumentation to control environmental variables: soil moisture sensors, air moisture and temperature sensors and meteorological station. One sensor was installed in each monitoring subplot to obtain three replicas. The soil humidity probes are S-SMC M 005. The sensors are connected to a U30-NRC Meteorological Station HOBO USB datalogger to record the data. Thus, 5 dataloggers and 18 soil humidity sensors were installed. The sensors, buried at 20 cm depth, are inserted in a corrugated tube for protection, mainly to avoid being bitten by livestock. The sensors are nailed in a vertical position at 20 cm depth, as recommended in the installation manual. We have also installed air temperature and relative humidity sensors (HOBO U23 Pro v2), one in each subplot (Figure 55).
- Vegetation inventory (pasture production and quality and biodiversity): A vegetation inventory will be done in all monitoring subplots several times along project duration. We sample the vegetation growing inside each of the sub-plots, recording every species found inside 1*1 m quadrats. Likewise, to assess the pasture production and quality, we collected systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats. The variables monitored are: pasture production and quality; pastoral value; pasture nutritive quality (protein and fibre content) and biomass productivity (Figure 56). Results of the species composition and richness recorded in the first vegetation inventory of the pasture are specified in Annex 2.

- Forest inventory: Forest inventory will be done in all monitoring subplots several times along project duration. The inventory is carried out in circular sub-plots with a radius of 10 m, uniformly distributed and preassigned in a map. A first forest inventory was carried out on May 2020 to set the initial conditions of the stand, as previously explained. Along the summer of 2020, the first monitoring campaign was carried out every 15 days to collect forest fuel samples. The variables monitored are: forest structure; understorey biovolume; regeneration; forest fuel continuity; and forest health status.

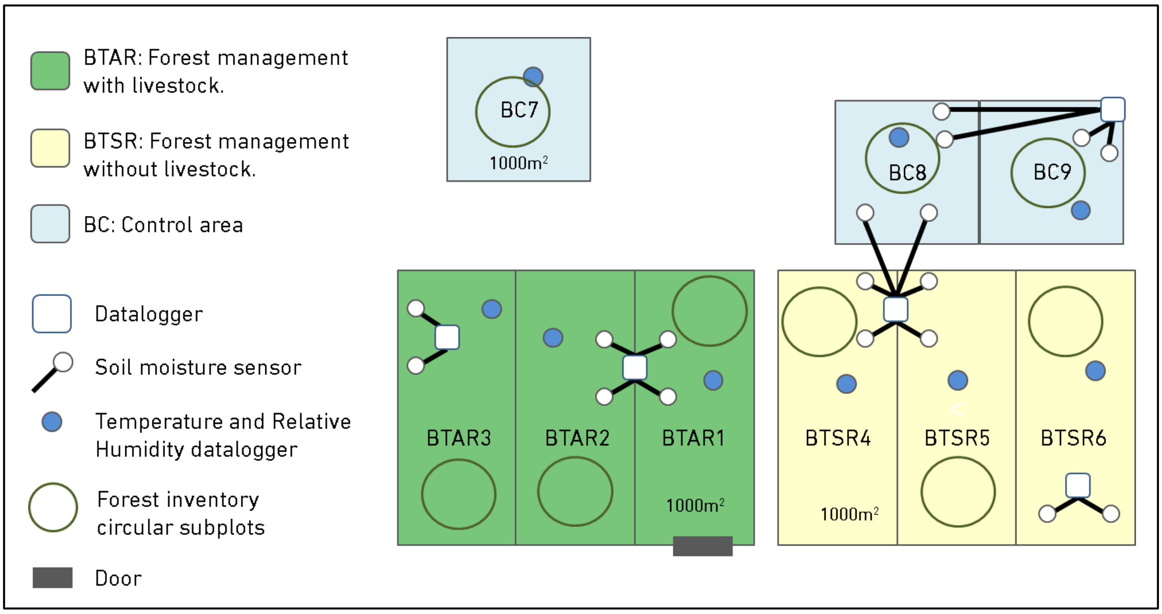


Figure 53. Diagram of the livestock and monitoring subplots.

- Rain simulation: Rainfall experimental generation will be done in all monitoring subplots several times along project duration. The variables monitored are: runoff coefficient, delay time, depth of infiltration and sediments. Rain simulation will be performed on October 2020.

Figure 54. Soil sampling in forest inventory subplots carried out in June 2020.

Figure 55. Instrumentation in the subplots: soil moisture and air moisture and temperature sensors.

Figure 56. First vegetation samplings in Requesens carried out in July 2020.

3.6. The improvement of the livestock infrastructure

In the chapter 3.2, we have explained the performed changes in the improvement of the livestock infrastructures with respect to the project proposal. Here, we give a detailed explanation on the improvement implemented.

When the project started, we found that there was an urgent necessity to recover pastures in the Requesens state, since the cattle was mainly feed with fodder with an important economic expenditure. A natural recuperation of the pastures was considered impossible, given the present deterioration state of the area. Thus, we selected two areas to be recovered:

1. An <u>old pasture field</u> of about 2.47 ha. The field had been abandoned during years, favouring the colonisation of scrubland (Figure 57 left). The recuperation consisted of the elimination of scattered scrubland and isolated trees (Figure 57 middle), recuperation of terraces, shallow soil plough (Figure 57 right) and mechanical direct seed sowing with a seed mixture of 120 kg of P3 type (dactyl 37%, English ryegrass 29%, Italian ryegrass 10%, white clover 24%), along with

30 kg of tall pistachio (Figure 58). The cost of these mechanical tasks has been about 3,725 € and were performed between October and November 2019. The cost of the seeds was 1,047€. This field will contribute to improve the socioeconomic development of the farming activity and its sustainability through the recuperation of pasture land; and to reduce fire risk through the recuperation of the agro-silvo-pastoral mosaic.

2. An abandoned pasture terraces of about 0.97 ha. The terraces were cleared in 2019 by the Protected Natural Area of l'Albera to establish a firebreak point according to firefighters' criteria and to reduce fire risk of Requesens neighbourhood. The recuperation of the terraces has consisted on manually sowing of a specific mixture of pasture seeds, ryegrass (50%) of weight, dactyl (30%) and alfalfa (20%) (Figure 59). The economical cost of the seeds was 561€.This activity will favour both the improvement of the socioeconomic development of the farming activity and its sustainability and the reduction of fire risk through the creation of a firebreak point.

Figure 57. (Left) Pasture field before recovering actions; (Middle) Pasture field after scrubland clearing; (Right) Pasture field during shallow soil plough activities.

Figure 58. (Left) Pasture field after two months of seed sowing; (Middle) Pasture field after six months of seed sowing; (Right) Pasture field with the cattle.

Figure 59. (Left) Terraces after scrubland clearing; (Middle) Terraces after two months of seed sowing; (Right) Terraces after six months of seed sowing.

4. Conclusions

One of the main objectives of this deliverable is the presentation and description of the implementation action: C.2. Climate change adaptation measure: Forest management.

During the previous action A.2., the localization of the pilot experiences was successfully fulfilled in all the study areas: Aragon (Aragon river valley, La Garcipollera) and Catalonia (Empordà region, Requesens).

Sub-action C.2.1. Forest management in Catalonia

- Forest management was carried out in the Requesens state in an area of 1.15 ha, following two objectives: 1) to reduce the forest vulnerability to climate change by reducing fire risk and forest water stress and increasing wood production/carbon sequestration; and 2) to improve the socioeconomic development of the farming activity to favour its sustainability. The management practice has mainly consisted of selective thinning and scrubland clearing. The treatment implied about 60%-reduction of aerial cover, 62%-reduction of basal area and 66%-reduction of density (number of trees per ha), causing a higher opening of the forest canopy in order to stimulate pasture production and regeneration.
- The managed area has been divided in two different pilot experiences, depending on the livestock management. The first sub-area (5,520 m^2) has been prepared for the entrance of the livestock (removal of logging residues; random and manual sowing of a specific mixture of pasture seeds). The second sub-area (5,978 m^2) has been left with the logging residues and without livestock. The objective of the first sub-area is to monitor the evolution of the adaptive forest management regarding climate change vulnerability when extensive livestock farming is use to maintain the effects of the management treatment, whereas the objective of the second sub-area is to monitor that evolution as traditionally applied, without neither logging residues elimination nor extensive livestock farming.
- An area with no actuation of 1.47 ha has been selected to monitor the site evolution with no actuation
- For the monitoring program, nine subplots of 1,000 m^2 have been selected: three typologies of plots with three replicates.
- The improvement of the livestock infrastructure has been promoted through the recuperation of two old pastures fields, with 2.47 and 0.97 ha respectively.

