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Understory Clearing in Open Grazed Mediterranean Oak Forests: Assessing the Impact on Vegetation

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Abstract: Over recent years, rural abandonment and climate change have challenged grazed wooded landscapes in Mediterranean mountain regions. Fire hazard management procedures such as grazing, prescribed burning, or mechanical clearing must be adjusted to the new socioeconomic and environmental situation and according to the context and circumstances of each territory. This study contributes to adjusting vegetation management techniques in response to low grazing pressure by evaluating the combined effect of mechanical clearing and grazing on the structural and floristic dynamics of understory vegetation in the open-grazed Mediterranean oak forests of northern Portugal. To this end, three treatments were established: mechanical clearing with grazing, mechanical clearing without grazing, and grazing without clearing (the control). The floristic inventories were carried out using the point quadrat method, and the structure was evaluated using line transects. Herbaceous biomass was determined by destructive methods. This study shows that mechanical vegetation clearing effectively reduces phytovolume and, thus, fire hazards. However, for its effects to endure, it must be combined with subsequent grazing, which does not always occur. No consistent pattern was found in the floristic dynamics of the shrub-grassland mosaic (species richness and diversity) related to shrub-clearing or grazing over the short term (24 months).

Keywords: northern Portugal; short term; sheep; phytovolume; species richness; diversity

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1. Introduction

Wood pastures can assume a wide diversity of functions and configurations, from scattered trees in a pasture to compact forests whose understory and natural regeneration are heavily grazed [1]. In this sense, any woody landscape where livestock grazing coexists with woody vegetation (trees and shrubs) could be referred to as wood pasture. Plieninger et al. [2] point out three main types across Europe: pastures with cultivated trees (mainly olive, chestnut, and almond groves), pastures with sparse trees (frequently riparian trees and hedges), and open woodlands where they occur mainly as holm oak and cork oak. Wood pasture has been one of Europe's oldest land use types [3] since the Neolithic [4,5].

Wood pastures have recently received increasing scientific attention across Europe, where they occur over a large area. They also occupy large areas in the study region where the provisioning, regulating, and supporting of ecosystem services, as well as cultural services, are essential to the well-being of local communities [6]. They cover about 4.7% of European countries (EU 27), 10.8% of the Mediterranean biogeographical region, and 16.4% of Portugal, the European country among the 27 that has the most significant area covered by pasture [2].

Despite their socio-cultural and biodiversity value and economic relevance [7–9], wood pastures in Mediterranean regions have been threatened due to land-use change, including both intensification and abandonment of agriculture [10–13]. Land-use intensification is associated with simplifying a wood pasture into either pasture without trees or annual croplands, which has occurred over the last half-century as the result of the mechanization of agriculture [14,15]. Bergmeier and Roellig [16] point out that in addition to land-use intensification, some of the most critical threats to wood pastures are the decline of old trees, the lack of tree regeneration, and the encroachment of woody vegetation.

Regardless of their configuration, wood pastures result from long-term human use of natural forests and are heavily dependent on this type of management [17]. Therefore, today's challenge for conserving woody grasslands is their anthropic nature and, thus, the need for specific day-to-day management [2]. Livestock grazing is the most influential and dominant management intervention which drives [2]. However, traditional pastoralism across Mediterranean Europe, mainly in the mountain and dry areas, is disappearing [18–21]. For example, cattle prevail over sheep in extensive pastoral systems in the Pyrenees, with herds on pasture for shorter periods, lower stocking densities, and less herding activity than before [22]. In other cases, extensive pastoralism has also been partially replaced by intensive production systems, with more extended stable periods and feeding with forage and concentrates [23]. In the dry regions of southern Portugal, it is common to replace sheep with cattle and replace native breeds with more productive non-native breeds and higher stocking densities [24,25]. Thus, the main challenge to preserving wood pastures is the low number of livestock and extensive systems currently observed in these regions [26,27].

