

SUMMARY

Tender category: Call for proposals.
Coordinator: Mme Anne Ganteaume (INRAE RECOVER).
Duration: 26 months (15 November 2022 – 15 January 2025).
Project partners: INRAE, amU, MTDA Agency.
AFORCE grant amount: €5000.



PROJECT CONTEXT AND OBJECTIVES

This research project aims to assess the impacts of treatments used in the management of fuel biomass on fire risk (fire behaviour and resulting effects), and on the vitality of tree stands, as well as on the structure and floristic composition in treated areas compared with the control area. Indeed, in the context of short- and long-term forest fire prevention, it is essential to gain a better understanding of how ignition mechanisms operate depending on the different types of fuel resulting from the treatments (forest residues and remaining trees/shrubs).

The starting hypothesis of this study is that the type and structure of the vegetation, the abiotic conditions of the environment resulting from vegetation treatments, and the return interval for each treatment, influence fire ignition and spread at forest-habitat and forest-network interfaces.

KEY DELIVERABLES AND TARGET AUDIENCES

Category	Deliverable	Description	Target audiences
Technical guide 	Publication by Ganteaume A., Boschet A., Cailleret M., 2025. Fuel management for the prevention of forest fires. >>>>	Current state of scientific and technical knowledge, implications for forest fire prevention management.	Institutions, fire, forest and protected area managers, forest owners, consultancy firms.
Accessible article for the general public 	Ganteaume A., Boschet A., 2025. Forêt méditerranéenne. Volume XLVI, No. 2, June 2025, pp. 107–118. >>>>	Summary of the project's results, focusing on flammability.	Institutional representatives, managers of fire, forests and protected areas, forest owners, consultancy firms and environmental organisations, research laboratories.
Seminar on science communication 	7 May 2024 in Lamanon, in partnership with the Alpilles Regional Nature Park, the AMU Master's programme in science communication and the association Les petits débrouillards (155 participants).	Communicating on forest fire risk management through brush clearing.	Institutional, fire, forest, and protected area managers, private forest owners, consulting firms.
Feedback Conference 	November 14, 2024 at Tholonet (61 participants).	Sharing all the results of the project (presentations and roundtable).	Institutional representatives, managers of fire, forests and protected areas, forest owners, consultancy firms and environmental organisations, research laboratories.

PROJECT PARTNERS

INSTRUCTIONS FOR USE

Management methods and types of vegetation studied

Four of the most commonly used vegetation management methods were selected: controlled burning and mechanical mulching to manage woody plants (Kermes oak) in various woodlands in the Bouches-du-Rhône, and mechanical mowing with a brush cutter and manual mowing with a strimmer to manage herbaceous vegetation (see Fig. 1 and Fig. 2). Mowing results in the production of cuttings left on site, but a method of mechanical mowing that leaves no cuttings was also tested for comparison. With regard to mechanical mulching and controlled burning, sampling was also carried out at different time intervals following treatment: the year of treatment (T0), one year later (T1) and two years later (T2), with the herbaceous vegetation being treated at least once a year (T0). Sampling was carried out whilst endeavouring to ensure as much homogeneity as possible between the plots.

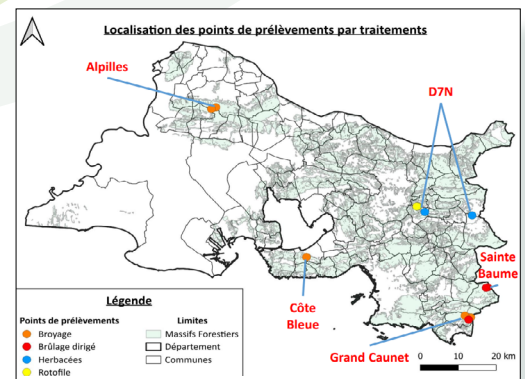


Figure 1: Map of sampling sites for the methods studied.



A. Target vegetation: woody plants



B. Target vegetation: woody plants



C. Target vegetation: herbaceous



D. Target vegetation: herbaceous

Figure 2: Example of the four selected types of vegetation management (A. Mechanical shredding, B. Controlled burning, C. Flail mower, D. Rototiller).

Effect of treatments on flammability

Sampling and burning protocols

Samples of treated and control vegetation were collected in such a way as to keep the vegetation structure intact. For woody plants, in addition to Kermes oak stems of varying heights depending on the return interval, the samples consisted mainly of leaf litter and pine needles. The bulk density of the treated vegetation and the moisture content (FMC) also varied according to the return interval and the treatment (highest values for the control and lowest for the T0 treatments). For mowing of herbaceous vegetation (cover > 95%), the samples consisted exclusively of brome grass for the brush cutter and mainly of *Oloptum* sp. for the rotary mower, with a lower bulk density and higher FMC in the control plots in both cases. These sample parameters, as well as site-specific environmental parameters, may also influence flammability. Where significant, the 'sample' and 'site' effects were controlled for during statistical analysis so that only the 'treatment' effect was taken into account in the analyses. For each treatment/control, at least ten samples per site and per rotation interval (for woody plants only) were collected in summer and burnt in the laboratory immediately after collection to prevent the samples from drying out (821 burns in total).

