Universidade de Aveiro Departamento de Biologia

2012

INÊS MARIA FERREIRA CAMARINHA

AVALIAÇÃO PÓS-FOGO DA REGENERAÇÃO FLORAL E DA COMUNIDADE DE ARTRÓPODES

POST-FIRE EVALUATION OF FLORAL REGENERATION AND ARTHROPOD COMMUNITY

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Aplicada, Ramo de Ecologia, Biodiversidade e Gestão de Ecossistemas, realizada sob a orientação científica do Professor Doutor Paulo Silveira, Professor Auxiliar do Departamento de Biologia da Universidade de Aveiro e coorientação do Doutor Nelson Abrantes, estagiário de Pós-Doutoramento do Departamento de Ambiente e CESAM da Universidade de Aveiro.

Esta Tese foi desenvolvida no âmbito do projecto:

"Factores que determinam a variabilidade da regeneração pós-fogo em Pinus pinaster e Eucalyptus globulus em Portugal: implicações para a biodiversidade e gestão pós-incêndios", financiado pela Fundação para a Ciência e a Tecnologia (PTDC/AGR-CFL/099420/2008)

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o júri

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palavras-chave fogo, regeneração, flora, artrópodes, comunidade

resumo

Devido ao aumento da incidência de incêndios em Portugal, torna-se cada vez mais urgente uma avaliação dos efeitos deste fenómeno nas florestas, estando estas entre os ecossistemas mais afetados. As florestas de eucaliptos, de pinheiros e mistas, abundantes no centro do país, apresentam características distintas, sendo fundamental um estudo comparativo destas espécies.

Este trabalho propôs-se a uma avaliação da regeneração da flora a médio prazo (5 anos após o evento), assim como da recuperação da comunidade de artrópodes, ambas componentes essenciais do meio florestal e severamente afetadas pelo fogo.

Na regeneração da flora, registaram-se diferenças entre parcelas ardidas e não ardidas. Houve diferenças significativas entre as comunidades de artrópodes de pinhais e de eucaliptais. Os índices de diversidade obtidos indicam que a recuperação da comunidade foi mais elevada em florestas de pinheiro do que em florestas de eucalipto.

A análise de redundância (RDA), demonstrou que as variáveis responsáveis pela distribuição de dados são as variáveis associadas com o horizonte orgânico do solo, nomeadamente a cobertura e profundidade da folhada, a percentagem de humidade e de matéria orgânica nesta camada.

De forma global, os resultados indicaram diferenças significativas entre os povoamentos de eucaliptos e pinheiros, incluindo ao nível da regeneração pós-fogo das comunidades, que foi mais rápida em pinhais. Em geral, as diferenças encontradas foram sempre mais significativas entre parcelas ardidas e não ardidas, do que entre os diferentes tipos de povoamentos.

keywords

Fire, regeneration, flora, arthropods.

abstract

The incidence of fire in Portugal has been rising, and with it the urgency for a complete evaluation of the effects of these phenomena in forests, which are among the most affected ecosystems. Eucalypt, pine and mixed stands – the most abundant types of forest in the centre of the country – present distinct characteristics, being fundamental a comparative study of these different stands.

This work is meant as a post-fire evaluation of the mid-term regeneration of the flora – 5 years after the event; as well as of the recovery of the arthropod community. Both these components are vital for the good functioning of a forest and are severely affected by fire.

Regarding floristic regeneration, there were significant differences between burnt and unburnt plots. For the arthropod data, there were significant differences between pine and eucalypt stands. The results obtained from diversity indexes indicate that the recovery in pine stands was higher than in eucalypt stands.

The redundancy analysis (RDA) revealed that the main variables responsible for the data variation were the ones associated with the organic horizon, namely litter depth and cover, humidity and organic matter percentage in this layer.

Globally, results indicate that there are significant differences between pine and eucalypt stands, which include differences regarding the post-fire regeneration of communities, which was faster in pine stands. Nonetheless, differences were generally more profound between burnt and unburnt plots, than between types of stand.

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Introduction

Fire is one of the most important sources of disturbance in forests, and ends up shaping the communities of these ecosystems. It balances the structure of both the floristic and faunal components of these habitats, triggering a new cycle of destruction and regeneration. In the Portuguese context, though, as its frequency has been increasing, fire is mostly a destructive force, causing more harm than good in our forests (Moreira et al. 2010). In such circumstances, preventive action may not be enough and some remedial proceedings are needed after the disturbance, requiring for that a deeper understanding of the forest natural ability to recover (Moreira et al. 2010).

Fire has great effects on forest soils and in this complex ecosystem, factors that affect one compartment will often have indirect consequences on others. As fire speeds up the mineralization of the soil and promotes erosion, and can lead to the formation of an hydrophobic layer which prevents water penetration, the effects of fire in soil quality will alter drastically the floral and faunal communities of the burnt areas (Ferreira et al. 2010b).

The expansion of the exotic species *Eucalyptus globulus*, also has a negative impact on the recovery of our forest, as this is a highly competitive species that prospers with fire. Although these forests recover faster, diversity levels in these stands will be lower as native species are not yet completely adapted to this exotic plant (Castro et al.).

The layered plant community of forests creates environmental complexity, which leads to a great diversification of animal species. As fire destroys this complexity, it alters the composition and structure of faunal communities (Moretti et al. 2004).

Plant responses to fire

Depending greatly on the characteristics of the fire, especially the severity and duration, the mortality of trees, shrubs and grasses will vary.

Concerning trees and shrubs, these might survive with a burnt or scorched canopy or stem – even though they will be extremely vulnerable and may still perish, even if not by the direct effect of the fire – as long as the core cells survive. A thick bark plays an important part in protecting the vital cells and a greater height favors the survival of the apexes where growth cell are located, as well as buds and seeds.

Roots are better protected from fire, being buried in the soil. If the fire lasts enough time, though, they might also be destroyed and the plant will die. If the thinner, more superficial roots, responsible for the capturing of water and nutrients are destroyed, the plant might also die even if the stronger support roots are undamaged (Ferreira et al. 2010a).

Regeneration of the flora after fire

Most species adapted to fire quickly recover after the event, either through vegetative or seminal regeneration. These species developed strategies to ensure progeny, even if the parent trees are destroyed.

Fire, and the damage it causes to the plants, triggers the sprouting of new plants from the canopy, stem or from basal structures, buried in the soil. Vegetative regeneration depends greatly on the intensity of the fire and survival of the buds. A mild fire might leave all these structures intact, promoting growth and expansion of the plant population. A severe fire though, might completely destroy the chances of the trees to ever recover, altering the structure of the community.

Some trees, like pines, do not present vegetative regeneration and depend on the germination of their seeds, which is sometimes also triggered by fire or the condition that follow this disturbance. Most seeds have a high tolerance to great temperatures, so that they can resist the action of the fire when grown trees cannot. Seeds that are buried in the soil, will also have higher chances of germinating later on (Ferreira et al. 2010a).

Plant regeneration will lead to a rejuvenated forest - granted that the severity of fire allows the seeds and/or buds to survive and that the frequency between fires will allow the forest to grow (Ferreira et al. 2010a) – and thus, on the landscape scale, result in a greater diversity. An old-growth forest and a new forest will often present different associated species (Jonsell 2004).

Arthropods in the forest ecosystem

Forests are complex ecosystems. As such, the interactions between the soil, the vegetation and the faunal community are plenty and form an intricate web. In this web, invertebrates, like the arthropods, play many important roles (Borror et al. 1989).

Arthropods are a very diverse group, varying greatly in size and shape and presenting a wide range of life stories and food habits. As such, they belong to several different guilds, all along the food chain. They are determinant in many processes in the forest, such as nutrient cycling, elimination of dead wood and pollination (Jeffery et al. 2010).

Arthropods inhabit all the structural levels in a forest. They live in the soil, the shrub layer and on the trees (living or dead). On the surface and litter layer, we find mostly ants, spiders, beetles and millipedes. Below the surface, mites and collembola are more common (Jeffery et al. 2010).

Spiders are all predators and their general morphology varies little; the eye arrangement, the conformation of their mouth parts and hind appendixes, the number and disposition of hairs, spines and nails are the most variable characteristics. They are easily identifiable by their four pairs of legs and non-segmented bodies. Although all spiders produce silk, not all of them spin webs to catch their prey. Many hide in holes or in strategic places in plants and ambush their prey, others might chase them actively (Wise 1995). They are highly mobile and some species are able to travel great distances by ballooning – a technique that involves spinning a sheet of web that will lift the spider and allow it to drift with the wind (Niwa and

Peck 2002). The diversity of niches they belong to allows for a wide range of responses (Abbott et al. 2003). The predacious habit of spiders means they serve an important role as pest controllers in natural habitats, feeding on insects whose growth might spiral out of control (Borror et al. 1989).