Sub-action C.2.2. Forest management in Aragon

- Forest management was carried out in the La Garcipollera Research Station in two plots: a 0.58 ha plot in a reforestation forest of *Pinus nigra* and 0.86 ha on a *Populus* forest, following two objectives: 1) to promote fuel discontinuity, with the purpose of reducing the forest fire risk; and 2) to increase the pasture production and reduce water stress within the forest. The management practice has mainly consisted high intensity scrubland clearing. In the *Pinus nigra* area, the treatment implied about 95%-reduction of understorey cover and 96%-reduction of understorey biovolume (m^3), in order to stimulate pasture production and regeneration. In the *Populus* area, the treatment implied about 84%-reduction of understorey cover and 97%-reduction of understorey biovolume (m^3).

- Two areas with no actuation of 0.55 ha have been selected to monitor the site evolution with no actuation
- For the monitoring program, eight subplots of 400 m^2 in each site, 16 subplots in total, have been selected: three typologies of plots with three replicates (except the control plots where only two replicates were possible).

<u>Sub-action C.2.3. Forest management monitoring</u>

- Two livestock pressure were selected in all the sites: no livestock pressure, and medium pasture pressure. The management has been different in each experience, in order to adapt to the available surface and the possibilities of the stockbreeder.
- After the implementation of the pilot experiences, some monitoring activities have already been carried out: (i) initial forest inventories; (ii) instrumentation to control climatic and environmental variables (soil moisture, air moisture and temperature); (iii) first soil samplings in all the sites and all the plots to know the initial conditions after forest management and before livestock pressure; and (iv) vegetation samplings to estimate pasture production and quality and biodiversity. Rainfall simulation experiments to test the hydrological and erosion response will be performed on October 2020.

Finally, and in spite of the changes already presented in A2, the activities defined in the proposal have been successfully completed: selection of the study areas, implementation of forest management and start on the monitoring program, being a perfect starting point for the future work defined in the LIFE MIDMACC project.

5. References

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6. Annexes

6.1. Annex 1. Statistical analysis

Basal Area – Requesens (Catalonia)

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	se
1	Control	3	36.2	5.9	29.5	33.9	38.3	39.5	40.7	3.41
2	Clearing with livestock	3	16.4	3.4	13.0	14.6	16.2	18.1	19.9	1.96
3	Clearing with no livestock	3	11.2	4.0	7.4	9.1	10.9	13.2	15.4	2.31

ANOVA

Call:
aov(formula = BA ~ Management)

Terms:

	Management	Residuals
Sum of Squares	1039.7406	125.4262
Deg. of Freedom	2	6

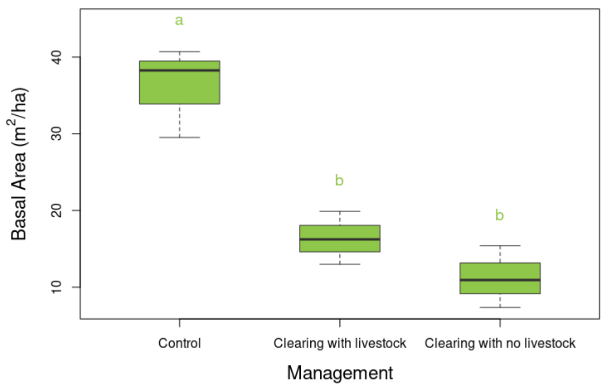
Residual standard error: 4.572128
Estimated effects may be unbalanced

Tukey

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = BA ~ Management)

	diff	lwr	upr	p adj	
Clearing with livestock-Control	19.793645	8.339387	31.247904	0.0043933	***
Clearing with no livestock-Control	24.931083	13.476825	36.385342	0.0013294	***
Clearing with no livestock-Clearing with livestock	-5.137438	-16.591697	6.316821	0.4094308	



Understorey Cover – Requesens (Catalonia)

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	se
1	Control	3	31.6	17.3	19.0	21.8	24.5	37.9	51.2	9.990
2	Clearing with livestock	3	3.2	0.6	2.5	3.0	3.5	3.5	3.5	0.346
3	Clearing with no livestock	3	25.9	5.9	19.2	23.6	28.0	29.2	30.4	3.410

ANOVA

Call:
aov(formula = Cover ~ Management)

Terms:

	Management	Residuals
Sum of Squares	1354.0568	664.6496
Deg. of Freedom	2	6

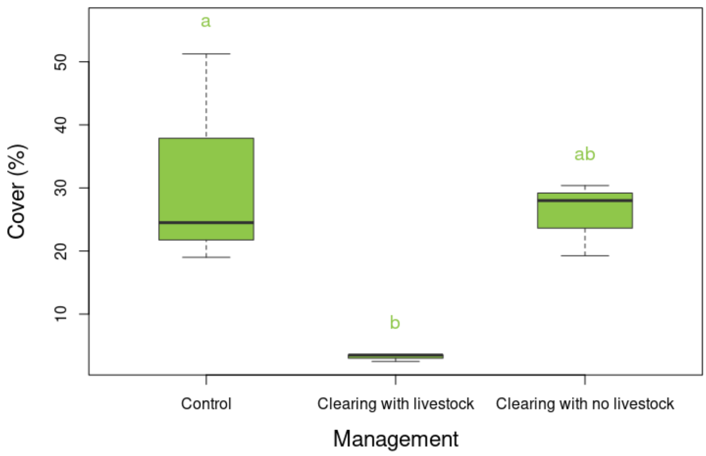
Residual standard error: 10.52497
Estimated effects may be unbalanced

Tukey

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = Cover ~ Management)

	diff	lwr	upr	p adj	
Clearing with livestock-Control	-28.400000	-54.767522	-2.032478	0.0374849	***
Clearing with no livestock-Control	-5.708333	-32.075855	20.659189	0.7916405	
Clearing with no livestock-Clearing with livestock	22.691667	-3.675855	49.059189	0.0853814	



Forest Decay – Requesens (Catalonia)

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	se
1	Control	3	13.0	2.2	10.5	12.2	14.0	14.2	14.5	1.27
2	Clearing with livestock	3	10.9	10.5	4.5	4.8	5.2	14.1	23.0	6.06
3	Clearing with no livestock	3	13.7	5.2	9.5	10.8	12.0	15.8	19.5	3.00

ANOVA

Call:
aov(formula = Decay ~ Management)

Terms:

	Management	Residuals
Sum of Squares	12.50889	283.52667
Deg. of Freedom	2	6

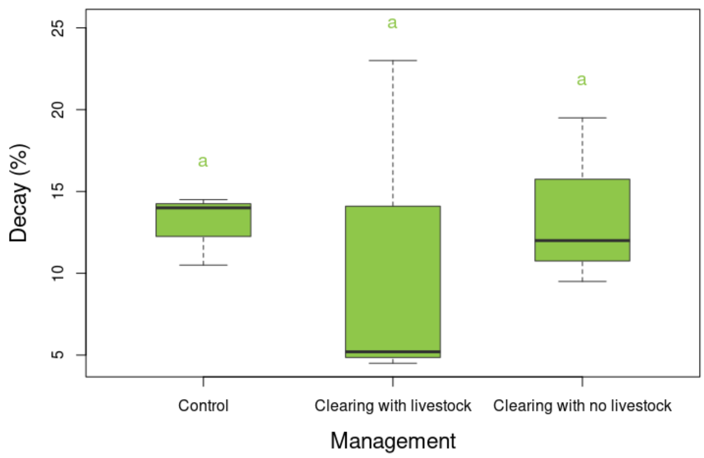
Residual standard error: 6.874187
Estimated effects may be unbalanced

Tukey

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = Decay ~ Management)

	diff	lwr	upr	p adj
Clearing with livestock-Control	-2.1000000	-19.32146	15.12146	0.9266551
Clearing with no livestock-Control	0.6666667	-16.55479	17.88812	0.9922623
Clearing with no livestock-Clearing with livestock	2.7666667	-14.45479	19.98812	0.8772432



Basal Area – La Garcipollera (Aragon), *Pinus nigra* forest

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	se
1	Control	2	18.2	0.7	17.7	18.0	18.2	18.5	18.8	0.495
2	Clearing with livestock	3	28.4	5.3	22.8	25.8	28.7	31.1	33.5	3.060
3	Clearing with no livestock	3	24.0	2.0	21.7	23.4	25.1	25.1	25.2	1.150