Several techniques have been proposed to manage these human-disturbance-dependent ecosystems. The combination of prescribed burning and directed grazing has been suggested as a suitable method to restore ecosystems in areas with a history of fire and grazing [22,28]. Fire is considered a cost-effective management tool to prevent the successional change of grassland toward forest [29]. Nevertheless, this technique also has significant constraints relating to the appropriate conditions for application and the risk of fire escape [30,31]. Alternatively, some authors [32–36] have proposed mechanical clearing of shrub vegetation, alone or combined with guided grazing. However, mechanical treatments usually require relatively gentle terrain and are typically expensive [37,38]. In addition, extensive livestock farming has been used to prevent shrub encroachment by subsidizing grazing in specific locations, such as firebreaks and other strategic areas, to prevent and control the further spreading of fires [39]. However, several studies show that grazing alone, with current stocking densities in the Mediterranean mountains, is not enough to prevent shrub encroachment [40,41]. Bailey et al. [42] suggested target grazing as a vegetation management tool. These authors point out that targeted grazing differs from traditional grazing in that it aims to provide defoliation or trampling to achieve specific vegetation management objectives.

Different interventions for fire-prone areas in high conservation value sites, such as those in the Natura 2000 network, have been recommended to achieve the common targets of biodiversity conservation and fire prevention [43]. Against this backdrop, and within the scope of the European project Open2preserve (https://open2preserve.eu/en/), mechanical clearing and extensive livestock grazing were applied in this study to understand how this combined technique could help to manage these kinds of wood pastures, especially with fire-hazard reduction goals and the conservation of shrub-grassland mosaic biodiversity in mind. This research aims to evaluate the combined effect of mechanical cleaning and grazing on the structural and floristic dynamics of understory vegetation in an open Mediterranean forest in northern Portugal. In this way, herbaceous biomass, vegetal cover, phytovolume, and species richness and diversity of Shannon–Wiener (H') were estimated over time.

2. Materials and Methods

2.1. Study Area

The study was undertaken in northeast Portugal (41°32′ N, 7°02′ W), on a site of community interest (SIC PT CON0043-Romeu), located at an altitude of about 500 m.a.s.l. and representative of open Mediterranean forests (Figure 1). It has a Mediterranean climate, with an average annual temperature of 14.3 °C and total annual precipitation of 508.6 mm (data for

1971–2000). The vegetation is dominated by an open mixed sclerophyllous forest of *Quercus faginea*, *Q. rotundifolia*, and *Q. suber*, with a moderately dense shrub layer comprised mainly of *Cistus ladanifer*, *Cytisus multiflorus*, and *Lavandula stoechas*. The soils are classified as Distric Leptosols derived from schists.