Beetles are the most diverse group of insects. They owe their name to and are recognizable by the elytra – the frontal wings, which are hardened and cover the hind membranous wings. They can be predators, xilophagic (feeds on wood), saproxylic (feeds on dead wood), detritivores or herbivores, and their food preference might change from one life stage to the other. Some ground beetles can run very fast and most still retain the ability to fly, being highly mobile (Chinery 1993). Some, like the Staphylinidae, are very agile and can bury themselves deep in the soil (Wikars and Schimmel 2001a).

Ants belong to the order Hymenoptera which, among the insects, is the second most diverse. The ant family is one of the richest and most abundant and their organized colonies, with different types of breed, expand on this diversity. They might share the general shape and colonial habit, but their food habits also vary, from hunting ants that are fierce carnivores, to herding ants who feed on the sweet juices of aphids they harvest, to farming ants who feed on fungus they grow in their tunnels (Chinery 1993).

In spite of the valuable services they provide in the ecosystem, and the weight they represent in global diversity, arthropods are still much understudied and, only recently, have been considered in forest management and planning.

Arthropods and fire

The response of the arthropod community to fire depends on several factors, related to the nature of fire, habitat condition and characteristics of the community (Moretti and Barbalat 2004).

When it comes to fire, frequency, duration, intensity and depth (amount of litter consumed by the fire) appear as the most influential (Wikars and Schimmel 2001a, b, Moretti et al. 2002, Niwa and Peck 2002, Christiansen and Lavigne 2010). The timing of the fire is also important, given that if it coincides with the most active season, the damages to the community might be worse (Abbott et al. 2003, Moretti and Barbalat 2004). It can also determine litter characteristics like depth and humidity, which can alter the intensity and heterogeneity of the fire, altering the chances of survival. If the litter is wet, the fire will be patchier and less intense, leading to higher number of survivors in the area, which may speed up the recolonization later on. If there is a high amount of litter accumulated, it works as fuel, leading to a more destructive fire. This is one of the reasons why prescribed fires might be important in some types of forest: by eliminating the excess of fuel and, being under control, these fires help prevent damages caused by a wilder and larger fire(Wikars and Schimmel 2001a, Niwa and Peck 2002, Moretti and Barbalat 2004, Moretti et al. 2006, Christiansen and Lavigne 2010).

As fire also changes the structure of the vegetation, resulting in a simplification of the habitat, it can favor some species that prefer sunnier, more open spots, and be detrimental to others, that rely on the complexity of the habitat to find refuge or to ambush their prey. The presence of rocks or chunks of dead wood, will also enhance the chances of survival to the fire (Wikars and Schimmel 2001a, Moretti et al. 2002, Niwa and Peck 2002, Moretti et al. 2006, Christiansen and Lavigne 2010).

These factors influence mostly the resistance of the community; that is, the ability to actively resist the immediate disturbance caused by the fire. The characteristics of the community, discussed in the next paragraph, play a bigger role in the resilience of the community; that is, the ability to recover to pre-disturbance levels, after the event (Niwa and Peck 2002, Moretti et al. 2006).

Mobility is a very important factor both in surviving the fire and returning to the area after the event. Highly mobile arthropods, such as spiders and staphilinids, are usually the first to recolonize a burnt area, coming from nearby unburnt patches of forest. They are also the ones who find it easier to escape fire (Wikars and Schimmel 2001a, Moretti and Barbalat 2004, Moretti et al. 2006).

Some morphological characters, like the cuticle, play a major role in resisting not only the fire, but also the dry environment that follows (Moretti et al. 2002).

Lastly, there is adaptation. In forests where fire is a frequent disturbance, it is common to find communities who respond quicker and better to fire and that might even depend on it(Wikars and Schimmel 2001a, Moretti et al. 2002, Niwa and Peck 2002, Abbott et al. 2003, Moretti and Barbalat 2004, Moretti et al. 2006). A mosaic of burnt and unburnt forest will present higher complexity than a uniform landscape, resulting in higher diversity (Abbott et al. 2003, Moretti and Barbalat 2004, Moretti et al. 2006).

Due to their specific roles and responses to fire, as well as being a significant part of the faunal community in forests, arthropod can serve as good indicators of post-fire recovery (Moretti et al. 2002).

Aim of the study

This study focuses on the effects of fire in different forest ecosystems, in Sever do Vouga, Portugal, in vegetation and arthropod communities. It is integrated in the FIREREG investigation project (PTDC/AGR-CFL/099420/2008) that aims to evaluate differences in the regeneration of eucalypt, pine and mixed forests. For this work, burnt and unburnt sites of each different type of forest stand were sampled, and soil, shrub vegetation and macro arthropod fauna were analyzed to assess their response to and ability to recover after fire.

Material and Methods

Study Area and Sites

The study sites were located in Sever do Vouga, Portugal (08°15'W - 08°20'W; 40°41' – 40°42'N). Six burnt plots were chosen from a grid, within the area that burned in 2006 (data obtained from AFN, 2006) (figure 1). Six unburnt plots were chosen in the same area, with similar characteristics to the burnt plots. Each type of stand (eucalypt, pine and mixed) is represented by two burnt plots and two unburnt. At each plot soil and arthropod samples were collected and relevant floristic variables were inventoried. The study area comprises a mosaic of resinous and deciduous forests, with cultivated areas and small populated areas

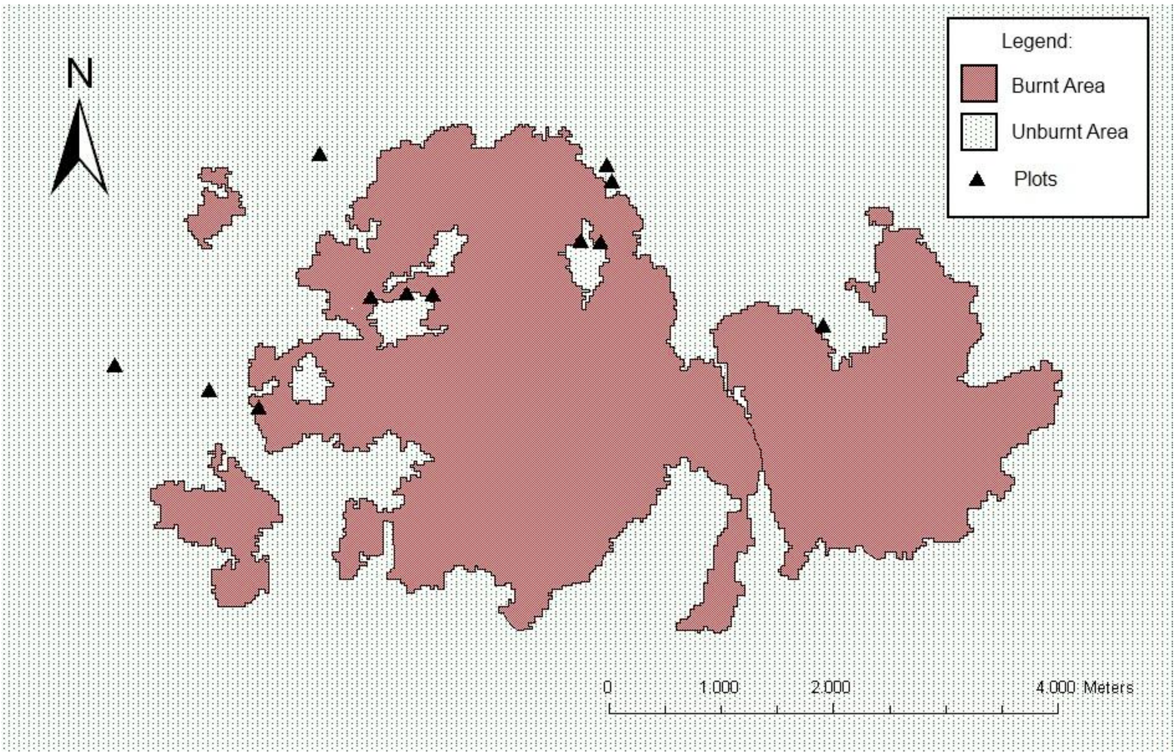

Figure 1 – area burnt in 2006, located in Sever do Vouga, with plots (triangles). Burnt area – red dotted area; unburnt area – green dotted area.

Experimental Design

To better fulfill the aim of this study, the experiment was design in two levels: to access differences between the three types of stand and the differences between burnt and unburnt plots within each type (figure 2). To evaluate these differences we analyzed the soil, vegetation and arthropod components separately first, and only then we proceeded to analyze all of the collected variables.

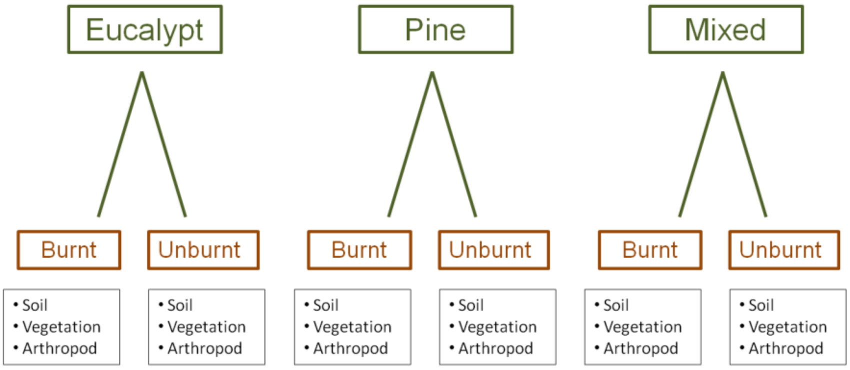

Figure 2 – experimental design.

