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POST-FIRE TREE REGENERATION PATTERNS IN DRY WESTERN FORESTS OF OREGON'S CASCADES: ABUNDANCE, COMPOSITION AND SIZE

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«Navega, velero mío,
sin temor,
que ni enemigo navío
ni tormenta, ni bonanza
tu rumbo a torcer alcanza,
ni a sujetar tu valor. »

Jose Espronceda. Canción del pirata.

Thank you
Gracias

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POST-FIRE TREE REGENERATION PATTERNS IN DRY WESTERN FORESTS OF OREGON'S CASACADES: ABUNDANCE, COMPOSITION AND SIZE

RESUMEN

La influencia de las politicas de supresión de quemas, durante el siglo XX, unido a los efectos del cambio climatico, producirá un cambio en la frecuencia y severidad de los incendios forestales, en los bosques de Tsuga heterophylla/ Pseudotsuga menziesii del Oeste de los Estados Unidos. Dos periodos de incendios fueron estudiados, "Willamette National Forest" en 1991, donde un total de 2823.7 ha fueron quemadas, y "Umpqua National Forest", en 2002, donde los incendios afectaron a 30730.2 ha. El objetivo es determinar si la regeneración natural post-incendio, en términos de abundancia, composición y tamaño, y en función a distintas clases de severidad (baja, moderada y alta), es suficiente para devolver al bosque a su estado original, sin la necesidad de realizar plantaciones con la idea de ayudar al desarrollo del regenerado. Para ello, se seleccionaron 6 parcelas dentro de cada severidad, y para cada zona de estudio, así como en zonas no quemadas, con 4 subparcelas, donde fue estudiado el regenerado entre los 2.54-20 cm de DBH, así como el <2.54 cm. Los resultados muestran que, no solo en ambos periodos el regenerado es abundante para todas las severidades, si no que además, existe una relación con la vegetación del estrato dominante, en las condiciones previas al incendio.

ABSTRACT

Fire suppression during the 20th century, and the effect of Climate change, will change the frequency and severity of wildfires, in *Tsuga heterophylla/ Pseudotsuga menziesii* forest across Western of the United States. Two fire periods were studied, first, Willamette National Forest, in 1991, where 2823.7 ha burned, and Umpqua National Forest, in 2002, where 30730.2 ha burned. The main objective is to quantify regeneration following wildfire, in terms of abundance, species composition and size, according to different fire severities classes (low, moderate and high), and check if it is enough to return the forest to its pre-fire situation, without reforestation as the main management tool. Six plots were selected in each severity, for both fire periods, and also for and unburned mature to old growth sites, with four nested subplots. Regeneration was studied as saplings (2.54-20 cm DBH) and seedlings (<2.54 cm DBH). Results show good post-fire regeneration abundance, in both fire periods, and besides, there is a relationship between pre and post-fire composition.

Keywords: fire ecology, post-fire regeneration, fire severity, management, Oregon Cascades Range

INTRODUCTION

Forest fires are the most common natural disturbance in the Pacific Northwest of the United States, being the main alteration that plays an essential role in the composition and structure of future forests. Franklin et al. (2002) define forest fires as a force on the spatial distribution of both forest composition and structure, with cumulative effects over long periods of time.

The Western Oregon Cascade Range is largely dominated by *Tsuga hetrophulla/Pseudotsuga menziesii* (Western hemlock and Douglas-fir) and *Abies amabilis/Tusga mertensiana* (Silver fir/Mountain hemlock) forest (Franklin and Dyrness., 1998) that burns with mixed severity. Fire return intervals, or the average period between two successive fires, under the presumed historical fire regime in a specified area within these forests, range from 100-300 years at lower elevations, and 300-500 years at higher elevations.

Forests in North America are strongly related with the country's history, and the diverse management of forest resources over time. Currently, the key issue for forest and fuel distribution and composition in the Northwest of the United States is linked with historical Euro-American settlement. Fire suppression during the 20th century has increased the density of young conifers and created a change in species composition, from shade intolerant to shade tolerant species (Perry et al., 2011), and successional processes have been accelerated, creating a weak forest structure, with a shift in tree species composition. After 1905, when Federal Policy of suppression fires was implemented, fire occurrences changed dramatically, and thus changed post-fire management practices (Taylor and Solem., 2001).