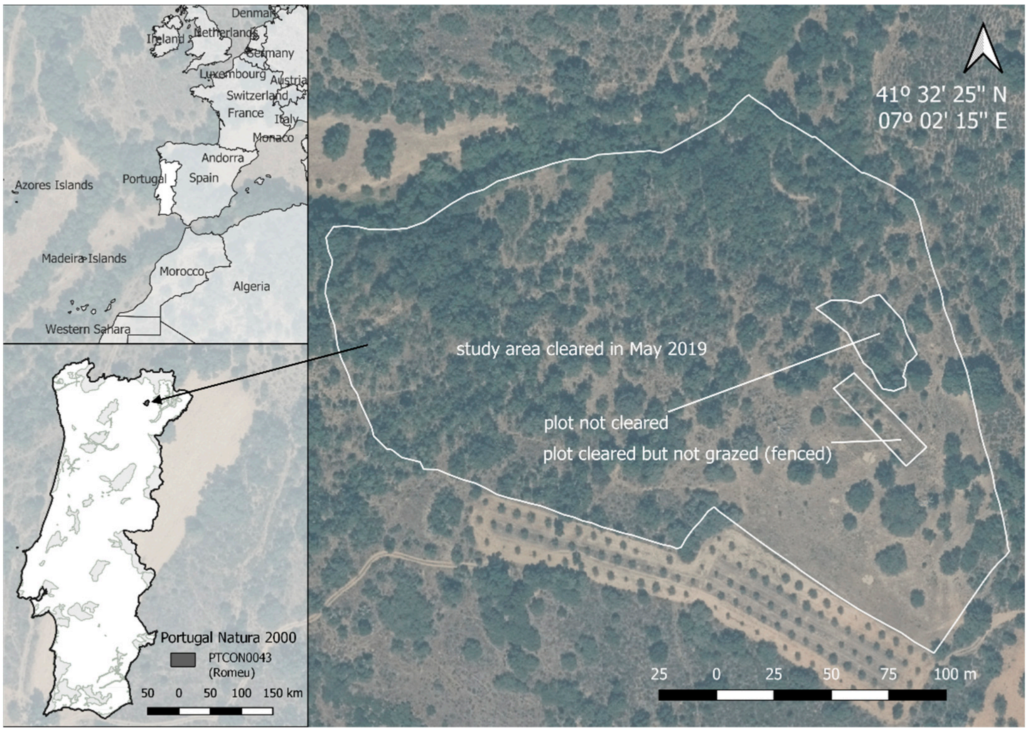

Figure 1. Aerial view of the experimental area and the Romeu site position in Portugal's Natura 2000 network (Sources: European Environment Agency and Direção Geral do Território).

The experimental area covers 43,246 m^2 whose understory shrubs were mechanically cleared in May 2019 (Clearing + Grazing), except for a 906 m^2 control plot (No Clearing + Grazing); it also includes another cleared 400 m^2 plot that was fenced to exclude grazing (Clearing + No grazing). The area was subjected to an intermittent grazing regime by a flock of 150 sheep from December 2019 to June 2021. In the first six months of monitoring, the flock was in the area for about 52 days and 88 h; in the second one, 97 days and 169 h; and in the third period (December 2020 to June 2021), 89 days and 132 h [44].

2.2. Field Sampling, Vegetation Surveys, and Data Collection

Vegetation surveys were conducted from 2019 to 2021, according to the approach followed.

2.2.1. Vegetation Structural Parameters

We used the line interception method [45] to evaluate the structural parameters of vegetation. We established four 20 m wide transects in each treatment and recorded the length occupied by each plant. In the case of herbaceous plants, no differentiation was made between them. The average height of each shrub was also recorded. Assessments were made during five periods (late spring 2019, 2020, and 2021 and winter 2019 and 2020). We estimated the plant cover by growth form (shrubs and herbaceous plants) and the phytovolume by shrub species from the data recorded above.

The herbaceous biomass was evaluated by cutting and weighing 0.25 m^2 at the end of spring 2020 and 2021. Three replicates were used in the first sampling period and five in the second.

2.2.2. Floristic Inventories

We used the point-quadrat procedure [46] to record the presence of individual plants along the four 20 m transects in each treatment. We identified and recorded all the plant species that touched a narrow pin placed vertically at 20 cm intervals. The floristic survey was carried out in May 2021 for the three treatments and in May 2019 for the control (No Clearing + Grazing). From the data recorded, we determined the species richness (total number of species in the transects—100 points per transect) and estimated the diversity through the Shannon diversity index. The floristic evaluations were performed in May 2021 for the three treatments and also in May 2019 for the control.

2.2.3. Calculus

The understory phytovolume was calculated, by shrub species, by multiplying the average height of the shrub by its canopy cover for each plant (Equation (1)); the phytovolume in each transect was obtained by summing the volumes of each plant.

$$\text{Phytovolume } (\text{m}^3\ \text{ha}^{-1}) = \%\ \text{cover } \textit{Sppi} \text{ in each interception} \times \text{height} \quad (1)$$

where the canopy cover (area below the plant that covers the soil surface) was calculated by Equation (2):

$$\%\ cover(SppA) = \left(\frac{total\ distance\ SppA}{total\ distance\ of\ line}\right) \times 100 \quad (2)$$

The Shannon–Wiener diversity index was calculated as follows:

$$H' = -\sum_{i=1}^{S} p_i \times \log_2 p_i \quad (3)$$

where S is the total number of species and p_i is the relative abundance of species i in the transect (measured as the frequency of that species in the transect divided by the summation of all the species' frequencies in that transect).