Sampling and processing

Soil

At each plot, six soil samples were collected, three from the O horizon (Oh) (composed of the litter, fragmented and humus layer) and three from A horizon (Ah) (the first inorganic horizon). At each sampling spot, the depth of the litter layer was measured. The samples were kept in labeled plastic bags and transported to the lab and air-dried for two weeks. The soil samples were grinded and sieved to 2mm fraction. Humidity was measured by oven-drying 2 g of soil, at 105ºC, for 24 hours (D2974 1987). Organic matter content was measured by soil ignition, burning in a muffle furnace for 4 hours, at 550ºC. To measure soil and litter pH, 5g of soil or litter were added to 25 mL of a calcium chloride solution, mixed in an end-to-end shaker for 5 minutes and left to rest for 2 hours. The ph was then measured with a pH-meter, previously calibrated (ISO10390 2005).

Vegetation

At each plot, the inventory was conducted in 4 smaller sub-plots and the following variables were recorded: five categories of soil cover (rocky outcrops (RO); large stones (LS); woody debris (WD); litterfall (LF) and bare soil (BS)); shrub species, respective cover and average shrub height. The collected variables reflect the complexity of the environment on the ground level, which is given to be an influential factor on the composition of the arthropod community (Christiansen and Lavigne 2010).

Arthropods

Five pitfall traps were assembled, in each plot These traps are effective at accessing activity and relative abundance of ground invertebrates (Niwa and Peck 2002, Underwood and Quinn 2010). Each trap consisted of a plastic container, 10 centimeters deep, (diameter), buried in the soil and covered with a large rock or leafs to minimize rain and litterfall, leaving way for the arthropods to “walk” into the trap. Each trap was half-filled with a 1:1 mixture of water and 70% ethanol. The traps were assembled following a pentagon design, spacing 5 meters from the center and roughly 5 meters from each other. The traps were collected one week later and the samples kept in lidded containers with 70% ethanol until sorting and identification.

The samples were sorted using a stereoscope; litter and ground-dwelling arthropods were separated by class and order. Only ground-dwelling arthropods were considered.

The arthropods were identified using identification keys and guides (Barrientos 1988, Chinery 1993) to the family or the smallest *taxon* possible.

Data Analysis

All data was analyzed using the statistics software R studio (R Core Team 2012). ADONIS is a non-parametric multivariate analysis of variance, that uses permutations and distance matrices and is considered a robust analysis for ecological data (Legendre and Anderson 1999). It was used throughout this study for hypothesis testing (R Core Team, 2012, package "vegan"). After the analysis of each separate section, a redundancy analysis (RDA) (R Core Team, 2012; package "vegan") was performed using selected data from each part.

Soil

For a preliminary analysis, a scatter-plot matrix was calculated in R. Normality was tested using the Shapiro-Wilks test. As two variables proved to have a normal distribution, a non-parametric test was used for significant differences (ADONIS (R Core Team, 2012; package "vegan")). A principal components analysis (PCA) was conducted to represent the underlying structure of the dataset.

Vegetation

A dissimilarity matrix, using the Euclidean distance, was calculated from the inventory data, after it was log-transformed. With this matrix, an MDS analysis was performed and the respective plot was constructed. Each variable was tested separately for normality using the Shapiro-Wilks test. An ADONIS analysis followed, to check for significant differences between the types of stand and between burnt and unburnt plots within each type. Finally, a principal components analysis (PCA) was performed and the respective biplot constructed.

Arthropods

For the community structure and diversity, the following indexes were calculated: Shannon's diversity (H') (Shannon 2001), Pielou's evenness (J') (Pielou 1966) and Fisher's alpha (α) (Fisher et al. 1943). The first and last both measure species diversity, Shannon's index being the standard in ecology and Fisher's alpha being especially suited for the data assembled in this study, as it is well adapted to communities containing many species with little abundance and a few with a significant larger abundance, as is the case with our data (Fisher et al. 1943). The indexes were calculated with the following formulae:

Shannon's Diversity Index

$$H' = -\sum_{i=1}^{R} pi \log pi$$

H': Shannon's Diversity Index;
p_i: proportion of each family in the data set
R: total number of families

Pielou's evenness index

$$J' = H' / H'_{max}$$

J': Pielou's evenness index;
H': Shannon's diversity index;
H'_{max}: Maximum value H can achieve for the given community

Fisher's diversity index

$$S = \alpha * \ln(1+n/\alpha)$$

S: Sample richness
α: Fisher's alpha;

Relative abundance was also calculated for each taxon. Taxa representing more than 10% of relative abundance, were considered dominant (Mühlenberg, 1993, through Moretti et al., 2006).

A Bray-Curtis dissimilarity matrix was constructed and an MDS analysis performed. The respective ordination plot was constructed.

The ADONIS test was also performed to check for significant differences between sites using both the complete data matrix and the index calculated (as well as the total number of individuals per plot (N) and the total number of families per plot (S)).

Results

Soil

The scatter-plot referring to the soil variables showed a linear correlation between humidity and organic matter for both the O and A horizon, the correlation within the organic horizon being higher (0,83; bold square in figure 3). Other correlations were not as strong (figure 3). The Shapiro-wilk test performed revealed that only the pH, in both horizons, showed a normal distribution. The ADONIS analysis showed that only between burnt and unburnt plots of all types, could significant differences be found (p = 0,046; bold type in table 1). The complete results from this analysis can be found in table 1.

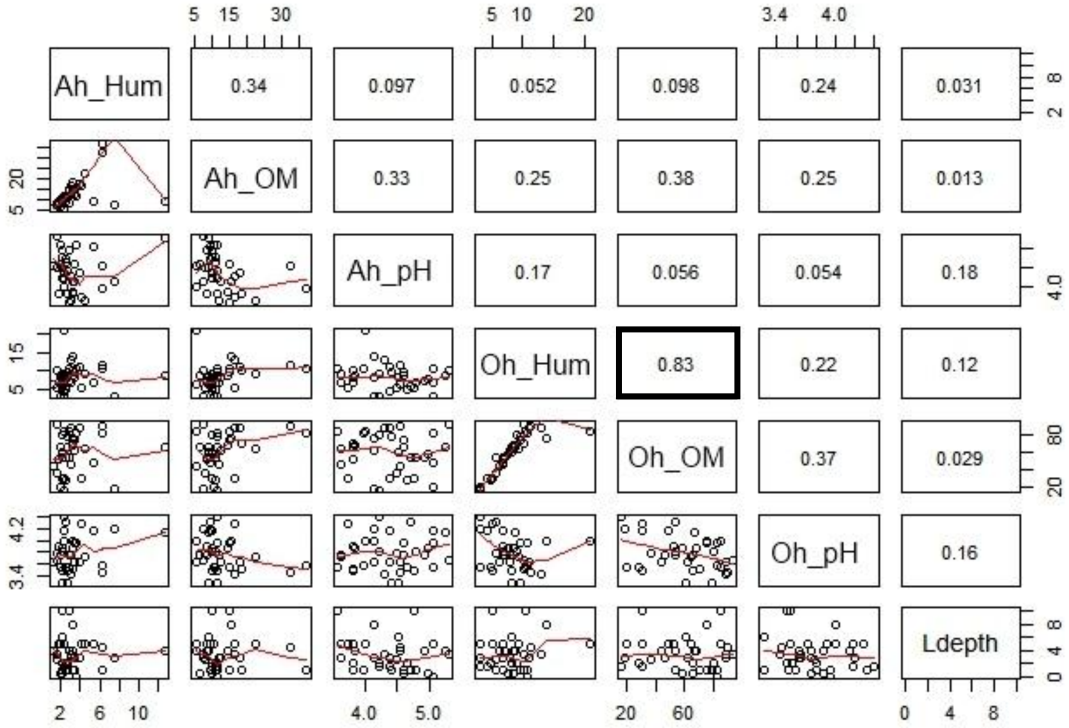

Figure 3 – Correlation matrix for soil data, burnt and unburnt plots, calculated with Pearson's coefficient. Lower pannels show scatter-plot and trend line and upper pannels display the correlation value. The diagonal pannels indicate the variables: Ah_Hum – A horizon humidity; Ah_OM – A horizon organic matter content; Ah_pH – A horizon pH; Oh_Hum – O horizon humidity; Oh_OM – O horizon organic content; Oh_pH – O horizon pH; Ldepth – litter depth.

TABLE 1 - ADONIS results for soil data (P < 0.05). Ec: Eucalypt plots; Pn: pine plots; Mx: mixed plots; B: burnt plots; U: unburnt plots.