ANOVA

Call:
aov(formula = BA ~ Management)

Terms:

	Management	Residuals
Sum of Squares	122.95787	65.27622
Deg. of Freedom	2	5

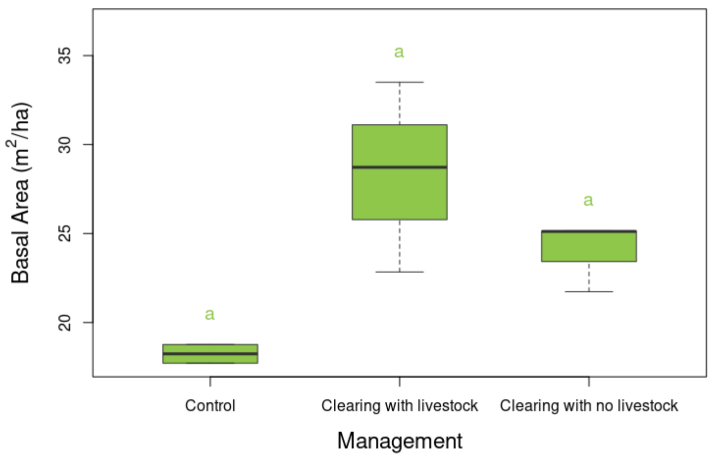
Residual standard error: 3.613204
Estimated effects may be unbalanced

Tukey

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = BA ~ Management)

	diff	lwr	upr	p adj
Clearing with livestock-Control	10.115259	-0.6174064	20.847924	0.0612288
Clearing with no livestock-Control	5.763023	-4.9696427	16.495688	0.2775726
Clearing with no livestock-Clearing with livestock	-4.352236	-13.9518239	5.247351	0.3765846



Understorey Cover – La Garcipollera (Aragon), *Pinus nigra* forest

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	percZero	se
1	Control	2	40.0	6.2	35.6	37.8	40.0	42.2	44.4	0.0	4.380
2	Clearing with livestock	3	0.4	0.3	0.0	0.2	0.5	0.6	0.6	33.3	0.173
3	Clearing with no livestock	3	3.4	2.2	1.0	2.5	4.0	4.7	5.3	0.0	1.270

ANOVA

Call:
aov(formula = Cover ~ Management)

Terms:

	Management	Residuals
Sum of Squares	2190.4361	48.3519
Deg. of Freedom	2	5

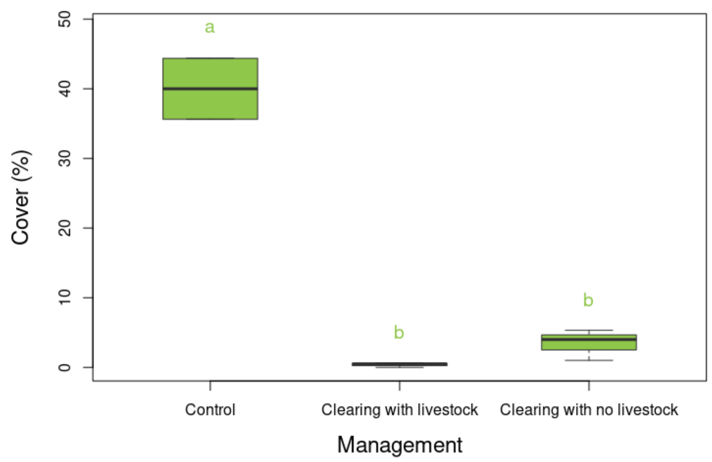
Residual standard error: 3.109722
Estimated effects may be unbalanced

Tukey

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = Cover ~ Management)

	diff	lwr	upr	p adj	
Clearing with livestock-Control	-39.625000	-48.862121	-30.38788	0.0000792	***
Clearing with no livestock-Control	-36.555556	-45.792677	-27.31843	0.0001181	***
Clearing with no livestock-Clearing with livestock	3.069444	-5.192488	11.33138	0.4983488	



Forest Decay – La Garcipollera (Aragon), *Pinus nigra* forest

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	se
1	Control	2	4.8	0.4	4.5	4.6	4.8	4.9	5	0.283
2	Clearing with livestock	3	8.8	3.3	5.5	7.2	9.0	10.5	12	1.910
3	Clearing with no livestock	3	9.7	1.3	8.5	9.0	9.5	10.2	11	0.751

ANOVA

Call:
aov(formula = Decay ~ Management)

Terms:

	Management	Residuals
Sum of Squares	31.41667	24.45833
Deg. of Freedom	2	5

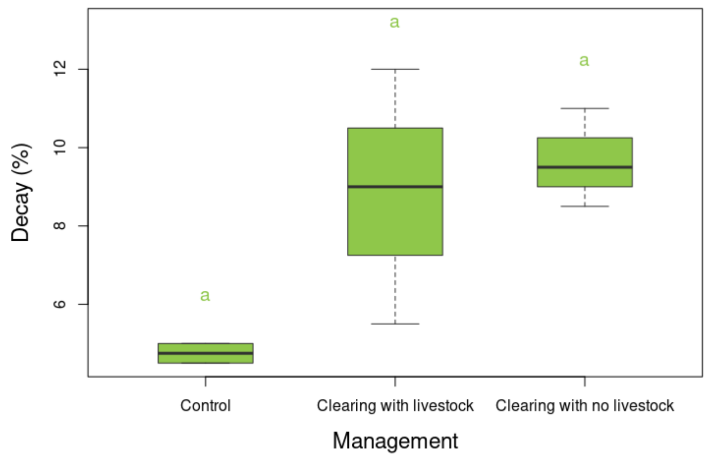
Residual standard error: 2.211711
Estimated effects may be unbalanced

Tukey

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = Decay ~ Management)

	diff	lwr	upr	p adj
Clearing with livestock-Control	4.0833333	-2.486336	10.653003	0.2018764
Clearing with no livestock-Control	4.9166667	-1.653003	11.486336	0.1248677
Clearing with no livestock-Clearing with livestock	0.8333333	-5.042758	6.709424	0.8916662



Basal Area – La Garcipollera (Aragon), *Populus* forest

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	se
1	Control	8	1.6	0.7	0.2	1.2	1.9	2.1	2.3	0.247
2	Clearing L	19	2.0	0.9	0.2	1.4	2.2	2.5	3.7	0.206
3	Clearing NL	12	2.1	0.8	1.2	1.4	2.0	2.7	3.3	0.231

ANOVA

Call:
aov(formula = model)

Terms:

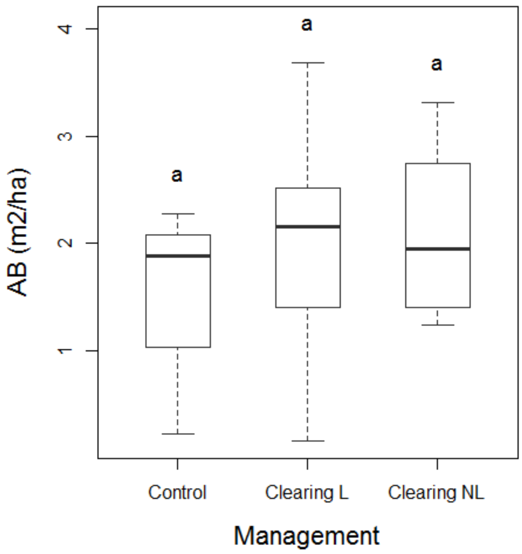
	Management	Residuals
Sum of Squares	1.633792	23.449423
Deg. of Freedom	2	36

TUKEY

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = model)

	diff	lwr	upr	p adj
Clearing L-Control	0.4231283	-0.4083078	1.2545645	0.4356654
Clearing NL-Control	0.5722330	-0.3281934	1.4726593	0.2787410
Clearing NL-Clearing L	0.1491046	-0.5783104	0.8765196	0.8712776



Understorey Cover – La Garcipollera (Aragon), *Populus* forest

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	se
1	Control	67	27.5	20.1	5	15	20	40	80	2.46
2	Clearing L	42	9.2	8.5	5	5	5	10	50	1.31
3	Clearing NL	61	8.3	5.7	5	5	5	10	30	0.73

ANOVA

Call:
aov(formula = model)

Terms:

