Characterisation of post-fire vegetation regeneration, successional patterns and underlying plant regeneration mechanisms in south-eastern Spain

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*Aus urheberrechtlichen Gründen sind die Originalarbeiten in der online-Version der Dissertation nur mit ihrem Abstract enthalten.

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1. Manuscripts included to the dissertation

(the personal contribution to the manuscripts is shown in parentheses)

I. Ohl, C., Meyn, A. & Jentsch, A. Submitted manuscript. The challenge of plant regeneration after fire in the Mediterranean Basin. Plant strategies, evolution of traits and scientific gaps. Plant ecology. VEGE 167.

- (90%: includes the development of figure 1 and table 1 and the major contribution to the literature research, ideas and writing)

II. Götzenberger, L., Ohl, C., Hensen, I., Sanchéz Gomez, P. & Wesche, K. (2003): Postfire regeneration of a thermo-Mediterranean shrubland area in south-eastern Spain. Anales de Biología. 25: 21-28.

- (40%: contribution to the field work and laboratory work, complete revision of the text and of the statistical analyses)

III. Ohl, C., Götzenberger, L., Wesche, K., Sánchez Gómez, P. & Hensen, I. Submitted manuscript. Post-fire regeneration in Mediterranean pine forest with historically low fire frequency. Acta Oecologica. AOe-05-053.

- (90%: writing, statistical analyses, ideas and major contribution to the field work and laboratory work)

IV. Buhk, C., Sánchez Gómez, P. & Hensen, I. 2005. Plant regeneration mechanisms during early post-fire succession in south-eastern Spain. Feddes Repertorium 116 (5/6). In press.

- (90%: complete field work, analyses and writing)

V. Ohl, C. & Hensen, I. Manuscript under revision. Evidence for species specific impacts of resprouters on herbal vegetation patterns during post-fire succession in south-eastern Spain. Ecologia Mediterranea. EM-120.

- (95%: Complete field work, analyses and writing)

VI. Buhk, C. & Hensen, I. 2005. Lack of hard-seeded species in pre- and post-fire seed banks in the region of Murcia (south-eastern Spain). Anales de Biología. In press.

- (95%: Complete field work, work in the green house and laboratories, analyses and writing)

VII. Ohl, C., Fothe, A. & Hensen, I. Submitted manuscript. Seed longevity of eight common plant species during early post-fire regeneration in south-eastern Spain – a three years` burial experiment. Israel Journal of Plant Sciences. 102/53.

- (90%: Complete field work, analyses and writing, major contributions to the laboratory work)

VIII. Ohl, C. & Hensen, I. Manuscript under revision. “Fire-plants” during early post-fire succession and their quantitative importance in the field: a case study from south-eastern Spain. Journal of Arid Environments. JAE04-351.

- (95%: Complete laboratory work, field work, analyses and writing)

Please note that all publications (except for the second) will finally be published under my new name: C. Buhk (valid from the end of July 2005).

2. Summary

Until recently, it was generally held that in the Mediterranean Basin post-fire vegetation composition returned directly to the pre-fire state even after recurrent disturbances by fire. This high degree of vegetation resilience was explained by the adaptation of species to frequent historical fire occurrence. In the last few years, however, the idea of strong vegetation resilience was criticised as local observations provided evidence for changes in vegetation composition after fire events which possibly result in a rise of enhanced degradation. Knowledge on the specific success of different regeneration mechanisms and their interrelation with ecological factors is essential for the understanding of the high variability of vegetation in response to ongoing changes in land-use and climate. Observations on re-colonisation of post-fire sites in the Mediterranean Basin are abundantly available, however, studies on the underlying regeneration mechanisms and adaptations to fire are usually restricted to single species only and do not characterise the totality of mechanisms found. Information on regeneration mechanisms e.g. the resprouting ability, the germination characteristics of all abundant species or the seed bank composition in a given area and the impact of their drivers help to forecast the post-fire regeneration success of the individual species. Thus, the focus of the present thesis was on the description of the natural process of secondary vegetation succession on post-fire sites in south-eastern Spain and on the study of underlying plant regeneration mechanisms including the impact of driving factors such as disturbance regime, soil and microclimate.