		Df	SS	MS	F.Model	R2	Pr(>F)
Ec	*B vs U*	1	0,02748	0,027478	0,94761	0,08656	0,367
	Residuals	10	0,28997	0,028997		0,91344	
	Total	11	0,31745			1,00000	
Pn	*B vs U*	1	0,09769	0,09769	23704	0,19162	0,119
	Residuals	10	0,41213	0,041213		0,80838	
	Total	11	0,50982			1	
Mx	*B vs U*	1	0,027552	0,027552	0,99093	0,09016	0,333
	Residuals	10	0,278047	0,027805		0,90984	
	Total	11	0,305599			1	
Ec vs Pn		1	644	643,96	1,0407	0,04517	0,334
	Residuals	22	13613	618,79		0,95483	
	Total	23	14257			1	
Ec vs Mx		1	78	77,96	0,14849	0,0067	0,793
	Residuals	22	11550	525		0,9933	
	Total	23	11628			1	
Mx vs Pn		1	406,4	406,4	0,68118	0,03003	0,459
	Residuals	22	13125,5	596,62		0,96997	
	Total	23	13531,9			1	
Ec vs Mx vs Pn	*Type*	2	752,2	376,11	0,672	0,03781	0,256
	B vs U	1	2182,8	2182,81	38998	0,10971	**0,046 ***
	Type : B vs U	2	170	85,01	0,1519	0,00855	0,916
	Residuals	30	16791,6	559,72		0,84394	
	Total	35	19896,6			1	

The biplot for the PCA performed with the soil variables showed that A horizon's humidity, O horizon's organic matter and humidity explain most of the data variation, the latter along the PC1 axis (explains 33,70% of data variation) and the first two along the PC2 axis, although in different directions (explains 21,11% of variation). There are not clear patterns in the distribution of the samples, although a gradient from burnt to unburnt appears to form from left to right (figure 4).

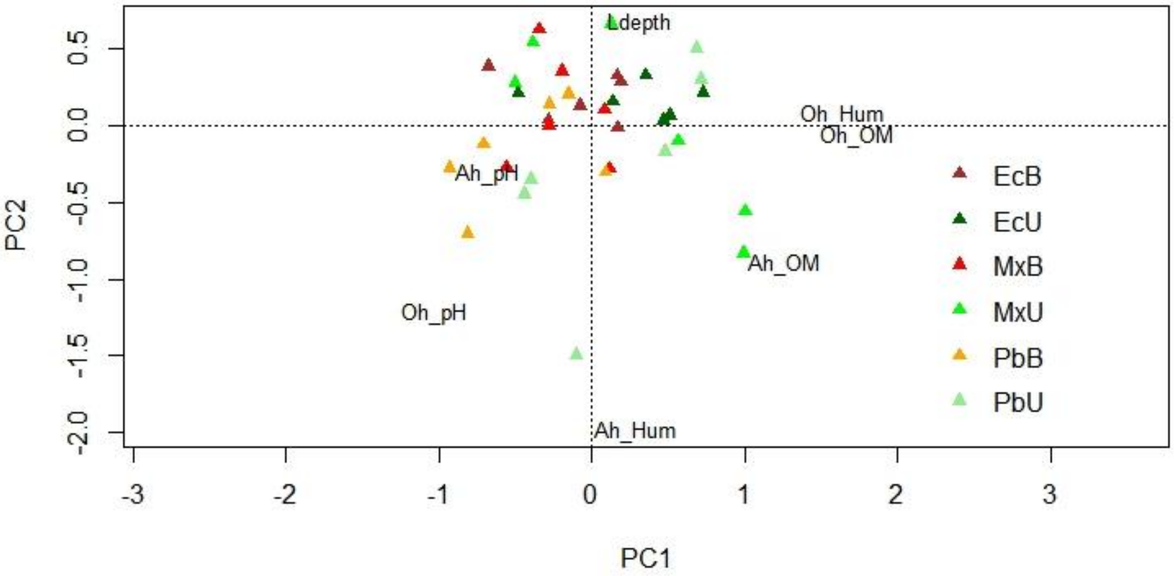

Figure 4 – biplot for the PCA analysis of the soil variables. Variables: Ah_Hum – A horizon humidity; Ah_OM – A horizon organic matter content; Ah_pH – A horizon pH; Oh_Hum – O horizon humidity; Oh_OM – O horizon organic content; Oh_pH – O horizon pH; Ldepth – litter depth. Legend: EcB – burnt eucalypt plots; EcU – unburnt eucalypt plots; MxB – burnt mixed plots; MxU – unburnt mixed plots; PnB – burnt pine plots; PnU – unburnt pine plots.

Vegetation

In total, 16 shrub species were found, belonging to 7 different familes. Fabaceae and Ericaceae were the two most common families (17,14% and 8,87% of total average cover, respectively). These were also the most diverse families with 6 and 5 of the total species number belonging to Ericacea and Fabacea, respectively. The two most common species also belong to each of these two families: *Pterospartum tridentatum* (Fabaceae; 18,42%) and *Calluna vulgaris* (Ericaceae; 7,81%). These were also the only two species found at every plot; they were especially common in mixed burnt plots (49,06% and 28,44%, respectively). Both species were generally more common in burnt plots. With the exception of *Erica umbellata,* which was only found in burnt plots, there were not other discernible patters on species composition, either between burnt and burnt plots, or between types of stand (table 2).

THE AVERAGE NUMBER OF SHRUB SPECIES WAS HIGHER IN BURNT PLOTS, FOR ALL TYPES OF STAND, WHILE AVERAGE SHRUB COVER WAS HIGHER ONLY IN BURNT EUCALYPT AND MIXED PLOTS, WITH THE AVERAGE COVER BEING QUITE SIMILAR IN BOTH BURNT AND UNBURNT PINE STANDS. THE AVERAGE SHRUB HEIGHT WAS HIGHER IN BURNT PINE AND EUCALYPT PLOTS, BUT NOT IN MIXED STANDS (FIGURE 5).

TABLE 2 – Average cover (%) of shrub families and species.

	Eucalypt		**Mixed**		**Pine**		
	Burnt	**Unburnt**	**Burnt**	**Unburnt**	**Burnt**	**Unburnt**	**TOTAL**
Araliaceae	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**1,25**	**0,21**
Hedera sp	0,00	0,00	0,00	0,00	0,00	1,25	0,21
Cistaceae	**0,00**	**0,00**	**3,33**	**0,00**	**0,00**	**0,00**	**0,56**
Cistus psilosepalus	0,00	0,00	3,33	0,00	0,00	0,00	0,56
Ericaceae	**11,19**	**2,50**	**18,47**	**2,50**	**5,25**	**13,33**	**8,87**
Calluna vulgaris	7,50	2,50	28,44	1,25	5,94	1,25	7,81
Erica arborea	12,50	1,25	1,25	1,25	0,00	18,75	5,83
Erica australis	0,00	0,00	0,00	0,00	0,00	1,25	0,21
Erica ciliaris	0,00	0,00	0,00	0,00	1,25	0,00	0,21
Erica cinerea	2,50	2,50	4,69	1,25	0,00	0,00	1,82
Erica umbellata	3,13	0,00	15,00	0,00	1,25	0,00	3,23
Fabaceae	**12,15**	**4,17**	**27,19**	**15,52**	**31,00**	**12,81**	**17,14**
Acacia melanoxylon	1,25	0,00	0,00	0,00	1,25	0,00	0,42
Genista triacanthos	0,00	0,00	3,96	0,00	0,00	0,00	0,66
Pterospartum tridentatum	4,69	1,25	49,06	12,71	31,25	11,56	18,42
Ulex micranthus	16,56	0,00	0,00	0,00	0,00	0,00	2,76
Ulex minor	5,00	4,58	0,00	15,00	0,00	1,25	4,31
Lauraceae	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**1,25**	**0,21**
Laurus nobilis	0,00	0,00	0,00	0,00	0,00	1,25	0,21
Rhamnaceae	**0,00**	**2,50**	**0,00**	**1,25**	**0,00**	**0,00**	**0,63**
Frangula alnus	0,00	2,50	0,00	1,25	0,00	0,00	0,63
Rosaceae	**0,00**	**0,00**	**0,00**	**1,25**	**1,25**	**1,25**	**0,63**
Rubus ulmifolius	0,00	0,00	0,00	1,25	1,25	1,25	0,63

The ordination analysis showed a clear separation between burnt and unburnt plots for all types of stand. It's also noticeable a separation within each type of stand of two smaller groups especially in the burnt eucalypt stands, burnt pine stands and unburnt mixed stands (figure 6).