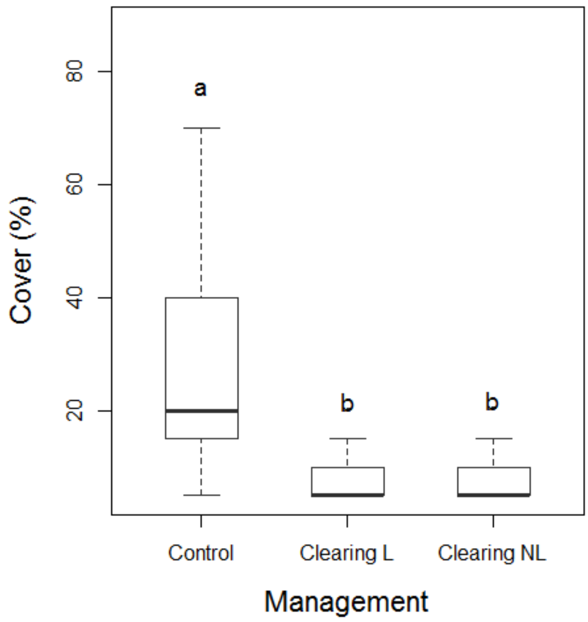
	Management	Residuals
Sum of Squares	14400.66	31508.75
Deg. of Freedom	2	167

TUKEY

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = model)

	diff	lwr	upr	p adj
Clearing L-Control	-18.2960199	-24.68899	-11.903049	0.0000000
Clearing NL-Control	-19.1839980	-24.93249	-13.435503	0.0000000
Clearing NL-Clearing L	-0.8879781	-7.40097	5.625014	0.9443304



Forest Decay – La Garcipollera (Aragon), *Populus* forest

Summary

	Management	n	mean	sd	min	Q1	median	Q3	max	percZero	se
1	Control	8	21.9	10.3	5	18.8	20	26.2	40	0.0	3.64
2	Clearing L	21	21.9	21.5	0	10.0	20	30.0	100	4.8	4.69
3	Clearing NL	15	22.0	23.9	0	10.0	15	27.5	100	13.3	6.17

ANOVA

Call:
aov(formula = model)

Terms:

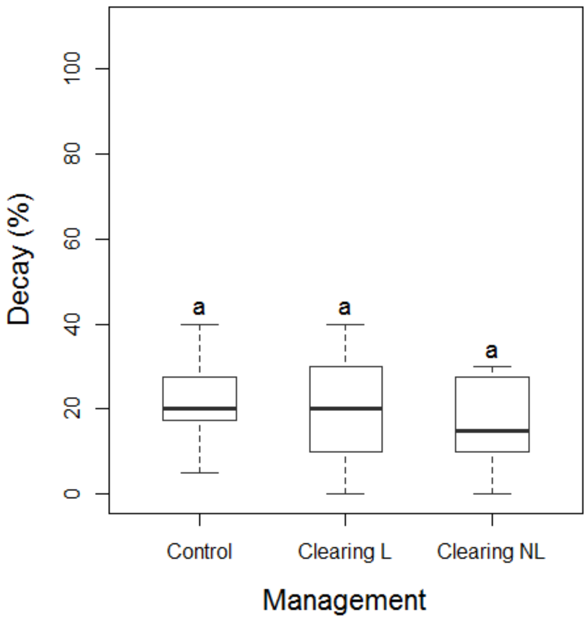
	Management	Residuals
Sum of Squares	0.111	17960.685
Deg. of Freedom	2	41

TUKEY

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = model)

	diff	lwr	upr	p adj
Clearing L-Control	0.0297619	-21.11560	21.17512	0.9999935
Clearing NL-Control	0.1250000	-22.15648	22.40648	0.9998974
Clearing NL-Clearing L	0.0952381	-17.11024	17.30071	0.9999001



6.2. Annex 2. Vegetation sampling. Pasture production and quality, and biodiversity

1. Vegetation sampling in the forest management plots in the *Pinus nigra* forest in Aragon.

To assess the pasture's biodiversity, we sampled the vegetation growing inside three sub-plots with no livestock and in three sub-plots submitted to livestock by cows (B) in the area submitted to clearing. As a control, we also sampled the vegetation growing in an area with the same environmental conditions and vegetation structure but with no clearing intervention and no livestock. We recorded the surface covered by every species found inside 1*1 m quadrats at each sub-plot in the clearing area (n= 3 sub-plots per livestock treatment * 4 quadrats= 36 quadrats) and in the control area (n=12 quadrats). We found a total of 118 species, being 93 herbaceous and 25 woody species (Table 1). We also tested for differences per management treatment in the number of species and the area covered by each lifeform.

To assess the pasture production and quality, we collected systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats (n=36 samples). Samples were divided into herbaceous and woody species separately Samples were cleaned (discarding the litter), and dried in a stove at 65ºC during 48 hours. Then, they were weighed to estimate the dry biomass production (T/ha). The sample processing is still in progress. All the samples will be grinded to a particle size of <1 mm to assess the pasture quality by analysing the content of proteins and fibers.

	Herbaceous species	Family	Life form
1	*Acinos arvensis*	*Lamiaceae*	Therophyte
2	*Agrimonia eupatoria*	*Rosaceae*	Hemichryptophyte
3	*Althaea hirsuta*	*Malvaceae*	Therophyte
4	*Anacamptis pyramidalis*	*Orchidaceae*	Geophyte
5	*Anthriscus silvestris*	*Apiaceae*	Hemichryptophyte
6	*Aphyllanthes monspeliensis*	*Asparagaceae*	Geophyte
7	*Arenaria serpyllifolia*	*Caryophyllaceae*	Therophyte
8	*Arrhenatherum elatius*	*Poaceae*	Hemichryptophyte
9	*Avenula pratensis*	*Poaceae*	Hemichryptophyte
10	*Bellis perennis*	*Asteraceae*	Therophyte
11	*Blackstonia perfoliata*	*Gentianaceae*	Therophyte
12	*Brachypodium pinnatum*	*Poaceae*	Hemichryptophyte
13	*Briza media*	*Poaceae*	Hemichryptophyte
14	*Bromus diandrus*	*Poaceae*	Therophyte
15	*Bromus erectus*	*Poaceae*	Hemichryptophyte
16	*Bromus hordeaceus*	*Poaceae*	Hemichryptophyte
17	*Carex divulsa subsp. leersi*	*Cyperaceae*	Hemichryptophyte
18	*Carex flacca*	*Cyperaceae*	Hemichryptophyte
19	*Carex flava*	*Cyperaceae*	Hemichryptophyte
20	*Centaurea scabiosa*	*Asteraceae*	Hemichryptophyte
21	*Centaurium erythraea*	*Gentianaceae*	Therophyte
22	*Cephalaria leucantha*	*Dipsacaceae*	Hemichryptophyte
23	*Cephalenthera damasonium*	*Orchidaceae*	Geophyte
24	*Cerastium ramosissimum*	*Caryophyllaceae*	Therophyte
25	*Cirsium vulgare*	*Asteraceae*	Hemichryptophyte
26	*Clinopodium vulgare*	*Lamiaceae*	Hemichryptophyte
27	*Convolvulus arvensis*	*Convolvulaceae*	Hemichryptophyte
28	*Coronilla scorpioides*	*Fabaceae*	Therophyte