The research was carried out in south-eastern Spain. Five sites located in the Province of Murcia were chosen as being representative for typical, but contrasting environments in mountainous and coastal, semi-arid Mediterranean areas. The sites of “Ricote” and “Moratalla” located in a mountainous area are part of the meso-Mediterranean zone (400 mm annual precipitation, dry period 6-8 months). Vegetation types found there comprise *Pinus halepensis* forests of different density, often mixed with *Quercus coccifera* and *Stipa tenacissima*. The coastal sites of “Algarrobo”, “Portman” and “Alumbres” are characterised by a thermo-Mediterranean climate (200-300 mm annual precipitation, dry period 7-11 months) and the dominance of *Stipa tenacissima* grasslands. The bedrock of the study sites primarily consists of limestone and dolomite of Triassic origin at the coast and of Jurassic origin in the mountains. The latest fire events on the sites date back to different times: fire sites at the coast burnt between 2 and 3 years before the study was carried out whereas fire events in the mountainous area occurred 1, 2, 3, 7 and 22 years ago. To make results comparable with respect to their regeneration age, most parts of this study focus on either one or two selected sites which are described in detail in the respective chapters.

An introduction to the state of scientific knowledge on plant regeneration after fire in the Mediterranean Basin can be found in a review on this topic in reference (I). The review comprises a comprehensive collection of published data on the functioning, limitations and the abundance of different regeneration mechanisms in various regions of the Mediterranean Basin and studies on fire regimes. Moreover, gaps in our knowledge are highlighted which especially

underlines the need of comprehensive studies linking data on the composition of adaptive strategies, local environmental factors, and the recent and historical disturbance regimes.

The baseline data in the study area in Murcia was the characterisation of the different successional processes in the two climatic areas. Observations were made both in sample plots on fire sites of a known regeneration age and in adjacent unburnt plots. This approach allowed the deduction of successional patterns. Mediterranean vegetation has been frequently described to regenerate directly after fire (autosuccession). Additionally, this process is often combined with an increase in species richness during the first years after fire due to the high abundance of short-lived herbaceous plants, which benefit from elevated supply with nutrients and light. The present study confirms the process of autosuccession for the thermo-Mediterranean coastal shrubland (II) and, to some extent, for the meso-Mediterranean mountainous pine forest (III). Results of Detrended Correspondence Analyses and of analyses of similarity indices indicated that fires induce only minor changes in the species composition. At the coast and on south-facing mountainous sites, however, the expected increase in species richness after fire was not confirmed whereas north-facing mountainous slopes followed this pattern. Although the initial species composition had re-established after 2 years, vegetation cover regenerated slowly: at high, montane altitudes, for example, the regeneration of *Pinus halepensis* was low even 22 years after the fire. It is generally held that a high degree of vegetation resilience, which is expressed in terms of autosuccession, should be explained by the selective pressure of fire in historical times. However, according to existing palaeoecological data and recent fire data, the Region of Murcia did not experience substantial fire impact before the presence of man and, unlike neighbouring areas, it is not especially fire-prone today. As direct succession can nonetheless be found, the present results support the theory that autosuccession is not restricted to fire-prone areas alone. Fire was certainly only one of several factors which exert selection pressure (associated with disturbance events) since humans settled, which probably led a set of species adapted to recurrent disturbance.

On the basis of this general characterisation of the vegetation succession in the area, characteristics and success of different regeneration mechanisms (seeders, sprouters and facultative sprouters) were studied. Different post-fire sites (2-3 y after fire) and undisturbed reference sites were compared (IV). While patterns of regeneration mechanisms of recently burnt plots were very similar to the mechanisms expected for the species on the undisturbed reference sites, the relative importance of various mechanisms differed considerably between the coastal and the mountainous areas and between contrasting direction aspects. Facultative sprouters close to the coast were more abundant than in the mountains (coverage of up to 40% vs. <10%) while primarily sprouting species (up to 70%) attained the highest cover values on north-facing mountain sites. Changes in the water balance seemed to account for major differences in regeneration mechanisms. As compared to the mountain area, the saturation deficit at the coast was clearly lower during summer although average annual precipitation in the coastal area is lower than in the mountains. The high proportion of species at the coast capable of regenerating from seeds in contrast to a low abundance of seeders in the