2.3. Statistical Analysis

The statistical analysis was made from an analysis of variance (two-way ANOVA—Type III SS), considering sampling date and treatments as sources of variation. The Tukey's Honestly Significant Difference Test was carried out for subsequent pairwise comparisons ($p < 0.05$) if the ANOVA was significant. Means and standard error by groups (treatment and sampling date) were calculated. The statistical software package SYSTAT 12.0.9 was used for all these analyses.

3. Results

3.1. Plant Species Composition and Diversity

Plant species richness was significantly lower in the grazed plot after clearing (CL + G, mean ± SD: $30^{B} \pm 1.96$) than in the plot cleared but not grazed (CL + NG, mean ± SD: $40.5^{A} \pm 2.90$) and grazed without being cleared (NCL + G, mean ± SD: $42.5^{A} \pm 2.10$, Figure 2). Similarly, plant species diversity (Shannon index) was also significantly lower in CL + G (mean ± SD: $2.250^{B} \pm 0.166$; Figure 2) than CL + NG (mean ± SD: $2.718^{A} \pm 0.033$) and NCL + G (mean ± SD: $2.740^{A} \pm 0.068$). In both cases, no significant differences were found between years for the untreated plot. The variation of plant species richness and diversity between treatments did not show a consistent pattern with any of the effects studied (shrub-clearing and grazing). In addition, both parameters did not differ significantly between years in the case of the plot NCL + G. The lists of species found in the floristic inventories are shown in the Table S1 (supplementary material).

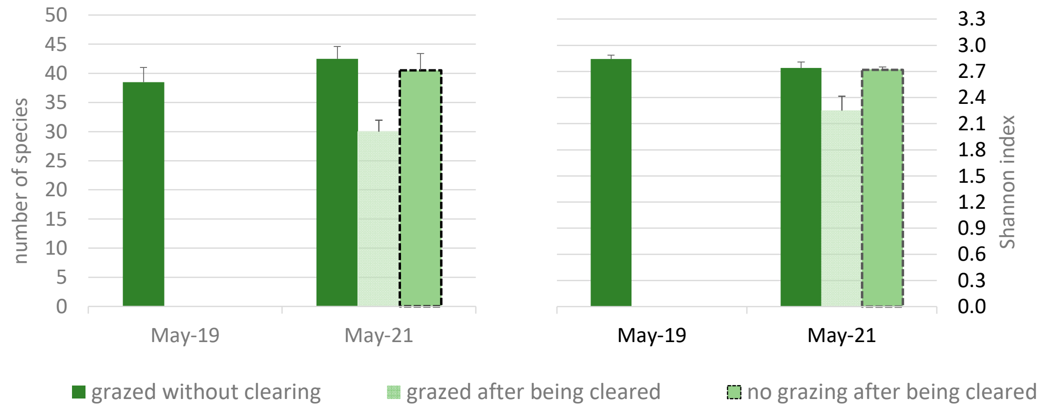

Figure 2. Species richness (**left**) and diversity (**right**) before clearing (May 2019) and after clearing (May 2021).

3.2. Structure

In general, the mechanical cutting treatment altered the vegetation structural variables, though the effects were not too persistent over time, particularly in the ungrazed plot. Herbaceous and shrub cover, and phytovolume, varied significantly between treatments ($p < 0.001$) and time since clearing ($p < 0.01$). However, no differences were found in plant cover, neither between treatments nor time since clearing, with an average value of 95.16%.

Herbaceous cover, on average, ranged from 53.71% for NCL + G and 83.90% for CL + G (Figure 3), showing a pattern of decrease over time, very noticeably in the plot treated by clearing without grazing. As expected, the percentage of shrub plant cover showed an opposite pattern, ranging on average between 39.85% for NCL + G and 9.53% for CL + G (Figure 3), being much smaller in the cleaned plots. However, 24 months after the shrub-cleared treatment, the ungrazed plot (mean ± SD: 29.94 ± 5.21%) showed a value approximately twice as high as the grazed one (mean ± SD: 14.63 ± 2.85%). In addition, it can be observed that the shrub cover evolution in the untreated plot was slow.