29	*Crepis albida*	*Asteraceae*	Hemichryptophyte
30	*Cynoglossum officinale*	*Boraginaceae*	Hemichryptophyte
31	*Dactylis glomerata*	*Poaceae*	Hemichryptophyte
32	*Daucus carota*	*Apiaceae*	Hemichryptophyte
33	*Eryngium campestre*	*Apiaceae*	Geophyte
34	*Festuca arundinacea*	*Poaceae*	Hemichryptophyte
35	*Festuca rubra*	*Poaceae*	Hemichryptophyte
36	*Filipendula hexapetala*	*Rosaceae*	Hemichryptophyte
37	*Galium lucidum*	*Rubiaceae*	Hemichryptophyte
38	*Galium verum*	*Rubiaceae*	Hemichryptophyte
39	*Geranium dissectum*	*Geraniaceae*	Therophyte
40	*Gymnadenia conopsea*	*Orchidaceae*	Geophyte
41	*Hieracium pilosella*	*Asteraceae*	Hemichryptophyte
42	*Hordeum murinum*	*Poaceae*	Therophyte
43	*Hypericum perforatum*	*Clusiaceae*	Hemichryptophyte
44	*Hypochaeris radicata*	*Asteraceae*	Hemichryptophyte
45	*Jasonia tuberosa*	*Asteraceae*	Hemichryptophyte
46	*Juncus bufonius*	*Juncaceae*	Therophyte
47	*Lathyrus aphaca*	*Fabaceae*	Therophyte
48	*Lathyrus pratensis*	*Fabaceae*	Hemichryptophyte
49	*Leucanthemum vulgare*	*Asteraceae*	Hemichryptophyte
50	*Linum catharticum*	*Linaceae*	Therophyte
51	*Lithospermum officinale*	*Boraginaceae*	Hemichryptophyte
52	*Lolium rigidum*	*Poaceae*	Therophyte
53	*Lotus corniculatus*	*Fabaceae*	Hemichryptophyte
54	*Medicago lupulina*	*Fabaceae*	Therophyte
55	*Medicago sativa*	*Fabaceae*	Hemichryptophyte
56	*Ophrys apifera*	*Orchidaceae*	Geophyte
57	*Ophrys scolopax*	*Orchidaceae*	Geophyte
58	*Orobanche sp*	*Orobanchaceae*	Geophyte
59	*Phyteuma orbiculare*	*Campanulaceae*	Hemichryptophyte
60	*Plantago lanceolata*	*Plantaginaceae*	Hemichryptophyte
61	*Plantago major*	*Plantaginaceae*	Hemichryptophyte
62	*Plantago media*	*Plantaginaceae*	Hemichryptophyte
63	*Platanthera bifolia*	*Orchidaceae*	Geophyte
64	*Platanthera chlorantha*	*Orchidaceae*	Geophyte
65	*Poa pratensis*	*Poaceae*	Hemichryptophyte
66	*Polygala vulgaris*	*Polygalaceae*	Hemichryptophyte
67	*Potentilla reptans*	*Rosaceae*	Hemichryptophyte
68	*Prunella laciniata*	*Lamiaceae*	Hemichryptophyte
69	*Prunella vulgaris*	*Lamiaceae*	Hemichryptophyte
70	*Ranunculus bulbosus*	*Ranunculaceae*	Hemichryptophyte
71	*Rumex longifolius*	*Polygonaceae*	Hemichryptophyte
72	*Sanguisorba minor*	*Rosaceae*	Hemichryptophyte
73	*Senecio jacobaea*	*Asteraceae*	Hemichryptophyte
74	*Seseli montanum*	*Apiaceae*	Hemichryptophyte
75	*Silene vulgaris*	*Caryophyllaceae*	Hemichryptophyte
76	*Sonchus oleraceus*	*Asteraceae*	Hemichryptophyte
77	*Taraxacum officinale*	*Asteraceae*	Hemichryptophyte
78	*Tetragonolobus maritimus*	*Fabaceae*	Hemichryptophyte
79	*Tragopogon pratensis*	*Asteraceae*	Hemichryptophyte
80	*Trifolium campestre*	*Fabaceae*	Therophyte
81	*Trifolium montanum*	*Fabaceae*	Hemichryptophyte
82	*Trifolium ochroleucon*	*Fabaceae*	Hemichryptophyte

83	*Trifolium pratense*	*Fabaceae*	Hemichryptophyte
84	*Trifolium repens*	*Fabaceae*	Hemichryptophyte
85	*Urtica dioica*	*Urticaceae*	Hemichryptophyte
86	*Verbena officinalis*	*Verbenaceae*	Hemichryptophyte
87	*Veronica chamaedrys*	*Scrophulariaceae*	Hemichryptophyte
88	*Veronica verna*	*Scrophulariaceae*	Therophyte
89	*Vicia angustifolia*	*Fabaceae*	Therophyte
90	*Vicia sativa*	*Fabaceae*	Therophyte
91	*Vicia sepium*	*Fabaceae*	Hemichryptophyte
92	*Viola sylvestris*	*Violaceae*	Hemichryptophyte
93	*Xeranthemum inapertum*	*Asteraceae*	Therophyte
	Woody species	**Family**	**Life form**
94	*Acer campestris*	*Sapindaceae*	Macrophanerophyte
95	*Berberis vulgaris*	*Berberidaceae*	Macrophanerophyte
96	*Buxus sempervirens*	*Buxaceae*	Macrophanerophyte
97	*Clemais vitalba*	*Ranunculaceae*	Macrophanerophyte
98	*Cornus sanguinea*	*Cornaceae*	Nanophanerophyte
99	*Coronilla minima*	*Fabaceae*	Chamaephyte
100	*Crataegus monogyna*	*Rosaceae*	Macrophanerophyte
101	*Dorycnium pentaphyllum*	*Fabaceae*	Chamaephyte
102	*Fraxinus angustifolia*	*Oleaceae*	Macrophanerophyte
103	*Genista scorpius*	*Fabaceae*	Nanophanerophyte
104	*Helianthemum nummularium*	*Cistaceae*	Chamaephyte
105	*Helleborus foetidus*	*Ranunculaceae*	Chamaephyte
106	*Juniperus communis*	*Cupressaceae*	Nanophanerophyte
107	*Juniperus oxycedrus*	*Cupressaceae*	Nanophanerophyte
108	*Lonicera etrusca*	*Caprifoliaceae*	Chamaephyte
109	*Ononis spinosa*	*Fabaceae*	Chamaephyte
110	*Pinus nigra*	*Pinaceae*	Macrophanerophyte
111	*Populus nigra*	*Salicaceae*	Macrophanerophyte
112	*Prunus spinosa*	*Rosaceae*	Macrophanerophyte
113	*Quercus cerrioides*	*Fagaceae*	Macrophanerophyte
114	*Rosa canina*	*Rosaceae*	Macrophanerophyte
115	*Rosa micrantha*	*Rosaceae*	Macrophanerophyte
116	*Rubus ulmifolius*	*Rosaceae*	Macrophanerophyte
117	*Teucrium chamaedrys*	*Lamiaceae*	Chamaephyte
118	*Teucrium pyrenaicum subsp guarensis*	*Lamiaceae*	Chamaephyte

Table 1. List of herbaceous and woody species found in Aragon (Garcipollera).

We found significantly more herbaceous species in the areas submitted to clearing than in the non-managed area (control). Contrarily, richness of woody species was significantly larger in the control area than in the clearing area (Figure 1). We did not find significant differences in species richness (neither herbaceous nor woody species) between the plots submitted to livestock and not submitted to livestock within the clearing area (Figure 1). Among the different vegetation lifeforms coverage, hemichryptophytes were dominant in all the management treatments (Figure 2). Besides, while we found a significant cover of woody species (macrophanerophytes, nanophanerophytes and chamaephytes) in the control area, those were almost absent in the plots submitted to clearing (both with and without livestock activity). Therophytes are not much dominant, but those covered a larger surface in the plots without livestock than in the plots with livestock (Figure 2).

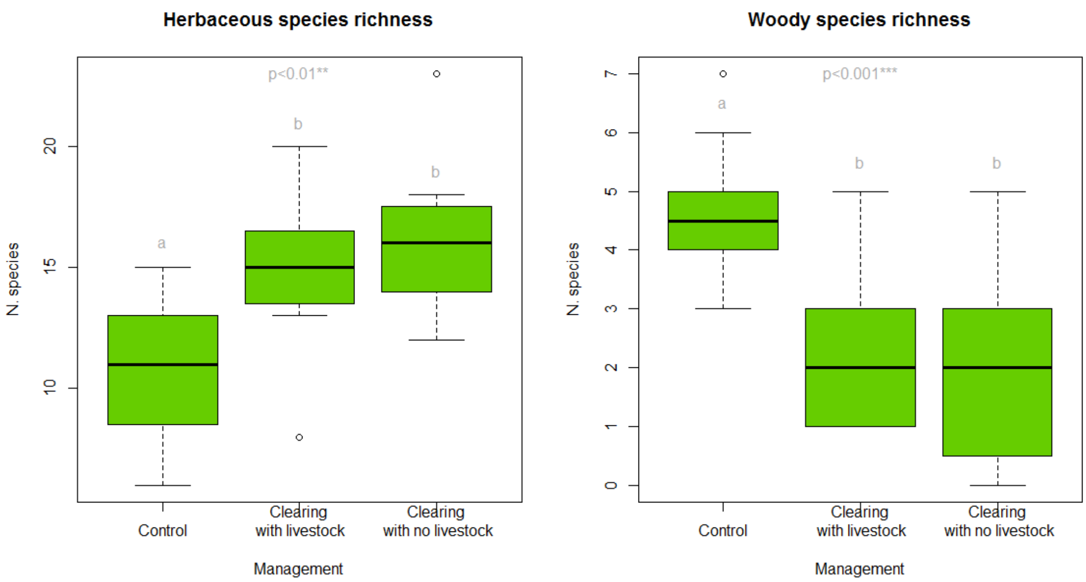


Figure 1. Mean species richness per management treatment (control, clearing with livestock and clearing with no livestock) for herbaceous and woody species separately in La Garcipollera. Different letters indicate significant differences when p<0.05.