Post fire stands change with type, extension, return interval, seasonality, intensity and severity of fires. It is well known that a patched distribution following a fire contributes to the composition and structure of the future forest which in turn depends on the size and shape of those patches, as in the pre fire vegetation. Size and shape of patches have an important effect on forest development, in particular with reference to large burns. Patches are primarily important in high severity fires, as seeds must travel more distance to establish, depending on their size. Fire severity is the main factor in studying regeneration after fire, since it is related with regeneration success.

Perry et al. (2011) define three types of existing severities: low severity fire, or surface fires, where at least 20 percent of overstory or basal area has died; high severity fires or canopy fires, where around 70 percent of overstory or basal area died; and mixed severity fires, or those where 20-70 percent of overstory or basal area died, resulting of a high variability of conditions. A spatial mosaic of stand conditions is found in mixed severity fires (Franklin 2002, Meigs 2009) affecting forest structure and composition.

Western hemlock/Douglas-fir forest of southern Willamette and Umpqua National Forest typically burn as mixed severity, creating a low to high burn severity gradient within a single fire. In forest dominated by mixed severity regimes, variation in fire frequency, severity, extent and seasonality depends on fuels, both surface and canopy, topography, climatic conditions and ignition.

Douglas-fir and Western-hemlock are the main conifers species in the Pacific Northwest. Douglas-fir is a fire resistant tree with a thick bark and lower bole that protects its cambium from fire with foliage in the upper bole, making Douglas-fir a high adapted tree associated with fire. Douglas fir is shade tolerant (Hemstrong et al.,1977), and is an early seral dominant colonizer in burned areas. (Larson and Franklin., 2005). Western-hemlock, on the other hand, is a shade tolerant colonizer that mixes with Douglas fir in forests. Its thin bark, shallow roots and flammable foliage make Western-hemlock a poorly adapted to fire (Hemstrong et al.,1987).

Large scale wildfires can eliminate seed sources and change the future regeneration dynamic more significantly than small burns, although these effects have received little study (Donato et al., 2009). The same as the impact of severity fires in ecological processes. The importance of fire in forest development is critical to maintaining native species and ecosystem processes (Hansen et al., 1991)

In fact, a large part of the population in the Western United States, considers salvage logging and reforestation after fire, two management practices to reduce future fire hazard, keeping the idea that natural regeneration is not enough to reestablish the forest. Patterns in conifer regeneration after wildfire will influence future succession, plant community composition and wildlife habitat. Forest succession in stands affected by mixed severity fire varies depend on the composition and abundance of the surviving overstory (Larson 2005).

GOALS AND OBJETIVES

The main goal of this research is to quantify post fire conditions--particularly the effect of fire severity on composition, abundance and size of natural tree regeneration--in economically and ecologically important Western hemlock/Douglas-fir forest of the Oregon Cascades Range.

METHODS

1. Study area

Dry Western Hemlock forests of Oregon's Cascades Range are located in the west coast of the United States (Figure 1). Two study areas were selected, Willamette National Forest and Umpqua National Forest. Central Oregon's Cascade Range has an average of temperatures between -6.7 and 4.4 ºC in winter and 7.2 to 29.5 ºC during the summer. Dry Oregon Cascades Range are well known for their low precipitation between 267 to 318 mm of annual precipitation (Appendix 1, figure 1).