mountains correlates with the more favourite conditions for seedling survival at the coast during the period of summer drought. The abundant resprouters (in the mountains) and facultative resprouters (at the coast) quickly recovered to their pre-fire sizes during early stages of post-fire regeneration. They therefore may have a considerable impact on the establishment and survival of other species, especially of short-lived seeders (V). Hence, the spatial distribution of herbaceous plants was mapped using a grid design with one of the following dominant resprouting species located in the centre: *Calicotome intermedia* C. Presl., *Periploca angustifolia* Labill., or *Stipa tenacissima* L. The effect of the centre plant on the number of herbaceous plants in its immediate surroundings differed between the species studied: *Calicotome intermedia* showed characteristics of a nurse plant whereas *Periploca angustifolia* had a significantly negative impact on the establishment of non-woody plants. The influence of *Stipa tenacissima* depended on the site and direction aspect and varied between a slight negative influence and a significant facilitation effect. The latter was possibly influenced by altered soil nutrient levels under the *Stipa* canopies as compared to the surrounding area. Accordingly, resprouter performance after fire is of high importance for the vegetation development of post-fire sites in south-eastern Spain.

However, apart from such effects which possibly facilitate or hamper seeder establishment, seed availability is the main factor in the success of obligate seeder species. A quick colonisation after fire depends either on effective seed dispersal from outside the disturbed site or on the presence of seeds in the local seed bank. Permanent seed banks are thought to be of high importance for the reproductive success of many obligate seeder species during early post-fire succession in the Mediterranean and are often held responsible for the vegetation's high resilience towards disturbance. In order to assess the role of seed banks in the research area, soil seed bank analyses were carried out on recently burnt sites and in long-unburnt areas in the different climatical regions (meso-Mediterranean and thermo-Mediterranean) using the seedling emergence method as well as the physical separation technique (VI). A great variability in the number of seeds was found between sites and aspects. The lowest seed numbers were found in mountain soils that contrasted sharply with the coastal sites, where very dense seed banks of > 3500 seeds/m² in the upper 2 cm of soil were present locally. Annual species such as *Asterolinum linum-stellatum* and especially species of Poaceae or Asteraceae characterised by wind-dispersal prevailed in the seed banks. The highest seed quantities were found close to strongly disturbed sites. In the mountains, soils on long-unburnt sites hardly contained any seeds, which indicates the little importance of the seed bank for the regeneration of these intact and dense forests. Considering the absence of soil seed banks, it seems reasonable to ask whether seed-longevity for the species of these long-unburnt vegetation types is limited. Therefore, the seeds of eight species which use to regenerate from seeds were subjected to a seed burial field experiment and tested for viability over a period of 30 months (VII). The study species showed very different patterns of seed persistence. Very many seeds of Cistaceae, Convolvulaceae and Fabaceae (*Cistus albidus, Cistus clusii, Fumana laevipes, Convolvulus lanuginosus* and *Calicotome intermedia*) survived at least one year of burial.Those of *Calicotome intermedia*, however, did not survive the second study year, and only 20 % of seeds of *Fumana laevipes* and *Convolvulus lanuginosus* survived 30 months of

burial. Especially the species of *Cistus* survived the burial in high numbers and should therefore be expected to build up permanent seed banks. Hard-seeded species (e.g. many Cistaceae, Fabaceae or Convolvulaceae) are frequently described to germinate immediately after fire from permanent seed banks. However, in the present study, such hard-seeded species were either sparse or absent in the local soil seed banks. Fire intervals (or those resulting from other disturbances) in the study area may exceed the longevity of seeds in the soil of these hard-seeded species. Hard-seeded species such as Cistaceae, though they are described by many authors to be dominant in the post-fire Mediterranean vegetation, are not necessarily present in the post-fire vegetation of the long-unburnt pine forests studied. As the dispersal capacity of these species is low the lack of hard-coated seeds in the seed bank suggests a limited regeneration capacity. Their re-establishment, then, probably depends on the survival or the input of a few seeds e.g. transported from recently disturbed patches in the neighbourhood or zoochorously over a larger distance.