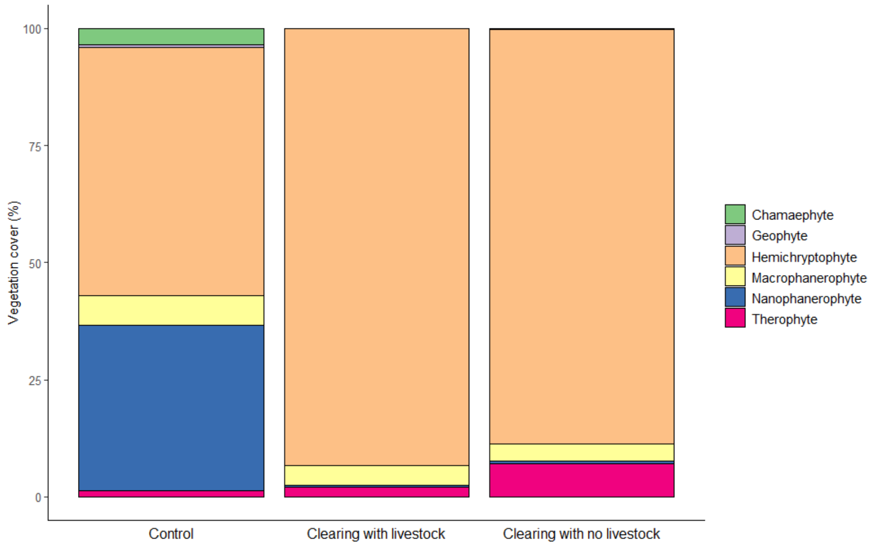


Figure 2. Percentage of surface covered by each plant lifeform classification (chamaephytes, geophytes, hemichryptophytes, macrophanerophytes, nanophanerophytes and therophytes) at each management treatment (control, clearing with livestock and clearing with no livestock) in La Garcipollera.

Regarding the pasture production in La Garcipollera, we did not find significant differences in the dry biomass of the herbaceous species (Figure 3).

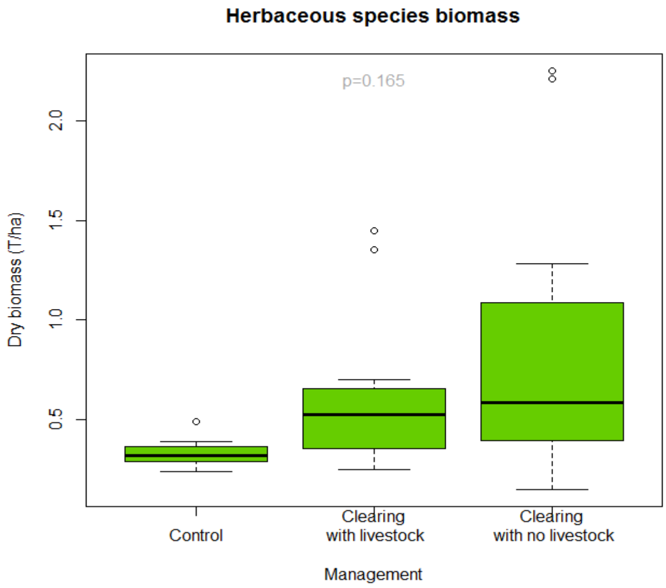


Figure 3 Mean dry biomass (T/ha) of herbaceous species per management treatment (control, clearing with livestock, clearing with no livestock) in La Garcipollera. Significant differences between management treatments when $p<0.05$.

2. <u>Vegetation sampling in the forest management plots in the *Populus* forest in Aragon.</u>

To assess the **pasture's biodiversity**, we sampled the vegetation growing inside three sub-plots with no livestock and in three sub-plots submitted to livestock by cows in the area submitted to clearing. As a control, we also sampled the vegetation growing in an area with the same environmental conditions and vegetation structure but with no clearing intervention and no livestock. We recorded the surface covered by every species found inside 1*1 m quadrats at each sub-plot in the clearing area (n= 3 sub-plots per livestock treatment * 4 quadrats= 36 quadrats) and in the control area (n=12 quadrats). **We found a total of 88 species, being 72 herbaceous and 16 woody species**.

To assess the **pasture production and quality,** we collected systematically the plants growing in 50 x 50 cm areas close to each of the previously surveyed quadrats (n=36 samples). Samples were divided into herbaceous and woody species separately. Samples were cleaned (discarding the litter), and dried in a stove at 65ºC during 48 hours. Then, they were weighed to estimate the dry biomass production (T/ha). The sample processing is still in progress. All the samples will be grinded to a particle size of <1 mm to assess the pasture quality by analysing the content of proteins and fibers.

	Herbaceous species	Family	Life form
1	*Acinos arvensis*	*Lamiaceae*	Therophyte
2	*Agrimonia eupatoria*	*Rosaceae*	Hemichryptophyte
3	*Anacamptis pyramidalis*	*Orchidaceae*	Geophyte
4	*Anthriscus silvestris*	*Apiaceae*	Hemichryptophyte
5	*Aphyllanthes monspeliensis*	*Asparagaceae*	Hemichryptophyte
6	*Arenaria serpyllifolia*	*Caryophyllaceae*	Chamaephyte
7	*Arrhenatherum elatius*	*Poaceae*	Chamaephyte
8	*Bellis perennis*	*Asteraceae*	Therophyte
9	*Blackstonia perfoliata*	*Gentianaceae*	Therophyte
10	*Brachypodium pinnatum*	*Poaceae*	Hemichryptophyte
11	*Briza media*	*Poaceae*	Hemichryptophyte
12	*Bromus diandrus*	*Poaceae*	Therophyte
13	*Bromus erectus*	*Poaceae*	Hemichryptophyte
14	*Carex flacca*	*Cyperaceae*	Hemichryptophyte
15	*Carex flava*	*Cyperaceae*	Hemichryptophyte
16	*Carex sp*	*Cyperaceae*	Hemichryptophyte
17	*Centaurea nigra*	*Asteraceae*	Hemichryptophyte
18	*Centaurium erythraea*	*Gentianaceae*	Therophyte
19	*Cephalenthera damasonium*	*Orchidaceae*	Geophyte
20	*Cerastium fontanum*	*Caryophyllaceae*	Therophyte
21	*Cirsium vulgare*	*Asteraceae*	Geophyte
22	*Convolvulus arvensis*	*Convolvulaceae*	Hemichryptophyte
23	*Crepis albida*	*Asteraceae*	Hemichryptophyte
24	*Cynosurus cristatus*	*Poaceae*	Hemichryptophyte
25	*Dactylis glomerata*	*Poaceae*	Hemichryptophyte
26	*Daucus carota*	*Apiaceae*	Hemichryptophyte