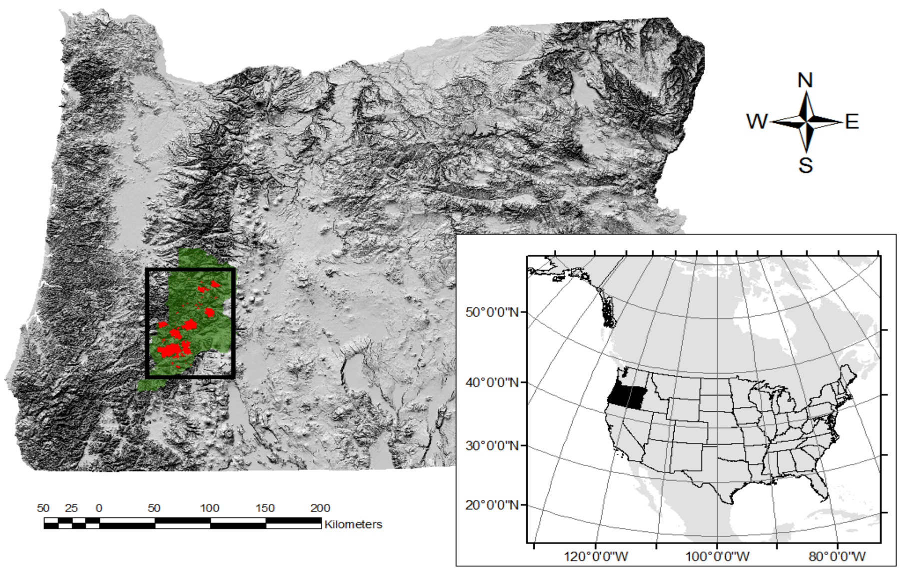

Figure 1. *Location map.*

2. Sampling design

Fire severity gradient creates distinct post-fire conditions, that were accounted for by stratifying plots across three burn severity classes, using the difference normalized burn ratio (dNBR) calculated on 30x30 meter pixels from LANDSAT satellite imagery.

Dry west side found in the southern extent of Oregon's western hemlock/Douglas-fir Forest, on the Middle Fork Ranger District of Willamette National Forest and Umpqua National Forest, has been burned several times in the last decades. Since 1987 four fire periods can be described in this region, although just 1987-1991 and 2002 have been studied in this research (Table 1)(Appendix 1, Figure 2).

Table 1. *Severity classes for each wildfire studied, with data in hectares and percentage.*

	Total	**Very low**		**Low**		**Moderate**		**High**	
Fire(Year)	Ha	Ha	%	Ha	%	Ha	%	Ha	%
Shady Beach (1988)	3188.5	1336.4	41.9	889,6	27.9	509.9	16	452.7	14.2
Warner Creek (1991)	2825.7	755.7	26.8	539.6	19.1	536.7	20	964.7	34.2
Boulder (2002)	19716.8	7018.6	35.6	6597.1	33.5	3657.1	18.5	2444.0	12.4
Apple (2002)	6681.3	2958.8	44.3	1585.1	23.7	1011.0	15.1	1126.4	16.9
Big Bend (2002)	4332,1	2299.4	53.1	1286.6	29.7	508.0	11.7	238.1	5.5
Average	7348.9	2873.8	40.34	2179.6	26.8	1244.5	16.3	1045.2	16.6
Maximund	19716.8	7018.6	53.1	6597.1	33.5	3657.1	20	2444.0	34.2
Minimum	2825.7	755.7	26.8	539.6	19.1	508.0	11.7	238.1	5.5

Sampling is constrained to forest stands with mature or old/growth Western hemlock/Douglas-fir forest, prior to the fire disturbance. Focusing on natural disturbance impacts, old-growth forests, provides insights into natural disturbance processes that historically impacted this landscape, and resulted in the old-growth forest conditions existing today.

The design resulted in a total of 78 intensive plots, 6 in each low, moderate and high severity, and also 6 unburned mature to old growth sites across three of the four fire periods, 4-5 years post fire, at 10 years post fire and 22 years post fire.

To achieve the objectives suggested, we focused the study to six intensive plots within low, moderate and high severity fire, and two post fire age classes were selected, 10 and 22 years. Mature old growth was studied in 6 intensive plots, as a reference group. A total of 42 plots were studied (Appendix 1, Table 1) Plots were selected randomly using ArcGIS 10.0 (ESRI 2011). Plots centers were a minimum of 500 meters apart to reduce spatial autocorrelation, and more than 100 meters from roads, water features and the fire boundary.

A nested, variable radius plot design was used to sample forest structure and understory composition (Appendix 1, Figures 3a. 3b). The full plot footprint is split in a 1 ha circular plot, with 4 nested tree subplots, and 4 quadrats within each subplot, orientated along a random azimuth. Nested understory vegetation and regeneration subplots, occur at the center of the tree subplots. Plot sizes and lengths described assume slopes of less than 10% and do not need slope correction since all plots and line transects were slope corrected in the field.

Tree regeneration (Appendix 1, Figure 3c) was set up in two parts, seedlings and saplings. Measures were made in subplots of 10x10m in size, but sampling occurred in quadrants of 5x5m. Subplots were orientated along the major axis of the plot. Both saplings and seedling were scaled to hectare to standardize the study.