Measured variables

In this study, we assessed the flammability of post-treatment vegetation using various variables characterising the three components of flammability: (1) for ignitability, the ignition frequency (%) and the ignition delay; (2) for sustainability, flame duration; and (3) for combustibility: the maximum temperature emitted by the flames and the total heat flux received at 10 and 40 cm above the sample, the intensity of the flame front, the ability to propagate the flame, the rate of propagation and the flame height. The ignition capacity of the vegetation (component 1 of flammability) was first studied using a glowing ember as the ignition source, with a wind speed of 9.8 km.h^{-1} to replicate roadside ignition conditions caused by cigarette ends. The fire spread phase (components 2 and 3) was then assessed using ignition along an alcohol line to ensure 100 per cent ignition (and in the absence of wind) to simulate fire spread from the forest towards the road.

Effect of treatment on floristic diversity and the health of Aleppo pine stands

Eight plots spread across the four forest blocks were studied in the vicinity of the plots sampled for flammability. For each plot, three $20 \times 20 \text{ m}$ cleared replicates and three control plots were sampled, ensuring consistent conditions (8×6 , making a total of 48 sub-plots). In order to characterise the site conditions and the structure and composition of the stand in each sub-plot, a dendrometric inventory was carried out in the field (measuring the diameter and species of all trees with a diameter > 5 cm), and vegetation cover was estimated across five vertical strata. The topographical situation was assessed visually and quantitatively using the IGN digital elevation model (calculation of a topographical position index; TPI), and the usable soil reserve was quantified using Jamagne's pedotransfer functions, taking into account soil depth measured with an auger and soil texture.

To analyse the health of Aleppo pines, foliar deficit was assessed on 194 (co-)dominant trees in accordance with the protocol used by the Department of Forest Health (DSF). With regard to the floristic surveys, the presence and abundance of vascular plants were recorded using the Braun-Blanquet coefficients, which enabled us to quantify the number of species, the (dis)similarities of the plant community and its functional characteristics (mean and diversity of Ellenberg indices).

■ RESULTS

Assessment of the effectiveness of treatment methods in reducing the risk of fire

Mechanical mulching and, above all, controlled burning (Fig. 3) result in a reduction in the flammability of the treated samples compared with the untreated control (mainly due to the reduction in biomass and the height of the treated vegetation), regardless of return period. Mechanical mulching, however, resulted in a high rate of vegetation ignition in the year the treatment took place, as well as greater flame spread. This could be explained by a greater amount of litter and a higher vegetation density.

In the case of mechanical mowing of herbaceous vegetation, with or without crop residues, there is an overall increase in flammability, with, in particular, a higher probability of ignition, which is the opposite of the expected effect. This result is due, on the one hand, to the greater contact area with the glowing ember compared to the control vegetation, and, on the other hand, to the mown residues left in situ, which form a mat of very dry herbaceous plants conducive to fire. When the cuttings are removed, only the natural litter from the vegetation remains, which is also very dry during the summer months and therefore highly combustible (favouring the ignition and spread of fire). Furthermore, in both cases studied, the samples are much more exposed to the wind, which reduces the ignition time but increases the speed at which the flames spread, which depends heavily on the wind. Finally, the intensity of the flames is greater, as it depends not only on the quantity of available biomass (which is admittedly reduced here) but also on the speed at which the flames spread, which is much greater following treatment.

Manual mowing with a brush cutter produces cuttings whose structure is more aerated and less dense, as they are discontinuous and scattered in different directions, which does not allow for an adequate contact surface with the kindling for ignition. Consequently, this treatment results in either a significant reduction in flammability or a non-significant effect compared with the control. Overall, the quantity of biomass is reduced for the same area, and this biomass is difficult for the flames to ignite, thereby severely limiting its flammability.