27	*Desmazeria rigida*	*Poaceae*	Therophyte
28	*Eryngium campestre*	*Apiaceae*	Geophyte
29	*Festuca arundinacea*	*Poaceae*	Hemichryptophyte
30	*Festuca rubra*	*Poaceae*	Hemichryptophyte
31	*Fragaria vesca*	*Rosaceae*	Therophyte
32	*Galium cf spurium*	*Rubiaceae*	Therophyte
33	*Galium lucidum*	*Rubiaceae*	Hemichryptophyte
34	*Geranium dissectum*	*Geraniaceae*	Therophyte
35	*Helleborus foetidus*	*Ranunculaceae*	Chamaephyte
36	*Hieracium pilosella*	*Asteraceae*	Hemichryptophyte
37	*Hypericum perforatum*	*Clusiaceae*	Hemichryptophyte
38	*Hypochaeris radicata*	*Asteraceae*	Hemichryptophyte
39	*Jasonia tuberosa*	*Asteraceae*	Hemichryptophyte
40	*Leucanthemum vulgare*	*Asteraceae*	Hemichryptophyte
41	*Lithospermum officinale*	*Boraginaceae*	Hemichryptophyte
42	*Lotus corniculatus*	*Fabaceae*	Hemichryptophyte
43	*Medicago lupulina*	*Fabaceae*	Therophyte
44	*Medicago minima*	*Fabaceae*	Therophyte
45	*Medicago sativa*	*Fabaceae*	Hemichryptophyte
46	*Phleum pratense*	*Poaceae*	Hemichryptophyte
47	*Plantago lanceolata*	*Plantaginaceae*	Hemichryptophyte
48	*Plantago media*	*Plantaginaceae*	Hemichryptophyte
49	*Poa pratensis*	*Poaceae*	Hemichryptophyte
50	*Polygala vulgaris*	*Polygalaceae*	Hemichryptophyte
51	*Potentilla erecta*	*Rosaceae*	Hemichryptophyte
52	*Potentilla reptans*	*Rosaceae*	Hemichryptophyte
53	*Prunella laciniata*	*Lamiaceae*	Hemichryptophyte
54	*Prunella vulgaris*	*Lamiaceae*	Hemichryptophyte
55	*Ranunculus bulbosus*	*Ranunculaceae*	Hemichryptophyte
56	*Sanguisorba minor*	*Rosaceae*	Hemichryptophyte
57	*Senecio jacobaea*	*Asteraceae*	Hemichryptophyte
58	*Seseli montanum*	*Apiaceae*	Hemichryptophyte
59	*Silene vulgaris*	*Caryophyllaceae*	Chamaephyte
60	*Taraxacum officinale*	*Asteraceae*	Hemichryptophyte
61	*Tetragonolobus maritimus*	*Fabaceae*	Hemichryptophyte
62	*Trifolium campestre*	*Fabaceae*	Therophyte
63	*Trifolium montanum*	*Fabaceae*	Hemichryptophyte
64	*Trifolium pratense*	*Fabaceae*	Hemichryptophyte
65	*Trifolium repens*	*Fabaceae*	Hemichryptophyte
66	*Trisetum flavescens*	*Poaceae*	Hemichryptophyte
67	*Verbena officinalis*	*Verbenaceae*	Hemichryptophyte
68	*Veronica chamaedrys*	*Scrophulariaceae*	Hemichryptophyte
69	*Vicia angustifolia*	*Fabaceae*	Therophyte
70	*Vicia craca*	*Fabaceae*	Hemichryptophyte
71	*Vicia peregrina*	*Fabaceae*	Therophyte
72	*Viola sylvestris*	*Violaceae*	Hemichryptophyte

	Woody species	Family	Life form
73	*Buxus sempervirens*	*Buxaceae*	Macrophanerophyte
74	*Coronilla minima*	*Fabaceae*	Chamaephyte
75	*Crataegus monogyna*	*Rosaceae*	Macrophanerophyte
76	*Fraxinus angustifolia*	*Oleaceae*	Macrophanerophyte
77	*Genista scorpius*	*Fabaceae*	Nanophanerophyte
78	*Helianthemum nummularium*	*Cistaceae*	Chamaephyte
79	*Juniperus communis*	*Cupressaceae*	Nanophanerophyte
80	*Ononis spinosa*	*Fabaceae*	Chamaephyte
81	*Pinus nigra*	*Pinaceae*	Macrophanerophyte
82	*Populus nigra*	*Salicaceae*	Macrophanerophyte
83	*Prunus spinosa*	*Rosaceae*	Macrophanerophyte
84	*Quercus faginea*	*Fagaceae*	Macrophanerophyte
85	*Rosa sp*	*Rosaceae*	Macrophanerophyte
86	*Rubia peregrina*	*Rubiaceae*	Nanophanerophyte
87	*Rubus ulmifolius*	*Rosaceae*	Macrophanerophyte
88	*Viburnum lantana*	*Caprifoliaceae*	Nanophanerophyte

Table 2. List of herbaceous and woody species found in the Populus forest in Aragon (Garcipollera).

We found significantly more herbaceous species in the areas submitted to clearing than in the non-managed area (control). Contrarily, **richness of woody species was significantly larger in the control area than in the clearing area**. We did not find significant differences in species richness (neither herbaceous nor woody species) between the plots submitted to livestock and not submitted to livestock within the clearing area.

	A	B	SD	
	Mean ± SE	Mean ± SE	Mean ± SE	p-value
Herbaceous species richness	19.08 ± 0.72 [a]	18.25 ± 1.21 [a]	13.75 ± 0.97 [b]	<0.01**
Woody species richness	2.17 ± 0.47 [a]	1.83 ± 0.51 [a]	2.67 ± 0.28 [a]	0.4033

Table 3. Results of the linear models to test significant differences between treatments

3. <u>Vegetation sampling in the forest management plots in Catalonia</u>

To assess the pasture's biodiversity, in an area submitted to forest management (thinning and scrubland clearing), we sampled the vegetation growing inside three sub-plots with experimental seeding and submitted to livestock by cows and inside three subplots with no experimental seeding and no livestock activity. As a control, we also sampled the vegetation growing in three sub-plots within an area with the same environmental conditions and vegetation structure but with no clearing intervention, no seeding and no livestock activity (control). We recorded the surface covered by every species found inside four 1*1 m quadrats at each sub-plot per forest management and livestock treatment (n= 3 treatments * 3 sub-plots * 4 quadrats= 36 quadrats). We found a total of 80 species, being 56 herbaceous and 24 woody species (Table 5). We also tested for differences per management treatment (control, managed with livestock, managed with no livestock) in the number of species and the area covered by each lifeform.

To assess the pasture production and quality, we were planning to collect systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats (n=36 samples). However, during this field campaign, vegetation sampling was not feasible because the plants were parched. In future field campaigns, samples will be collected, weighed and analysed for the content of proteins and fibers.

	Herbaceous species	Family	Life form
1	*Agrostis capillaris*	*Poaceae*	Hemichryptophyte
2	*Anagallis arvensis*	*Primulaceae*	Therophyte
3	*Asphodelus fistulosus*	*Lilliaceae*	Geophyte
4	*Bellis perennis*	*Asteraceae*	Therophyte
5	*Brachypodium retusum*	*Poaceae*	Chamaephyte
6	*Carex distachya*	*Cyperaceae*	Hemichryptophyte
7	*Carex muricata*	*Cyperaceae*	Hemichryptophyte
8	*Carex sp*	*Cyperaceae*	Hemichryptophyte
9	*Centaurea pectinata*	*Asteraceae*	Hemichryptophyte
10	*Cerastium pumilum*	*Caryophyllaceae*	Therophyte
11	*Chenopodium vulvaria*	*Chenopodiaceae*	Therophyte
12	*Crepis capillaris*	*Asteraceae*	Therophyte
13	*Crepis vesicaria*	*Asteraceae*	Hemichryptophyte
14	*Dactylis glomerata*	*Poaceae*	Hemichryptophyte
15	*Elymus repens*	*Poaceae*	Hemichryptophyte
16	*Euphorbia peplus*	*Euphorbiaceae*	Therophyte
17	*Festuca rubra*	*Poaceae*	Hemichryptophyte
18	*Filago pyramidata*	*Asteraceae*	Therophyte
19	*Galium lucidum*	*Rubiaceae*	Hemichryptophyte
20	*Galium pumilum*	*Rubiaceae*	Hemichryptophyte
21	*Geranium robertianum*	*Geraniaceae*	Therophyte
22	*Gnaphalium sylvaticum*	*Asteraceae*	Hemichryptophyte
23	*Helianthemum gutattum*	*Cistaceae*	Therophyte
24	*Hieracium glaucinium*	*Asteraceae*	Hemichryptophyte
25	*Hieracium murorum*	*Asteraceae*	Hemichryptophyte
26	*Hypericum perforatum*	*Clusiaceae*	Hemichryptophyte
27	*Koeleria phleoides*	*Poaceae*	Therophyte
28	*Lolium mutiflorum*	*Poaceae*	Therophyte
29	*Lolium perenne*	*Poaceae*	Hemichryptophyte
30	*Lotus corniculatus*	*Fabaceae*	Hemichryptophyte
31	*Luzula sulvatica*	*Juncaceae*	Hemichryptophyte
32	*Medicago sativa*	*Fabaceae*	Hemichryptophyte
33	*Plantago lanceolata*	*Plantaginaceae*	Hemichryptophyte
34	*Polycarpon tetraphyllum*	*Caryophyllaceae*	Therophyte
35	*Polygonum aviculare*	*Polygonaceae*	Therophyte
36	*Polypodium vulgare*	*Polypodiaceae*	Hemichryptophyte
37	*Pteridium aquilinum*	*Dennstaedtiaceae*	Geophyte
38	*Rumex acetosella*	*Polygonaceae*	Hemichryptophyte
39	*Rumex longifolius*	*Polygonaceae*	Hemichryptophyte
40	*Sedum album*	*Crassulaceae*	Chamaephyte
41	*Senecio inaequidens*	*Asteraceae*	Hemichryptophyte
42	*Silene gallica*	*Caryophyllaceae*	Therophyte
43	*Solanum nigrum*	*Solanaceae*	Therophyte
44	*Solidago virgaurea*	*Asteraceae*	Hemichryptophyte