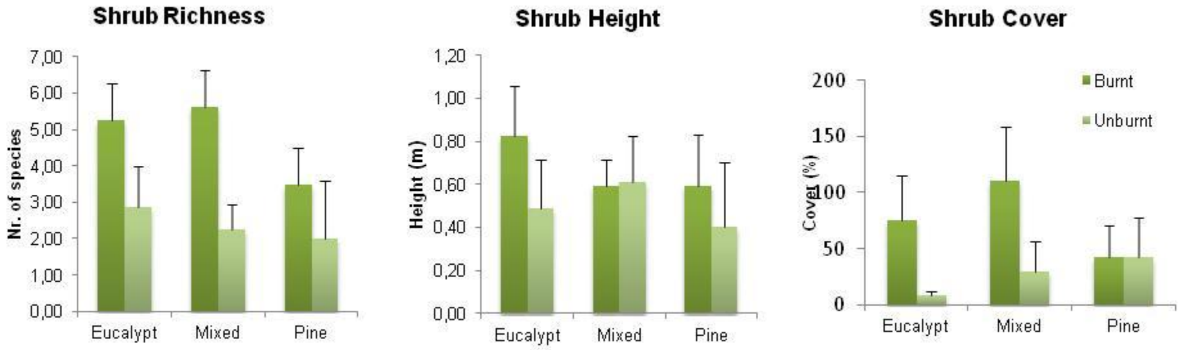

Figure 5 – shrub vegetation richness (number of species), height (m) and cover (%), average per type, with standard deviation. Darker bars stand for burnt plots, lighter bars for unburnt plots.

We followed with a non-parametrical analysis of variances (ADONIS), that showed significant differences between burnt and unburnt plots ($p < 0{,}01$), these being highly significant ($p < 0{,}001$) between burnt and unburnt eucalypt and mixed stands and significant ($p < 0{,}05$) between burnt and unburnt pine stands. There were highly significant differences between all three types when tested together, although when we tested each pair no significant differences were found (table 3).

The PCA showed that shrub and litterfall cover are the variables with higher values on component 1 axis (35,82% of variance), although in different directions. Bare soil cover is the variable with higher variability in component 2 (19,73% of variance), although it shows rather less variation than the other two variables. Two clear groups form in this analysis: one consisting of mixed and eucalypt burnt plots; on the other mixed unburnt

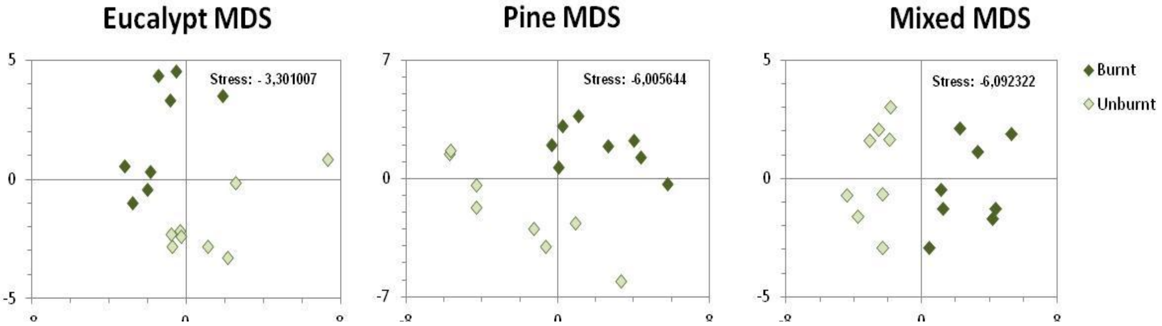

Figure 6 – plotted mds results for each type of stand. Dark green symbols were used for burnt plots; light green symbols for unburnt plots.

plots and both unburnt and burnt pine plots. Eucalypt unburnt plots are split between the two groups (figure 7).

TABLE 3 - ADONIS results for the vegetation data. data (P < 0.05). Ec: Eucalypt plots; Pn: pine plots; Mx: mixed plots; B: burnt plots; U: unburnt plots.

		Df	SS	MS	F.Model	R2	Pr(>F)
Ec	*B vs U*	1	19932	19931,7	10,06	0,41813	**6e-04*** **
	Residuals	14	27737	1981,2		0,58187	
	Total	15	47669			1,00000	
Pn	*B vs U*	1	8881	8881	4,6212	0,24817	**0,0297***
	Residuals	14	26905	1921,8		0,75183	
	Total	15	35786			1	
Mx	*B vs U*	1	48306	48306	24.52	0,63655	**2e-04*** **
	Residuals	14	27580	1970		0,36345	
	Total	15	75886			1	
Ec vs Pn		1	6745	6744,5	2,4245	0,07477	0,0792
	Residuals	30	83455	2781,8		0,92523	
	Total	31	90199			1	
Ec vs Mx		1	11029	11029,4	2,678	0,08195	0,0803
	Residuals	30	123555	4118,5		0,91805	
	Total	31	134584			1	
Mx vs Pn		1	8740	8739,9	2,3479	0,07258	0,1108
	Residuals	30	111672	3722,4		0,92742	
	Total	31	120412			1	
Ec vs Mx vs Pn	*Type*	2	30755	15377,6	7,014	0,17374	**0,0003*** **
	B vs U	1	13159	13159,4	6,0022	0,07434	**0,0048** **
	Type : B vs U	2	41020	20509,9	9,3549	0,23173	**0,0001*** **
	Residuals	42	92082	2192,4		0,52019	
	Total	47	177017			1	

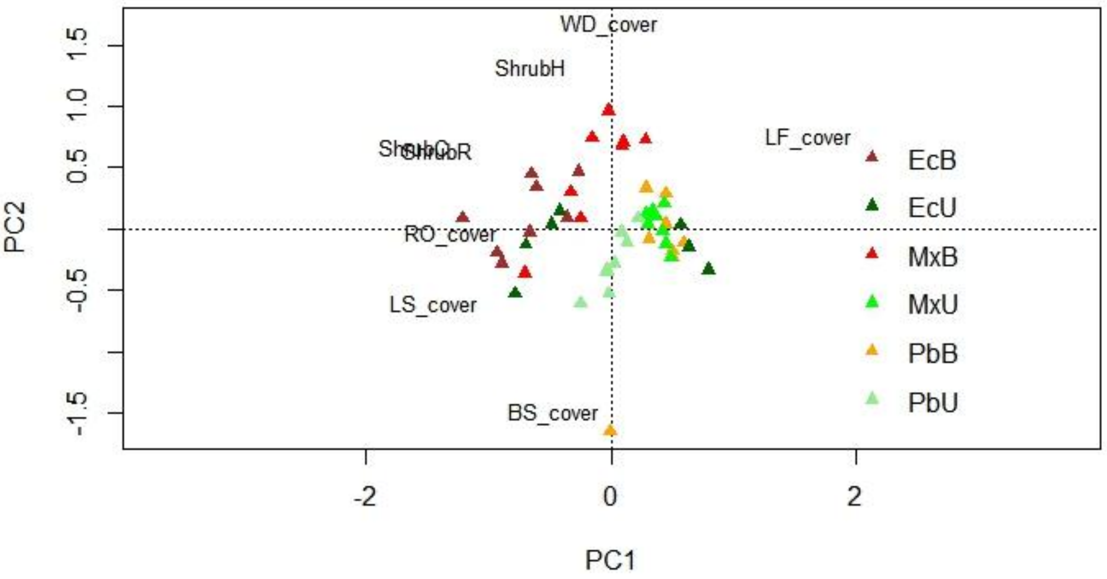

Figure 7 – PCA biplot for the vegetation data. ShrubR – shrub richness; ShrubH – hrub height; ShrubC – shrub cover; RO_cover – cover of rocky outcrops; LS_cover – large stones cover; WD_cover – woody debris cover; LF_cover – litterfall cover; BS_cover – bare soil cover. Legend: EcB – burnt eucalypt plots; EcU – unburnt eucalypt plots; MxB – burnt mixed plots; MxU – unburnt mixed plots; PnB – burnt pine plots; PnU – unburnt pine plots.

Arthropods

The average number of individuals and average richness showed diverging tendencies: number of individuals was higher in burnt plots, with exception of eucalypt stands where the unburnt plots showed higher number of individuals; richness was higher in unburnt plots, except for the unburnt mixed plots where it was slightly lower both richness and number of individuals were higher in pine stands than in mixed or eucalypt stands (figure 8).

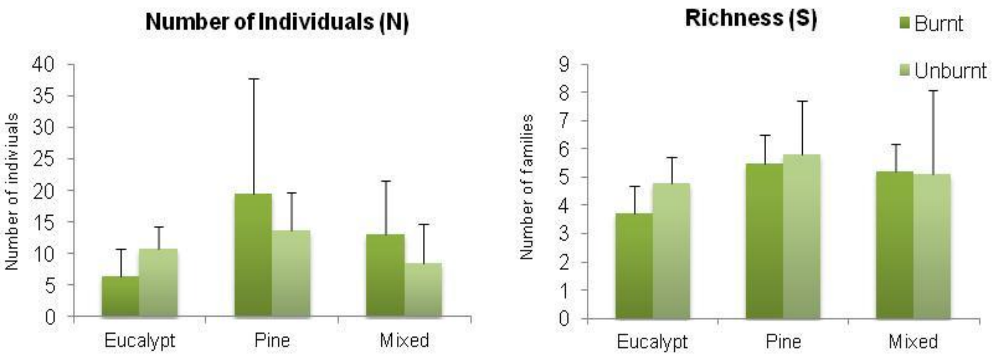

Figure 8 – Average number of individuals and families (richness). Error bars represent standard deviation. Darker bars stand for burnt plots, lighter ones stand for unburnt plots.