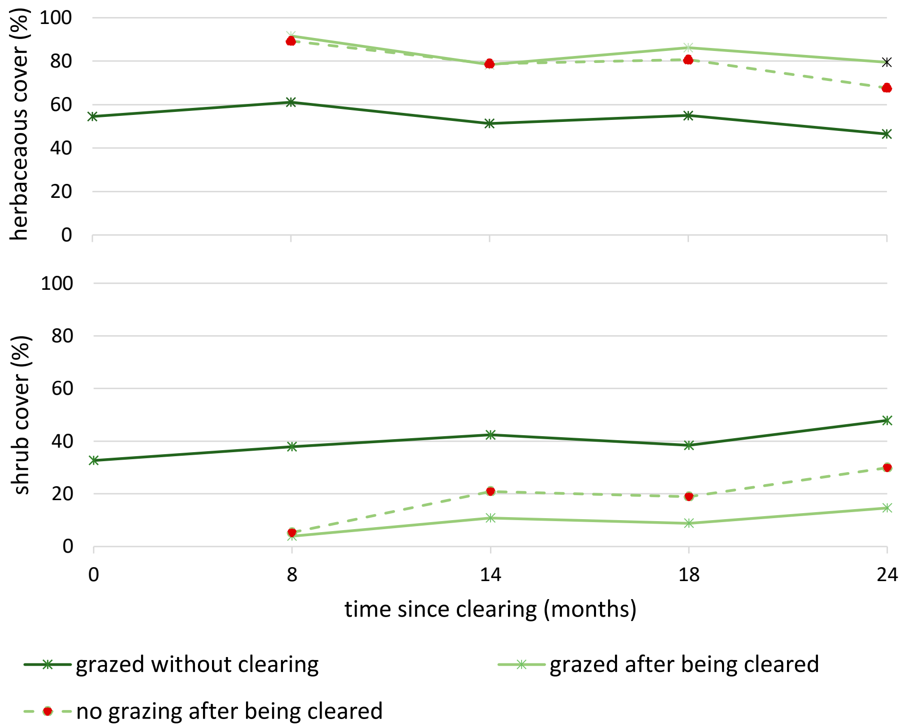

Figure 3. Development of herbaceous (**above**) and shrub (**below**) cover since the clearing in May 2019.

The understory phytovolume was the structural variable most sensitive to clearing and grazing effects. The post hoc test revealed that the means of the three treatments were significantly different, ranging on average between 280.17^{C} ± 51.06 m^3 ha^{-1} (Cl + G) and 4534.31^{A} ± 476.52 m^3 ha^{-1} (NCl + G), being much lower in the mechanical cutting plots than uncut ones. All plots showed increased phytovolume over time but at different rates (Figure 4). However, the temporal dynamics on the untreated plot were not significant. The woody plant layer of the treated plots without grazing (CL + NG) overgrew during the study period, reaching after 24 months since clearing the value of 2210.75 ± 481.92 m^3 ha^{-1}, approximately four and a half times the values of the grazed one (Cl + G).

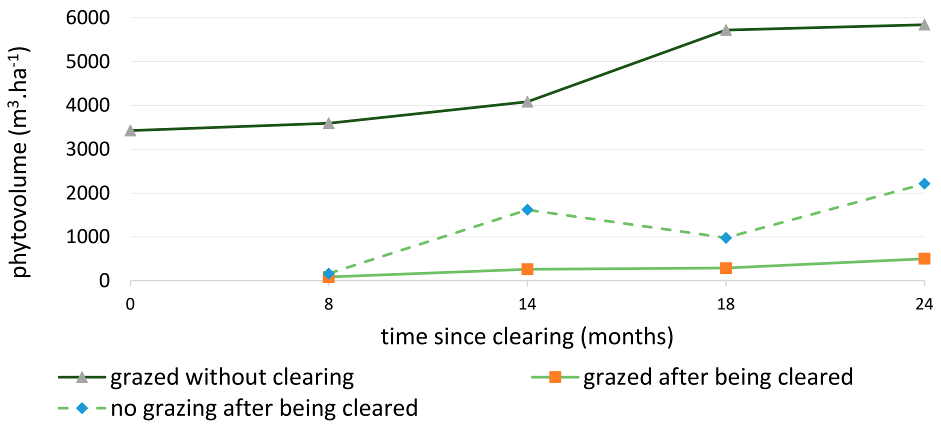

Figure 4. Development of the phytovolume since clearing in May 2019.