45	*Sorghum halepense*	*Poaceae*	Geophyte
46	*Stachys officinalis*	*Lamiaceae*	Hemichryptophyte
47	*Stellaria holostea*	*Caryophyllaceae*	Hemichryptophyte
48	*Teucrium scorodonia*	*Lamiaceae*	Hemichryptophyte
49	*Trifolium arvense*	*Fabaceae*	Therophyte
50	*Trifolium campestre*	*Fabaceae*	Therophyte
51	*Trifolium glomeratum*	*Fabaceae*	Therophyte
52	*Urtica pilulifera*	*Urticaceae*	Therophyte
53	*Verbascum lychnitis*	*Scrophulariaceae*	Hemichryptophyte
54	*Veronica persica*	*Scrophulariaceae*	Therophyte
55	*Vicia sativa*	*Fabaceae*	Therophyte
56	*Vulpia myuros*	*Poaceae*	Therophyte
	Woody species	**Family**	**Life form**
57	*Acer monspessulanum*	*Sapindaceae*	Macrophanerophyte
58	*Arbutus unedo*	*Ericaceae*	Macrophanerophyte
59	*Calycotome spinosa*	*Fabaceae*	Nanophanerophyte
60	*Cistus monspeliensis*	*Cistaceae*	Nanophanerophyte
61	*Cistus salvifolius*	*Cistaceae*	Nanophanerophyte
62	*Clemais vitalba*	*Ranunculaceae*	Macrophanerophyte
63	*Crataegus monogyna*	*Rosaceae*	Macrophanerophyte
64	*Cytisus scoparius*	*Fabaceae*	Macrophanerophyte
65	*Erica arborea*	*Ericaceae*	Nanophanerophyte
66	*Euphorbia characias*	*Euphorbiaceae*	Nanophanerophyte
67	*Galium maritimum*	*Rubiaceae*	Chamaephyte
68	*Genista pilosa*	*Fabaceae*	Chamaephyte
69	*Genista triflora*	*Fabaceae*	Nanophanerophyte
70	*Ilex aquifulium*	*Aquifoliaceae*	Macrophanerophyte
71	*Phillyrea latifolia*	*Oleaceae*	Nanophanerophyte
72	*Pinus nigra*	*Pinaceae*	Macrophanerophyte
73	*Populus nigra*	*Salicaceae*	Macrophanerophyte
74	*Prunus spinosa*	*Rosaceae*	Macrophanerophyte
75	*Quercus humilis o petraea (hibrido)*	*Fagaceae*	Macrophanerophyte
76	*Quercus ilex*	*Fagaceae*	Macrophanerophyte
77	*Quercus suber*	*Fagaceae*	Macrophanerophyte
78	*Rubia peregrina*	*Rubiaceae*	Nanophanerophyte
79	*Rubus ulmifolius*	*Rosaceae*	Macrophanerophyte
80	*Solanum chenopodioides*	*Solanaceae*	Nanophanerophyte

Table 5. List of herbaceous and woody species found in Catalonia (Requesens).

We did not find significant differences in the richness of woody species between management treatments (Figure 4). Woody species (macrophanerophytes and nanophanerophytes) are dominant in all the management treatments (Figure 5). On the contrary, we found significantly more herbaceous species in the area submitted to management than in the control area, with no significant differences between the livestock treatments (Figure 4). Among herbaceous species in the managed areas, therophytes and hemichryptophyes covered a larger surface in the plots submitted to livestock than in the plots without livestock (Figure 5).

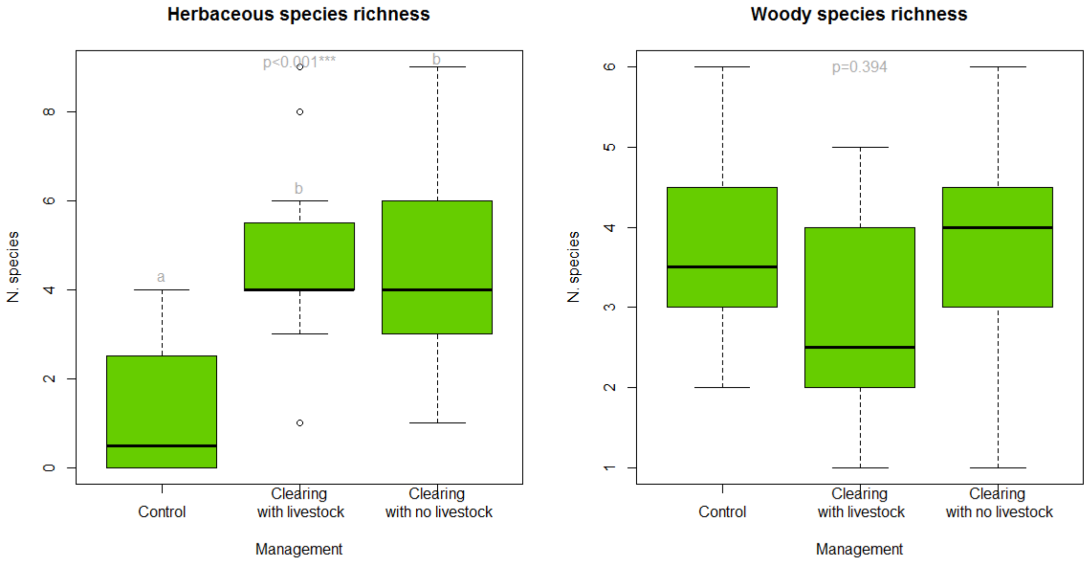


Figure 4. Mean species richness per management treatment (control, managed with livestock and managed with no livestock) for herbaceous and woody species separately in Requesens. Different letters indicate significant differences when p<0.05.

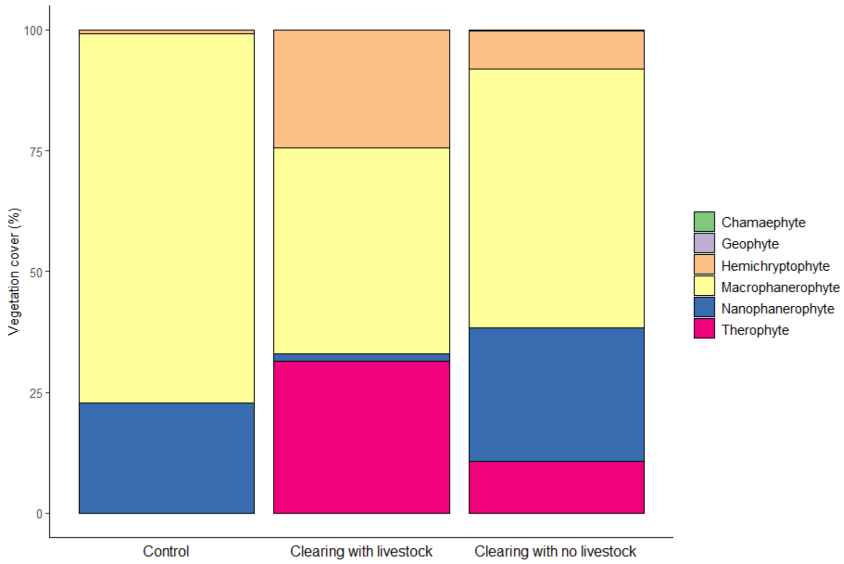


Figure 5. Percentage of surface covered by each plant lifeform classification (chamaephytes, geophytes, hemichryptophytes, macrophanerophytes, nanophanerophytes and therophytes) at each management treatment (control, managed with livestock, managed with no livestock) in Requesens.