Insects and arachnids were the most dominant classes, representing 69,63% and 21,64% of all data, respectively. This dominance was constant in every type of stand, burnt and unburnt. Insect dominance was lowest in in mixed unburnt plots (61,90%) and highest in unburnt eucalypt plots(74,77%); spider dominance was lowest in burnt mixed plots (15,27%) and highest in unburnt pine plots (32,12%). Diplopods were the third most dominant class, with highest relative abundance in mixed plots (burnt and unburnt) and in unburnt pine plots.

Within the arachnid class, only two families (Agelenidae and Disderidae) and one order (Acari) proved to be dominant and only in one type of stand each (unburnt eucalypt; burnt eucalypt and unburnt pine plots, respectively.

Among insects, the most dominant families were the Staphilinidae (order Coleoptera) and ants (Formicidae; order Hymenoptera). The first represented 18,17% of specimens collected and were most abundant in burnt eucalypt stands (32,31%) and less common in burnt pine plots (4,06%). Ants represented 17,06% of collected data and were most dominant in burnt pine plots (30,46%) and less so in unburnt pine plots (2,19%). The superfamily Entomobroydea (order Collembola) were the third most dominant taxa within the insects, comprising 12,76% of collected specimens and showed higher abundance values in eucalypt plots (burnt and unburnt) and in burnt mixed plots (table 4).

For eucalypt stands, Pielou's evenness index (J') and Fisher's diversity index (α) were higher in burnt plots, while Shannon's diversity index (H') was higher in unburnt plots. In mixed stands, the trend was opposite with H' presenting higher values in burnt plots, while both J' and a showed higher values in unburnt plots. Pine stands showed higher values for H' and J' in unburnt plots, but higher a in burnt plots. J' showed the least variation, with its lowest value being for burnt pine stands (0,83); while (a) presented a widest range of values from 5,98 in burnt plots to 3,81 in unburnt eucalypt plots. Generally the data vary greatly, not being discernible a clear trend when comparing types of stand (table 5).

Table 4 – Relative abundance (%) for each taxa collected and identified, for each type of stand, burnt and unburnt.Numbers in bold denote dominant taxa (≥10%).

TAXA		**TYPE OF STAND**						
	Family (or Superfamily)	**Eucalypt**		**Mixed**		**Pine**		
Class: Order		**Burnt**	**Unburnt**	**Burnt**	**Unburnt**	**Burnt**	**Unburnt**	**TOTAL**
Class Arachnida:		**21,54**	**22,43**	**15,27**	**25,00**	**16,75**	**32,12**	**21,64**
Acari		1,54	0,00	4,58	3,57	2,54	**18,25**	5,55
Aranea	Agelenidae	0,00	**13,08**	0,00	8,33	0,00	3,65	3,61
	Anyphaenidae	3,08	0,00	4,58	0,00	3,05	0,00	1,94
	Araneidae	1,54	0,00	0,00	0,00	0,51	0,73	0,42
	Atypidae	0,00	0,00	0,00	0,00	0,00	0,73	0,14
	Dipluridae	1,54	0,93	0,00	1,19	1,02	0,00	0,69
	Dysderidae	**10,77**	0,00	1,53	4,76	1,52	0,73	2,36
	Linyphiidae	1,54	4,67	0,76	2,38	0,00	5,11	2,22
	Lycosidae	0,00	0,00	0,76	1,19	5,58	0,00	1,80
	Mimetidae	0,00	0,00	0,00	0,00	0,51	0,00	0,14
	Nesticidae	0,00	0,00	0,00	1,19	0,00	0,00	0,14
	Oxyopidae	1,54	0,00	2,29	0,00	0,51	0,00	0,69
	Zoridae	0,00	0,00	0,00	0,00	0,00	0,73	0,14
Opiliones	Nemastomatidae	0,00	0,93	0,00	1,19	0,00	0,00	0,28
	Phalangiidae	0,00	0,00	0,76	1,19	1,02	1,46	0,83
Pseudoscorpionida	Neobisiidae	0,00	2,80	0,00	0,00	0,51	0,73	0,69
Class Chilopoda:								
Lithobiomorpha	Lithobiidae	3,08	0,00	0,00	0,00	0,00	0,00	0,28
Class Diplopoda:		3,08	2,80	**12,98**	**13,10**	**11,17**	2,92	8,18
Chordeumatida		3,08	2,80	**12,21**	**13,10**	**11,17**	2,92	8,04
Polyxenida		0,00	0,00	0,76	0,00	0,00	0,00	0,14
Class Insecta		**70,77**	**74,77**	**71,76**	**61,90**	**71,57**	**64,96**	**69,63**
Coleoptera	Bostrichidae	0,00	0,00	0,76	3,57	**28,43**	0,00	8,32
	Carabidae	0,00	0,93	0,00	1,19	0,51	0,73	0,55
	Chrysomelidae	0,00	0,00	0,00	1,19	2,03	0,00	0,69
	Cicadelidae	0,00	0,00	0,00	0,00	0,51	0,00	0,14
	Cicindelidae	0,00	1,87	9,16	0,00	0,00	**20,44**	5,83
	Cucojoidea	0,00	0,00	0,00	3,57	0,00	0,00	0,42
	Curcolionidae	0,00	0,93	0,00	0,00	0,00	0,73	0,28
	Curcolionidae (larva)	0,00	0,00	0,00	1,19	0,00	0,00	0,14
	Eucinetidae	0,00	0,00	0,76	0,00	0,00	0,00	0,14
	Geotrupidae	0,00	0,00	0,00	0,00	0,51	0,00	0,14

Table 4 - Relative abundance (%) for each taxa collected and identified, for each type of stand, burnt and unburnt. Numbers in bold denote dominant taxa.(≥10%). (cont)

TAXA		**TYPE OF STAND**						
		Eucalypt		**Mixed**		**Pine**		
Class: Order	Family (or Superfamily)	**Burnt**	**Unburnt**	**Burnt**	**Unburnt**	**Burnt**	**Unburnt**	**TOTAL**
	Heteroceridae	1,54	0,00	0,00	0,00	0,00	0,00	0,14
	Lampyridae (larva)	0,00	0,00	1,53	0,00	0,00	0,00	0,28
	Nitidulidae	0,00	1,87	0,00	0,00	0,51	0,00	0,42
	Silphidae	0,00	0,00	0,00	0,00	0,51	0,00	0,14
	Staphylinidae	**32,31**	**25,23**	**13,74**	**26,19**	4,06	**25,55**	**18,17**
	Tenebrionidae	0,00	0,00	0,00	1,19	0,00	0,00	0,14
	Ptinidae	0,00	0,00	0,00	0,00	0,00	0,73	0,14
Coleoptera (larva)		1,54	0,00	1,53	0,00	0,00	1,46	0,69
Collembola	Entomobryoidea	**13,85**	**34,58**	**17,56**	8,33	3,05	7,30	**12,76**
	Sminthuridae	0,00	0,00	0,00	0,00	0,00	0,73	0,14
Hemiptera		0,00	0,00	0,76	1,19	0,00	3,65	0,97
	Aphidoidae	0,00	0,00	0,76	0,00	0,51	0,00	0,28
	Pentatomidae	0,00	0,00	0,76	0,00	0,00	0,00	0,14
Hemiptera (larva)		0,00	0,00	0,00	1,19	0,00	0,00	0,14
Hymenoptera	Formicidae	**20,00**	8,41	**21,37**	**11,90**	**30,46**	2,19	**17,06**
	Ichneumonoidea	0,00	0,00	0,76	0,00	0,00	0,00	0,14
Hymenoptera (larva		0,00	0,93	0,00	0,00	0,00	0,00	0,14
Lepidoptera (larva)		1,54	0,00	1,53	0,00	0,00	0,73	0,55
Orthoptera	Tettigoniidae	0,00	0,00	0,00	0,00	0,51	0,00	0,14
Thysanura	Machilidae	1,19	0,00	0,73	0,42	0,00	0,73	0,42
Class Malacostraca								
Isopoda		0,00	0,51	0,00	0,28	0,51	0,00	0,28

Table 5 – Diversity indexes Mean ± SD. H' – Shannon-weaver diversity index; J' - Pielou's evenness index; α – Fisher's diversity index.

		Diversity Indexes								
Type of Stand		H'			J'			α		
Eucalypt	Burnt	0,45	±	0,27	0,91	±	0,09	5,98	±	5,45
	Unburnt	0,60	±	0,07	0,89	±	0,05	3,81	±	2,57
Mixed	Burnt	0,58	±	0,26	0,88	±	0,09	4,82	±	5,41
	Unburnt	0,56	±	0,27	0,90	±	0,07	5,86	±	3,64
Pine	Burnt	0,55	±	0,16	0,83	±	0,16	4,38	±	1,97
	Unburnt	**0,65**	±	0,15	0,88	±	0,06	4,10	±	2,20

Plotted MDS results showed a clear separation between burnt and unburnt plots, withing eucalypt and pine stands, although not so in mixed stands. Here the data dispersion is larger and no clear groups are formed (figure 9).