Saplings were measured inside tree subplots (Appendix 1, Figure 3b), in the data sheet, was considered tree regeneration those individuals with a DBH between 2.54-20 cm. In these ones, species, diameter at breast height (DBH), height, circumference at breast height (CBH), scorch and cores were measured.

On the other hand, seedlings with a DBH <2.54 cm were measured at each quadrant by tallying species in 6 height classes; in addition, also species name were written down. Estimates were made by 2 individuals, to minimize error of cover estimates. Seedling data were transformed to subplot, with the purpose of work with data in the same study level. Next table shows the species that were found in the study area, and that have been taken into account in the analyses

Table 2. *Common and scientific name, and symbol of the species in the study area.*

Common name	***Scientific name***	**Symbol**
White fir	*Abies concolor*	ABCO
Bigleaf maple	*Acer macrophyllum Pursh*	ACMA
Pacific madrone	*Arbutus menziesii Pursh*	ARME
Golden chinquapin	Castanopsis chrysophylla	CACH
Incense cedar	*Calocedrud decurrens (Torr.)*	CADE
Sugar pine	*Pinus lambertiana Douglas*	PILA
Douglas-fir	*Pseudotsuga menziesii* (Mird) Franco	PSME
Pacific yew	*Taxus brevifolia Nutt*	TABR
Western redcedar	*Thuja plicata Donn*	THPL
Western Hemlock	*Tsuga heterophylla*	TSHE

3. *Data analysis*

Species abundance

Data used in this point came from the data collected in the two fires studied. Both seedlings and saplings were taking in account, subplot level was chosen to make the statistical analysis.

On one hand, the number of seedlings in each height class was summed for each subplot and the scale was changed to hectare. On the other hand, saplings data are diameter at breast height (DBH) and height. In this case, trees with a diameter higher than 2.54 centimeters were considered saplings. Taking the DBH as the main information to check species abundance, as a better predictor. To complete the data, quadratic mean diameter, trees per hectare, basal area, and basal area mortality, were used as variables that show fire effects in a subplot level, and aspect, elevation, slope, heat, northing, easting and latitude, to complete the environmental data sheet.

First, to check if the data is normally distributed, boxplots with R studio version 0.98.994 (http://www.rstudio.com) were used to determine the distribution of the data. Biological variables must fit the main assumptions of data, namely normal distribution and homogeneity of variances. In this case, the distribution was not normally distributed. To try to solve this problem, data transformation was performet to fit the assumption of normally distributed data. First, with log transformation by taking natural logs, with the idea that many biological variables have log normal distribution and thus by using log-transformation the values would be normally distributed. Then, square root transformation, as it is commonly used when the variable is a count. However, in spite of these transformations, the data was not normal distributed with random effects.

Nested data with 4 level spatial structures (tree regeneration nested within quadrants, nested within subplots, nested within random plots) is used so it is not possible to claim independence of values, so the use of Kruskal-Wallis test of variance was discarded (Zuur et al., 2009). Finally, a generalized-linear mixed models (GLMMs) with a Poisson distribution and a log link function, using "glmer" in R code was used. Poisson distribution is widely used for count data. Generalized linear mixed models provide a better approach for analyzing non-normal data with random effects and include the main ideas of linear mixed models (for random effects) and generalized linear models (for nonnormal data) due to the use of link functions and exponential families (Bolker et al., 2008). Fixed effect parameters were the estimated parameters. Generalized linear mixed models are considered a recent tool for the statistical program used here. Model selection in generalized linear mixed models are not commonly available (Bolker et al., 2008; Dunn and Bailey., 2012), so manual stepwise model selection was used to find variables that fit the model. Graphical checking was made to verify variances homogeneous, and follow the assumed distribution. Years since fire and severity data was combined to fit better GLMM request. Data was overdispersed, meaning that there is more variance in the data than predicted by a statistical model. The main causes for overdispersed data are (1) correlated data (2) omitted variables (3) misspecified distribution, if data don't follow the assumed distribution (Ramsey and Schafer 2012).