To highlight the interrelation of seeder performance and the impact of fire, it was necessary to assess the influence of burning on the process of germination. The germination behaviour under fire impact of many obligate seeder species in the Mediterranean had been known before, detailed information on the germination characteristics of many common species in the study area, however, was lacking. Thus, germination experiments were conducted (VIII). Seeds of all abundant species were collected excluding those which predominantly recover by sprouting (assessment based on literature research or initial experimental studies). Numerous fire-related germination tests were carried out to test for the impact of smoke, charred wood or heat on germination. On the basis of these results, species that showed positive reaction to any of these treatments were classified as potential “fire seeders”. Germination of seven out of a total of 21 tested species was significantly increased by heat. Germination of eleven hard-seeded species was mainly triggered by mechanical and/or chemical scarification but none of them reacted positively to treatment with ash, charred wood, and smoke. In order to assess the importance of such “fire seeders” in the real vegetation, their cover was estimated in a plot-based sampling approach employing cover values. During early succession stages, coastal sites showed clearly less “fire seeder” coverage than sites in the mountains although the overall coverage was very low in both regions (<4%). Moreover, during mid-successional stages (7-9 years) the abundance of “fire seeders” on fire sites was compared to sites that had suffered other kinds of disturbance (logging and fire break areas) or undisturbed reference sites. Surprisingly enough, a similar cover (of about 15%) of “fire seeders” was recorded on the fire sites and in the fire breaks (unburnt strongly disturbed sites) whereas their abundance on logging and undisturbed reference sites was significantly lower. Thus, the term “fire seeder” might be misleading as fire impact is not essential for inducing germination of heat-triggered seeds. This outcome underlines the hypothesis stated in the discussion: Fire events in south-eastern Spain did not lead to specific evolutionary adaptations of plant species but to a selection towards general disturbance-tolerance which is mainly due to early human impact including repeated disturbances of various kinds.

This work contributes to the knowledge of various important aspects of post-fire succession in south-eastern Spain including details on all abundant species. Among the main questions arising from this work that need to be answered is the impact of historical fires on the evolution of plant traits. Further comparative studies between regions of high and low historical fire frequency are urgently needed to elucidate this question. Furthermore we concluded that even little climatic changes could easily alter the species composition in the area. Although strong limitations for vegetation recovery could not be found, this study shows that climatic differences between the coast and the mountains and, at a microclimatic level, between contrasting aspects have a great influence on successional processes and on the specific success of species with different regeneration mechanisms. Moreover, such climatic changes, possibly paralleled by land abandonment, may alter the frequency of fire events which, in turn, influences the specific success of plant strategies.

3. The challenge of plant regeneration after fire in the Mediterranean Basin: plant strategies, evolution of traits and scientific gaps

Abstract

Observations on re-colonisation of post-fire sites in the Mediterranean Basin are plentiful. However, there still is an ongoing debate on the interrelation of fire regimes and species traits related to fire adaptation. Most studies found are restricted to particular species or claim to present community attributes. They often lack information for the evaluation of evolutionary evidence and historical contingency of the local fire regime and other abiotic conditions, which may act as selective pressure for plant regeneration strategies. Indeed, the knowledge about the success of regeneration mechanisms and their interrelation with ecological factors is essential for the interpretation of the high spatio-temporal variability found in post-fire species performance. A crucial scientific challenge is to assess the potential of different regeneration mechanisms to cope with ongoing land-use and climate change.

We summarise knowledge about the limits and potentials of plant regeneration mechanisms after fire. Moreover, we explain positive or negative impacts of particular parameters of a fire regime on different regeneration strategies (seeders, sprouters, and facultative sprouters). Published data determining the abundance of regeneration mechanisms in various regions of the Mediterranean and information on local fire regimes is presented. Finally, we make reference to some scientific gaps which need to be filled in order to analyse species resistance and community resilience absorbing possible climate or land use changes.

4. Successional patterns

4.1. Postfire regeneration of a thermo-Mediterranean shrubland area in south-eastern Spain

Abstract

Postfire regeneration of thermo-Mediterranean shrublands burnt in 1998 was studied in the Province of Murcia (SE Spain). The vegetation structure of sites with different exposures was compared with that of adjacent unburnt areas. Three years after the fire, the mean vegetation cover of the burnt sites was still significantly lower than that of the non-burnt areas. However, the results of a Detrended Correspondence Analysis indicate that fires induce only minor changes in the species composition and the vegetation structure. Fire seems to be a common phenomenon, and the dominant species are characterized by pre-adaptations to withstand fires. The most frequent pre-adaptation is the ability to resprout rapidly from subterranean parts, whereas the regeneration from seeds is clearly less important in the most dominant species.