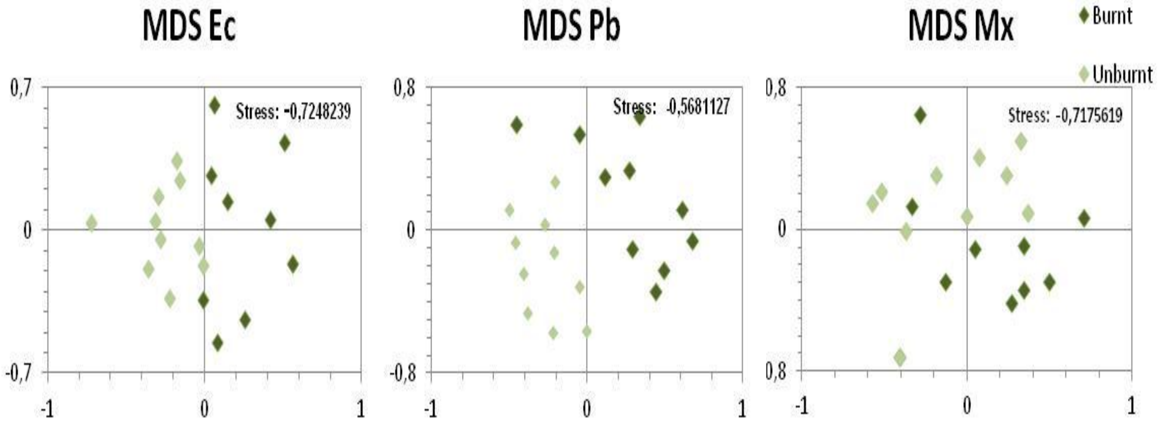

Figure 9 – plotted MDS results for each type of stand. Dark green symbols stand for burnt plots; light green symbols stand for unburnt plots. Ec – eucalypt stands; Pn – pine stands; Mx – mixed

The ADONIS analysis showed highly significant differences (p < 0,001) between burnt and unburnt plots, generally and within types. When tested pairwise, the burnt and unburnt plots within pine stands showed highly significant differences (p < 0,001) and very significant differences within eucalypt stands (p < 0,006). There were not significant differences between burnt and unburnt plots, within mixed stands. When all types were tested together, there were significant differences (p < 0,011); the pairwise analysis revealed only significant differences between pine and eucalypt stands (p < 0,014) (table 6).

Table 6 – ADONIS results for arthropod data. (P < 0.05). Ec: Eucalypt plots; Pn: pine plots; Mx: mixed plots; B: burnt plots; U: unburnt plots.

		Df	**SS**	**MS**	**F.Model**	**R2**	**Pr(>F)**
Ec	*B vs U*	1	56,7	56,7	4,0055	0,18202	**0,006****
	Residuals	18	254,8	14,156		0,81798	
	Total	19	311,5			1,00000	
Pn	*B vs U*	1	446,8	446,8	3,5875	0,16618	**0,001*****
	Residuals	18	2241,8	124,54		0,83382	
	Total	19	2688,6			1	
Mx	*B vs U*	1	45,5	45,5	1,3265	0,06864	0,222
	Residuals	18	617,4	34,3	0,93136		
	Total	19	662,9			1	
Ec vs Pn		1	200,2	200,15	2,5351	0,06254	**0,014***
	Residuals	38	3000,1	78,95		0,93746	
	Total	39	3200,3			1	
Ec vs Mx		1	34,55	34,55	1,3474	0,03424	0,236
	Residuals	38	974,4	25,642		0,96576	
	Total	39	1008,95			1	
Mx vs Pn		1	110,2	110,15	1,2489	0,03182	0,241
	Residuals	38	3351,5	88,197		0,96818	
	Total	39	3461,7			1	
Ec vs Mx vs Pn	*Type*	2	229,9	114,95	1,9934	0,05906	**0,011***
	B_U	1	219,4	219,367	3,804	0,05635	**0,001*****
	Type:B_U	2	329,6	164,817	2,8581	0,08468	**0,001*****
	Residuals	54	3114	57,667		0,79992	
	Total	59	3892,9			1	

RDA

The selected variables (shrub height, cover and richess; woody debris, litterfall and bare soil cover; organic matter and humidity in the organic and inorganic horizons) explained 29,72% of the data. In the plot, shrub height and woody debris explain most of the variation among the sample plots; while the soil variables (humidity and organic matter in both horizons) explain the most variability among species.

There are two plots that stand out from the cluster: one of the burnt pine plots (yellow triangle on the far right) and one mixed burnt plot (red triangle on the bottom). Three taxa also clearly stood out from the cluster and are marked with a red circle: Bostrichidae (coleopteran); Formicidae (ants) and Chordeumatida (diplopods) (figure 8).

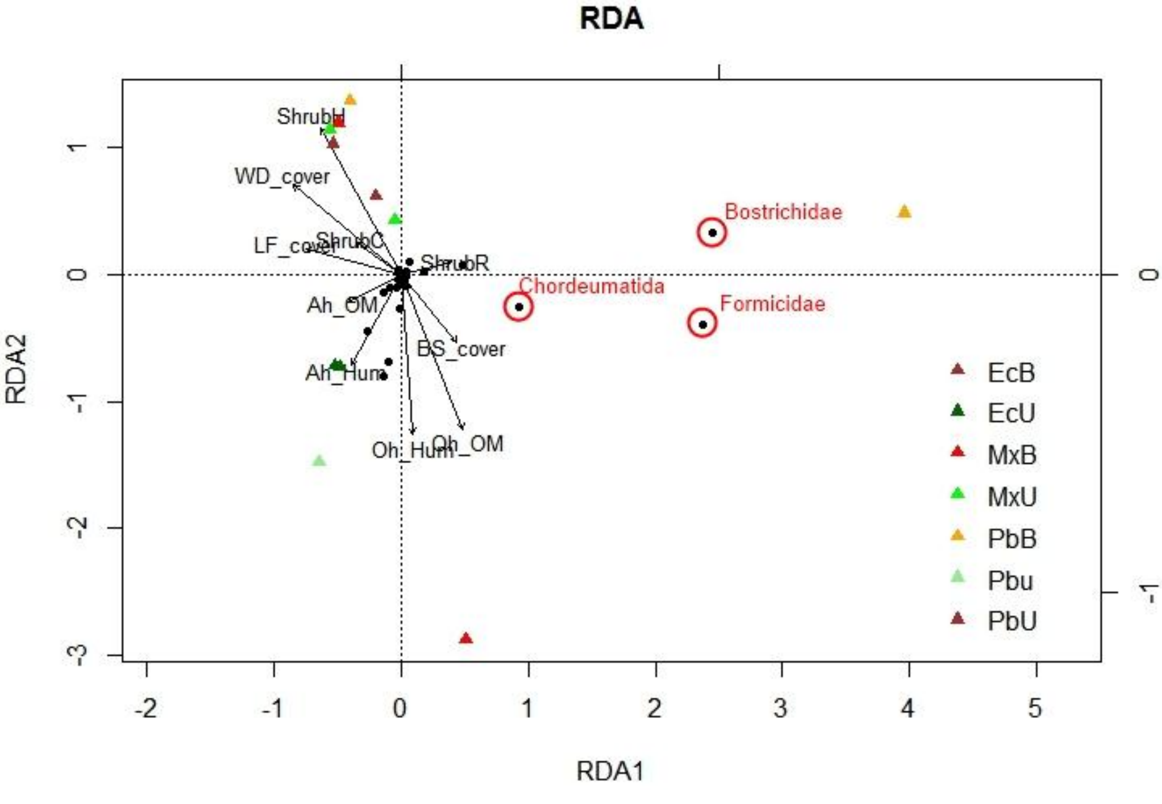

Figure 10 – plotted RDA results. Black – soil and inventory variables (Ah_Hum – humidity in the A horizon, Ah_OM – organic matter in the A horizon; Oh_Hum – humidity in the o horizon; Oh_OM – organic matter in the o horizon; ShrubC – shrub cover; ShrubH – shrub height; ShrubR – shrub richness. WD_cover –woody debris cover; LF_cover – litterfall cover;BS_cover – bare soil cover); Black dots – arthropod families. Legend: EcB – burnt eucalypt plots; EcU – unburnt eucalypt plots; MxB – burnt mixed plots; MxU – unburnt mixed plots; PnB – burnt pine plots; PnU – unburnt pine plots.

Discussion

The results of the scatter-plot and the PCA both show a strong association between the humidity and organic matter in both layers. That these two variables would be correlated was to be expected, being intrinsically linked.