3.3. Herbaceous Biomass

Herbaceous biomass varied significantly between treatments and years after clearing ($p < 0.01$). One year post-clearing, significant differences were observed between cleaned (CL + G mean ± SD: 118.41^{B} ± 22.60 g m^{-2} and CL + NG mean ± SD: 94.91^{B} ± 11.62 g m^{-2}) and uncleaned plots (NCL + G mean ± SD: 234.71^{A} ± 24.12 g m^{-2}).

The herbaceous biomass increased between the first and the second year post-treatment in the plots under mechanical clearing. However, it was significantly higher in the ungrazed plot (mean ± SD: 264.10^{A} ± 10.40 g m^{-2}) in comparison with the other one (mean ± SD: 193.34^{C} ± 16.05 g m^{-2}). After two years, the plot without mechanical treatment showed a lower biomass value than the ungrazed plot (NCL + G. mean ± SD: 229.07^{B} ± 9.20 g m^{-2}). The three plots showed that biomass values significantly differed two years after shrub clearing. This suggests that mechanical clearing alone after two years does not affect the available herbaceous biomass; surprisingly, the grazed ones, even without previous treatment, have little effect on the available herbaceous biomass. The last plot showed similar values between years (mean ± SD: 234.71 ± 24.12 g m^{-2} and 229.07 ± 9.20 g m^{-2} in 2020 and 2021, respectively; Figure 5).

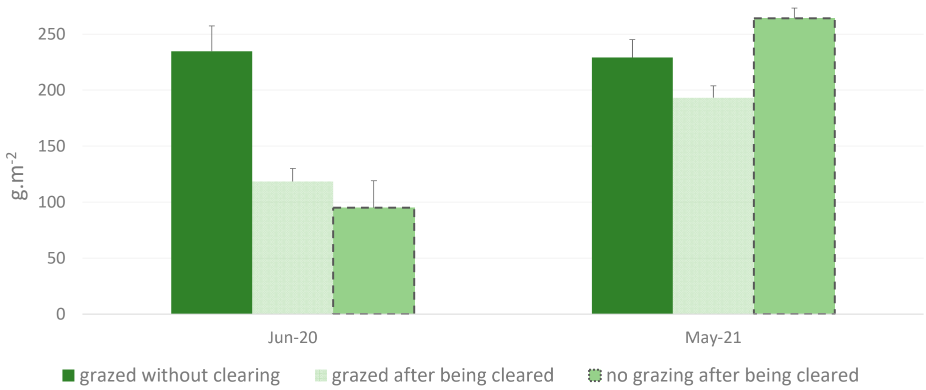

Figure 5. Evolution of herbaceous biomass over time in different treatments.

4. Discussion

This research aimed to evaluate the effectiveness of extensive grazing by sheep to control woody understory in open Mediterranean forests after mechanical clearing. In doing so, it sought to increase knowledge on better management and conservation of this landscape type, particularly concerning fire risk reduction. Twenty-four months after mechanical clearing, the results showed lower plant richness and diversity in the grazed plot than in the others that had either not been cleared or been grazed without being previously cleared. This differs from previously published research [47–51]. Furthermore, our results do not allow us to identify any direct relationship between floristic traits and grazing or clearing shrub vegetation.

Peréz-Ramos et al. [52] studied the effect of shrub clearing of cork oak forests on understory herbaceous plant diversity. They found that the different diversity components were modified by the effect of shrub clearing practices, probably due to the new abiotic conditions resulting from structural changes in the shrub layer. According to these authors, shrub clearing increases species richness (α-diversity) and decreases the spatial heterogeneity in the studied cork oak forest herbaceous composition (β-diversity). On the other hand, they found that the impact of shrub clearing on diversity components was site-specific and depended on the forest structure, having found a higher species richness in the *Open woodland* sites and only negligible effects in the *Closed forest* ones.