Explanation of the effects of controlled

Reduction of vegetation heightburning

Controlled burning reduces the height of vegetation and therefore the height of the flame

Reduction in the amount of biomass

Less biomass available during combustion, therefore less energy released

The intensity of the flame front depends in part on the amount of biomass for flames

A beneficial effect or no effect

No flammability variables increased by the treatment

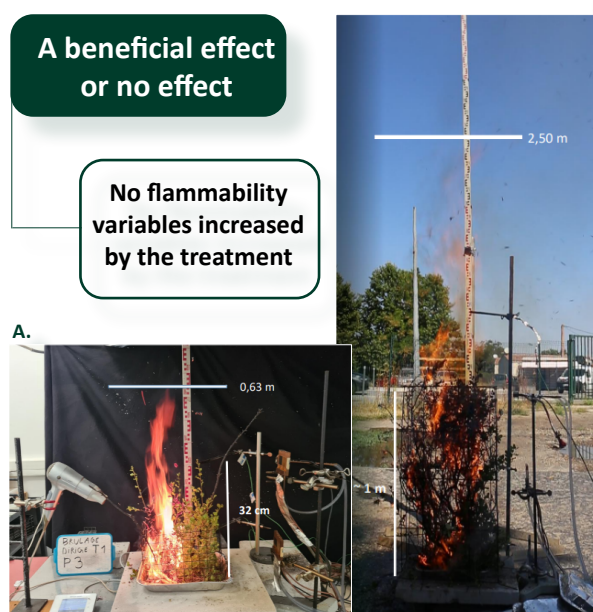


Figure 3: Comparison of flame height between vegetation treated by controlled burning (A.) and the control (B.).

Effect of treatment on plant diversity and the health of Aleppo pine stands

On average, more species were recorded in cleared areas than in control areas, but with a lot of variability between plots. In the Alpilles and on the Côte Bleue, there are about twenty species in the control areas and between 40 and 60 in the cleared areas, whereas on the Sainte-Baume, around 35 species were noted regardless of the treatment. This increase in species diversity in cleared areas comes along with greater functional richness and is due to the presence of both pioneer species and mesophilic and shade-tolerant species, while only the latter are found in control areas. The variability of the treatment effect between plots doesn't seem to be caused by the type of treatment applied, but rather linked to a 'forest massif' effect and potentially to the proximity to sources of ruderal plant seeds. We also did not observe any significant effect of the treatment on protected species (2 species with regional protection status present in cleared and control areas).

On average, the foliar deficit is 44% (similar to DSF observations in Provence) and is higher in the control area than in the cleared area (48% vs. 40%). The largest pines are the least defoliated, but for trees of the same size, the foliar deficit is greater in the cleared area than in the control area. The most defoliated pines are located on soils with a high available water capacity, which would indicate a "maladaptation" of the trees; this result has also been observed in other massifs in Provence (although it is the opposite for holm oak or Scots pine). Within a plot, the difference in foliar deficit between the cleared and control treatments is not associated with the opening of the stand induced by clearance, but is explained by the difference in available water capacity, as the control subplots generally have deeper soils with a better texture.

■ KEY LESSONS

First of all, regarding brush clearing in the forest stands, controlled burning and mechanical mulching significantly reduce the flammability of vegetation post-treatment, with the former being more effective over time.

For roadside mowing, the use of a flail mower results in an increase in flammability, with or without cutting residues, in contrast to manual trimming with a string trimmer due to the difference in residue structure.

Concerning the health condition of the tree layer, no direct effect of brush clearing on the foliar deficit of Aleppo pines could be observed. Pines in the control area are more defoliated, but probably due to better soil conditions.

In general, floristic diversity is higher in cleared areas due to the presence of pioneer species in addition to the mesophilic forest “shade” species. However, there is a significant variability between plots and between forest stands that is not yet well understood, which would need to be examined with a larger and more homogeneous sampling.

■ CONTACT

The project leader is Ms. [Anne GANTEAUME](#), Research Director at INRAe in Aix-en-Provence, within the “Mediterranean Ecosystems and Risk” team of UMR RECOVER.

For more information about the project, you can also contact Mr. [Maxime CAILLERET](#) (Research Officer) and Mr. [Arthur BOSCHET](#) (PhD Student) of UMR RECOVER.

The project was conducted with the participation of the MTDA agency and Aix Marseille University (amU).

■ FOR MORE INFORMATION

Further information is available on the [GECОВI project page](#) on the AFORCE RMT website.



References

- ¹ Ganteaume A., Boschet A., Cailleret M., 2025. Fuel management for the prevention of forest fires. State of scientific and technical knowledge, implications for WUI management. RMT Aforce, 58 p. [>>>>](#)
- ² Ganteaume A., Boschet A., Cailleret M., 2025. GECОВI project report - What type of fuel management for what type of vegetation in what type of interface. RMT AFORCE, 59 p. [>>>>](#)
- ³ Ganteaume A., Boschet A., 2025. Fuel management for fire prevention: do treatment methods effectively reduce fire risk? Mediterranean Forest. Volume XLVI, No. 2, June 2025, pp. 107-118.. [>>>>](#)
- ⁴ Boschet et al., 2024. Poster on the Evaluation of Vegetation Flammability According to Different Types of Fuel Treatment. [>>>>](#)

PROJECT FUNDERS