The amount and composition of the litter layer depend mostly on the type of forest and density of the canopy, and are responsible for the variation in the litter layer depth and organic matter and humidity in the organic layer. The quality and quantity of the litter changes after the fire, as it works as fuel (Castro et al.). Fire also speeds up the mineralization of organic matter in the soil (Ferreira et al. 2010b). It's plausible that they are responsible for the significant differences found between the burnt and unburnt plots Forest soil properties are influenced by several factors: such as the bedrock and lithology or the nature of the canopy (Jeffery et al. 2010). Given the different characteristics of pine needles and eucalypt leaves, differences in the chemical properties of soil would have been expected (Castro et al.). Perhaps a more detailed analysis of nutrient content would be more revealing, but that should be material for further studies. On the other hand, bedrock and lithology were virtually the same for all our plots and this may explain part of the uniformity of the data. Between burnt and unburnt plots, there were in fact significant differences, although these differences don't appear to be very deep. This could indicate that the soil has already partially recovered.

Soil affects and is affected by the shrub layer composition, as part of the litter comes from this type of vegetation (Jeffery et al. 2010). The shrub layer in forest ecosystems is greatly altered in the event of fire; this leads to changes in the litter layer composition and in the ground cover (Niwa and Peck 2002). Both the ADONIS analysis (table 2) and the MDS plots (figure 6) showed differences between burnt and unburnt plots within each type of stand, validating this observation.

All the shrub layer values were higher in the burnt plots, for every type of stand, indicating that fire might have had a beneficial effect on these communities, promoting the development and diversification of the shrub layer, which is often well adapted to fire and highly benefits from the clearing of the aerial space. Management practices, or absence of these, can also help the regeneration process along, contributing to an increase in biodiversity. Common species like *Pterospartum tridentatum* and *Calluna vulgaris,* that showed high cover values, were consistently more abundant in burnt plots, probably having benefited from the clearing of space. Shrub diversity as well as the type and density of the ground cover, are determinant in the community of arthropods that develops in a certain forest, as they create a more complex habitat, favoring the diversification of the community. Litter is also the food source of many animals (detritivores) that will be highly impacted by the fire . As such, lower richness of arthropod families in burnt plots might be expected and was actually found, but the difference is not significant. But, as shrub richness was actually higher in burnt plots and, if we consider the intermediate disturbance hypothesis (Grime 1973) that indicates that higher richness could be expected in burnt plots (post-disturbance), we can probably assume that the arthropod community is actually recovering from the fire. Nonetheless, the various ADONIS analysis showed there were significant differences between burnt and unburnt plots, indicating that even if the community recovers it still might be quite different from the one that existed before.

Between the types of stand, though, differences were not so clear. Soil and vegetation variables did not showed significant differences between types of stand. These two responses are most likely connected, as mentioned previously, as one affects the other and vice-versa (Jeffery et al. 2010).

The PCA plot (figure 7) for the vegetation data shows us a close association between burnt pine plots and unburnt plots (of all three types), while some unburnt eucalypt plots associate more closely with the burnt plots. Litterfall cover (LF_cover) and shrub cover and richness (Shrub_C and Shrub_R), explain this gradient, although in different directions. The amount of litterfall is highly dependent on the type of forest, which also affects the type of litter and this, in its turn, will affect the shrub layer composition (Jeffery et al. 2010).

For the arthropod data, the ADONIS showed significant differences only between eucalypt and pine stands. This is coherent with the fact that mixed stands contain both tree species, being somewhere between the two “extremes”. This might also justify the lack of significant differences between burnt and unburnt mixed plots, as the characteristics of these stands might influence directly and indirectly the resilience of the arthropod community and mask the effect of fire. The ADONIS analysis of the vegetation data provided a similar pattern, attesting to this hypothesis.

Eucalypts are exotic species in Portugal and have, as such, characteristics that are very distant from the native species. They affect the soil, the shrub and faunal components of the ecosystem they are in and do so in a prejudicial form, more often than not. Soil in eucalypt stands is less stable and fertile and the eucalypt leaves have determined chemical properties that affect the decomposition rate and the mineralization of the soil. As an exotic species, our faunal community is simply not as well adjusted to this type of forest and local biodiversity will tend to be lower (Silva et al. 2007). The lower number of arthropod families and individuals in eucalypt stands than in pine or mixed stands (even lower in burnt eucalypt plots) reflects the status of the eucalypt as an exotic species.

The high variability in the indexes values, on the other hand, indicates that the intrinsic variability of the stands might be masking the effects of both fire and type of stand.

The redundancy analysis arranges the explanatory variables (soil and inventory data) according to calculated axis and then scores the response variables (arthropod data) and plots it in the created space (Makarenkov and Legendre 2002). The strong differences between burnt and unburnt plots reported in the previous analysis are not as clear in this one. The plot shows us that the sample plots differed more due to vegetation variables, while soil appeared more determinant in the variability of arthropod families.

Regarding arthropod dominance results, as expected, insects and spiders where the most common arthropods found. Spiders, despite all sharing the same basic morphology and predacious habit, present an incredible diversity of strategies and habitats (Moretti et al. 2002). The fact that no arachnid family stood out, proves that diversity is the keystone of the success of these animals. Among insects though, ants and staphylinids (coleopteran) were dominant and again here the diversity within these two families is probably the key to their success. Ants are also colonial animals, always presenting high densities if a colony is nearby. On the other hand, staphylinids share with spiders the predacious habit and diversity of strategies, allowing this taxa to be adapted to a great variety of habitats and conditions (Chinery 1993).

Final Remarks

Forests are important reservoirs of biodiversity and provide many valuable services to the human population. One of the main disturbance sources in these ecosystems is fire, thus it is vital to understand how it affects each type of forest in order to prevent and respond better to the damage it may cause. With this work, we aimed to assess if different types of forests respond differently to fire and we came to inconclusive results; it seems clear that the type of stand affects biodiversity, and that fire changes the community structure; there was also some indication that pine stands recovered more quickly than eucalypt stands (figure 8 and table 4). The high proximity between burnt pine and unburnt plots, as well as unburnt mixed plots (figure 7) also validates this observation.

It should be noted that, even though we did obtain interesting and valid results, much could still be done to improve their quality. First, the plots ought to have been chosen more carefully as, in hindsight, a detailed survey before the sampling of arthropods would have been useful to eliminate possible masking factors, such as slope and aspect.

In the same way, fire severity should have been assessed at the plots as it is a determinant factor in the community that follows the event, but this is not an easy variable to assess in the field and even less when 5 years have passed.

The time of the sampling was not ideal, as arthropod activity was probably dwindling when the sampling occurred (late October). Considering that activity is a contributing factor in the success of the pitfall traps employed in this study, the importance of the timing is doubled. So a second sampling during the spring or summer would have been more appropriate.

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APPENDICES

Table A – Soil data resulting from lab analysis. Mean + SD.

		Mineral Layer									Organic Layer								
Type of Stand		Humidity (%)			Organic matter (%)			pH			Humidity (%)			Organic Matter (%)			pH		
Eucalypt	B	2,50	±	0,62	11,22	±	2,29	4,40	±	0,73	7,24	±	2,37	57,74	±	24,56	3,69	±	0,15
	U	2,82	±	0,38	13,76	±	3,49	4,25	±	0,28	10,08	±	3,27	70,32	±	21,27	3,59	±	0,27
Pine	B	3,43	±	2,03	9,19	±	2,13	4,56	±	0,38	6,16	±	3,18	44,51	±	26,84	4,04	±	0,26
	U	5,27	±	3,76	13,02	±	6,25	4,21	±	0,75	10,25	±	5,59	63,38	±	21,06	3,98	±	0,29
Mixed	B	2,57	±	0,70	10,87	±	2,49	4,50	±	0,44	7,20	±	1,61	55,23	±	14,60	3,86	±	0,29
	U	3,58	±	2,26	18,36	±	13,54	4,41	±	0,22	8,80	±	2,57	67,30	±	23,43	3,55	±	0,18

Table B – Ground cover data collected at each site. Mean + SD.

		Ground cover (%)														
Type of Stand		Rocky Outcrops			Large Stones			Woody Debris			Litterfall			Bare Soil		
Eucalypt	Burnt	4,06	±	5,50	1,88	±	2,59	27,19	±	14,48	72,50	±	13,89	2,19	±	2,48
	Unburnt	0,00	±	0,00	0,63	±	1,16	10,00	±	6,94	82,50	±	28,16	12,81	±	33,31
Pine	Burnt	3,13	±	4,96	7,81	±	6,19	17,19	±	17,03	16,88	±	19,99	6,25	±	5,67
	Unburnt	0,63	±	1,16	0,63	±	1,16	8,44	±	5,82	90,00	±	5,35	0,63	±	1,16
Mixed	Burnt	9,06	±	5,33	5,31	±	4,52	7,50	±	8,35	29,69	±	17,45	10,00	±	5,67
	Unburnt	0,00	±	0,00	0,31	±	0,88	7,81	±	7,73	73,13	±	34,63	0,31	±	0,88