4.2. Post-fire regeneration in a Mediterranean pine forest with historically low fire frequency

Abstract

Species of Mediterranean vegetation are known to regenerate directly after fire. The phenomenon of autosuccession (direct regeneration) has been found to be often combined with an increase of species richness during the first years after fire due to the high abundance of short-lived herbal plants facilitated by good supply with nutrients and light. The high degree of vegetation resilience, which is expressed in terms of autosuccession, has been explained by the selective pressure of fire in historic times. According to existing palaeoecological data, however, the *Pinus halepensis* forests in the Ricote Mountains (Province of Murcia, SE Spain) did not experience substantial fire impact before the presence of man nor are they especially fire-prone today. Therefore we studied post-fire regeneration to find out if direct succession is present or if species from pre-fire vegetation are absent during post-fire regeneration at different stages. Patterns of succession were deduced from observations made in sample plots on sites of a known regeneration age as well as in unburnt adjacent areas.

The results of the vegetation analyses including a Detrended Correspondence Analysis indicate that *Pinus halepensis* forest regeneration after fire resembles autosuccession. As regards the presence of woody species, there is a high percentage of similarity (N: 83%, S: 70%) during the first year after fire vs. reference areas which is due, e.g., to direct regeneration of the resprouting *Quercus coccifera* or seeders like *Pinus halepensis* or *Fumana laevipes*. However, if herbal species are included to the comparison, the similarity on north-facing sites decreases (to 53%) with the presence of additional species, mainly ruderals like *Anagallis arvensis* or *Reseda phyteuma*, and even woody species at the burnt plots. This effect indicates “enhanced autosuccession”, which is not found on south-facing sites where overall species richness was very high irrespective of the impact of fire. Locally we found limitations for single species to regenerate directly, e.g. for *Pinus halepensis* 22 years after fire at high altitudes (1000 m).

As we assume that historical fires did not play an important role in the area and direct succession is present nevertheless, our results support the theory that autosuccession is not a process restricted to fire-prone areas. Fire was only one of several selective forces since human settlement, which probably led to a set of species pre-adapted against recurrent disturbance.

5. Regeneration mechanisms

5.1. Regeneration mechanisms during early post-fire vegetation regeneration in south-eastern Spain – a quantitative approach

Abstract

Regeneration mechanisms during vegetation succession were quantified on different post-fire sites (2-3 y after fire) in south-eastern Spain (Province of Murcia) and compared (a) to undisturbed reference sites and (b) considering different locations and aspects. While patterns of regeneration mechanisms between the recently burnt plots were very similar to the undisturbed reference sites, the quantity of mechanisms between the coastal and the mountainous areas and between northern and southern aspects differed considerably. Facultative sprouters were more abundant close to the coast than in the mountains, while mainly sprouting species covered the largest areas in north-facing mountainous sites. An altered water balance seems to be responsible for major differences in regeneration mechanisms between mountainous and coastal sites and contrasting aspects. The local prevailing fire regimes play important roles shaping the constellation of regeneration mechanisms. According to the data available to us, we do not expect reduced vegetation resilience following possible changes in the climate or disturbance regime.

5.2. Evidence for species specific impacts of resprouters on herbal vegetation patterns during post-fire succession in south-eastern Spain

Abstract

Plant interactions- be they positive or negative- are known to strongly influence successional pathways. On early post-fire sites in south-eastern Spain, resprouting shrubs and perennial grasses regenerate rapidly and may reach their original size after only the second year of succession. The present study aims to analyze if an influence of dominant resprouting species on herbal regeneration patterns exists. Therefore, we used a grid design of several subplots of a 4 m² plot with one of the following species located in the centre: *Calicotome intermedia* C. Presl., *Periploca angustifolia* Labill. or *Stipa tenacissima* L. Our results show that the effect of the canopy on the number of herbal plants is different between the species studied: *Calicotome intermedia* serves as a nurse plant, whereas *Periploca angustifolia* has a significantly negative impact on the establishment of non-woody plants, possibly due to allelopathic effects. The influence of *Stipa tenacissima* is dependent on the location and varies between a slightly negative influence and a significant facilitation effect; the influence was found to be positive at sites with enhanced soil nutrient levels under the *Stipa* canopies as compared to the surrounding area. We conclude that plant interactions are of great importance to the vegetation development of post-fire ecosystems.