Several reasons could contribute to the fact that the grazed plot after clearing had fewer species than those not grazed or grazed but not previously cleared, as evidenced by authors who studied the effect of fuel reduction on vegetation recovery and diversity. Overall, they describe similar effects of prescribed burning, clearing, or mastication on the time of vegetation recovery and species richness [48]. A large number of studies [43,48,53–56] have reported an increase in species richness after fuel load treatments. This is the case of Peréz-Ramos et al. [52], who found a more pronounced effect two years later in an open cork oak forest, or Silva et al. [43], who also described this effect for at least four years after prescribed burning in shrublands in central Portugal. In contrast, Fuentes et al. [57] found a reduction in species richness and diversity only during a short period after prescribed burning.

In short, species richness is due to the balance between local extinction and colonization [58], and their relationship can be affected by site-specific abiotic conditions (moisture, shade [59]) or be modified by tree-shade, composition, and herbaceous vegetation (perennial versus annual plants), and this was not considered in this study.

The results indicated that after 24 months, the clearing treatment was effective, with a substantially lower level of phytovolume than in the non-intervention plot; this effect persisted in the grazed plots, which aligns with research based on fuel load management by mechanical clearing [32,60–64]. However, the phytovolume values achieved in the short term (24 months) show the failure of mechanical clearing if grazing is not kept up [49,65]. Biomass accumulation, a key determinant of fire hazards, was rapid following vegetation disturbance, reflecting in part the persistence of the resprouters root system and the rapid recruitment of seedlings from the seed bank [53,63].

The results also show that grazing alone, i.e., without any prior action such as mechanical clearing, does not limit phytovolume, which is in line with results found in other Mediterranean regions [40,62,65–67]. In fact, there is research that contrasts with our results, showing that livestock themselves can control shrub regrowth. However, certain specific conditions are referred to, such as high stocking densities [68] in small areas or ecosystems dominated by grass and perennial herb fuels [69], but not in extensive Mediterranean mountain areas with the current numbers of livestock [62].

The present study is consistent with previous research on herbaceous cover increasing immediately after mechanical clearing [48,56,70]. We state that mechanical clearing followed by grazing can reduce fire hazards in the short term, which has been demonstrated in similar ecosystems in northern [62] and southern Spain [33] and France [71]. The Andalusian network of grazed fuel breaks consists of mechanical clearing followed by grazing, which extends clearance intervals from 10 to 12 years [72]; this is "targeted grazing" based on biomass reduction targets [73]. In the long term, the effectiveness of this combined technique allows the fuel loading level to be kept low by biomass consumption at levels previously determined as a target. The evaluation of the effectiveness of the combined technique of mechanical cleaning with grazing over the medium term (4–6 years) is therefore of significant interest.

Future research should focus on the grazing pressure in the area so that after mechanical clearing, understory control by grazing becomes sustainable. Together with an economic evaluation of such operations, this information could provide land managers with decision-making tools on the most appropriate control of fuel biomass to achieve their goals. On the other hand, the fact that higher phytovolume situations coincide with those of higher species richness and diversity also needs to be clarified.

5. Conclusions

This study shows that mechanical cutting treatment effectively reduces phytovolume and, therefore, fire hazards, but its effect was not too persistent over time, especially when not combined with grazing. No consistency was found in the relationship of shrub mosaic vegetation dynamics (species richness and diversity) to clearing or grazing, at least in the short term (24 months). However, there seems to be a tendency for species richness and diversity to be higher in the plots with higher phytovolume in the short term, which is worth investigating. Mitigating the conflict between biodiversity conservation and fire prevention in open Mediterranean forests is central to the management of Natura 2000 sites, which requires trade-offs in deciding on appropriate fuel management measures. Further studies are also needed to define the frequency of mechanical clearing and the intensity of grazing, adjusted to vegetation development in each situation. Only in this way can the objectives of fire risk reduction be reconciled with habitat management objectives for nature conservation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su141710979/s1, Table S1: List of plant species present in the floristic inventories.

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