5.3. Lack of hard-seeded species in pre-fire and post-fire seed banks in the region of Murcia (south-eastern Spain)

Abstract

Permanent seed banks are thought to be of essential importance for the reproductive success of many obligate seeder species during early post-fire succession. To evaluate the role of seed banks for post-fire regeneration in SE Spain, seed bank analyses were carried out on recently burnt sites and in long-unburnt areas in two climatically different regions of the province of Murcia, using the seedling emergence method as well as the physical separation technique. We found great variability in the number of seeds between sites and expositions. Lowest seed numbers were found in the mountains while locally very dense seed banks of > 3500 seeds/m² in the upper 2 cm of soil were present at the coast. Species of Poaceae, Asteraceae as well as annual species such as *Asterolinum linum stellatum* prevailed whereas hard-seeded species known to occur frequently in post-fire Mediterranean vegetation (e.g. Cistaceae, Fabaceae or Convolvulaceae) were sparse or absent in the seed bank. We conclude that the hard-seeded species are not a self-evident compound of the species composition during post-fire succession of long-unburnt sites in south-eastern Spain.

5.4. Seed longevity of eight common plant species during early post-fire regeneration in south-eastern Spain – a three years' burial experiment

Abstract

In south-eastern Spain (Province of Murcia) a seed burial field experiment was carried out over a period of 30 months to study seed longevity of eight species of plants which had formerly been found to reproduce mainly generatively during early post-fire succession. Accompanying experiments were conducted to compare the results with seed longevity of seeds stored at room temperature and to consider alterations in dormancy characteristics after the soil storage. The study species showed very different patterns of seed persistency. Seeds of the hard-seeded species *Cistus albidus, Cistus clusii, Fumana laevipes, Convolvulus lanuginosus* and *Calicotome intermedia* survived at least one year of burial in high numbers. However, those of *Calicotome intermedia* did not survive the second study year, and only 20 % percent of seeds of *Fumana laevipes* and *Convolvulus lanuginosus* outlived 30 months of burial. The number of viable seeds of the latter species as well as *Stipa tenacissima* was not significantly different between two sites under study. Longevity of seeds of *Asterolinum linum stellatum, Teucrium pseudochamaepitys* and *Stipa tenacissima* did not exceed 2 years in the soil. Seeds of all species showed better survival rates after room than after soil storage.

5.5. “Fire seeders” during early post-fire succession and their quantitative importance in south-eastern Spain

Abstract

Resilience against fire disturbance of Mediterranean vegetation has been frequently described. However, due to climatic change and abandonment of local land use practices, fire regimes change. Thus, some knowledge of the importance of fire-specific and unspecific mechanisms during regeneration is advantageous to predict changes in species resilience under an altered fire regime. In six burnt areas in a mountainous and in a coastal region in south-eastern Spain we collected information on fire-related germination characteristics (impact of smoke, charred wood or heat) of all abundant species, excluding those species predominantly recovering by sprouting, either by literature research or experimental studies. According to these results we classified species that showed positive reaction to any of the treatments as potential “fire seeders”. Germination of seven out of a total of 21 tested species was significantly increased by heat. Germination of eleven hard-seeded species was mainly triggered by mechanical and/or chemical scarification but none of them reacted positively to the treatments of ash, charred wood, and smoke.

According to a quantitative plot-based vegetation analysis we then compared the coverage of the “fire seeders” of a) 2-3 year old fire sites at the coast with sites of similar age in the mountains and b) fire sites in the mountains of mid-successional stages (7-9 years) with areas of different types of disturbance (logging and fire break area) but of comparable age and location and with undisturbed reference sites. Results of comparison a) showed that “fire seeder” coverage is below 4% and even lower in the coastal area. Comparison b) showed similar coverage (about 15%) of “fire seeders” on the fire sites and on the fire breaks (strongly disturbed sites) whereas their abundance on logging and undisturbed reference sites was significantly lower. Thus, the term “fire seeder” might be misleading as fire impact is not essential for inducing germination of heat-triggered seeds. In south-eastern Spain, the low abundance of “fire seeders and their successful regeneration on other disturbed sites are in line with historically early and strong human disturbance and low fire frequencies as the fuel load is limited due to the dry conditions. The tested species are not dependent on a certain regular fire impact though strong disturbance is very favourable to create dense populations.

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Erklärungen

Die Arbeit wurde selbstständig und ohne fremde Hilfe verfasst, andere als die von mir angegebenen Quellen und Hilfsmittel wurden nicht benutzt und die den benutzten Werken wörtlich oder inhaltlich entnommenen Stellen als solche kenntlich gemacht.

Ich hab noch keinen Doktorgrad erworben oder mich in der Vergangenheit darum bemüht.

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