To solve this problem first, data that are overdispersed relative to a Poisson distribution may not be overdispersed relative to a negative binomial distribution, using "glmer.nb" in R code (Ismail and Jemain 2007). After that failed, glmmADMB package (http://glmmadmb.r-forge.r-project.org) was used, with an approximation to the overdispersion parameter (http://glmm.wikidot.com/faq) to check the results. The value of this parameter and the one given by glmmADMB should be lower than 1 to be sure the data is not overdispersed, although for community data this is not an strict limit. A six steps procedure suggested by Bolker et al (2008) was used for creating a full model.

Species composition

Species composition was studied according to three different analyses to understand species composition: first, a Nonmetric multidimensional scaling (NMS) for the ordination analysis, second a Multi-Response permutation procedure (MRPP) for the statistical analysis, and finally, the Indicator species analysis (ISA) to identify species associated with environmental conditions.

Using species and environmental data, the objective of this point is to improve the knowledge of the distribution of species across fire severity, once it is known if there is enough regeneration. In this case, without taking in account old growth plots as the main objective is to examine natural regeneration composition after fire. It is important to understand species composition, and to check which species dominate in each fire severity case, to better comprehend successional processes after fire. Environmental data was used in this section, helping to understand succession in areas with different fire effects and environmental conditions. Two main years post fire were studied, 1991 and 2002, with the intention of understanding the successional stage in different post-fire conditions and time since fire.

The study was made according to three categorical variables: years post fire, severity, and percentage of basal area mortality. For basal area mortality, the classification proposed (Agee 1996, Agee 2005), where low severity fires were those in which 0-25% of basal area die, moderate severity between 25-75%, and high severity fires higher than 75% of the basal area dies. Regeneration data was taken at the subplot level in hectares. As a result of the objective of this point, seedling and sapling regeneration was summed as the total regeneration for each species, and in every subplot.

To compare similarities in natural regeneration composition across fire severities, analyses were conducted using PCORD version 5.18 (McCune 2006). Regeneration values were log transformed before starting statistical analysis because there was a high degree of variation within the regeneration data. First, with the use of non-normal count data in a relatively small sample, Nonmetric Multidimensional Scaling (NMS) ordination analysis was used, a useful ecology tool to examine patterns in community composition (Lindh and Muir., 2004). Data should have non-normal distribution; so Sørensen distance, the most common and convenient distance in ecology, was used to determine the species response to a change in the environment with each sample unit contributing equally to the distance measure

(McCune and Grace, 2002), with the count of seedlings and saplings for each severity and year post fire using two matrices, the main one with natural regeneration data for each species, and the secondary matrix with the environmental data. NMS used random starting coordinates and tested the significance of the solution by Monte Carlo simulation. The best number of axes was chosen for this case, such that axis 1 explains the greatest amount of variance, following by axes 2 and axes 3 if it corresponds. NMS gives stress data as the closer the points lie to a monotonic line, the better fit and the lower stress are the best result (McCune and Grace, 2002).

Second, Multi-Response permutation procedure (MRPP) of sample units in an environmental context, it is a non parametric procedure, used for testing the hypothesis of no differences between two or more groups (McCune and Grace, 2002, Mielke and Berry., 2007). MRPP provides a test of whether there is a significant difference between two or more groups of sampling units. MRPP generates a probability that community composition is more similar within treatment groups than within groups based on random reassortment of the data. In this case, MRPP is used to test the difference in species composition between fire severities, using pre-existing group rates or successional change (Biondini et al., 1985). The study design is not balanced across measurement periods because not all plots were measured at the same time.

MRPP is a statistical test that can be used with the Indicator species analysis (ISA) to give a value of individual species for different groups. MRPP gives a value for the observed and expected delta, that measures the weighted mean within group distance. MRPP also gives a value of chance corrected within group agreement (A), that is a measure of homogeneity of the groups and ranges from 0 to 1 (Lindh and Muir., 2004) and A is 1 when all plots within groups are identical, but in ecology it is commonly below 0.1 (Abella and Covington., 2004).

Categorical groups (years post fire, severity class, and percentage of basal mortality) appear in the secondary environmental matrix. The main advantage of MRPP is that it does not require multivariate normality and homogeneity of variances. The same Sørensen distance was used in this analysis as the one used in NMS analysis, since it is recommended to use the same distance in both analysis to get better results. Sørensen distance is the one that better represents the variation of interest in the data. MRPP analyses used PC-ORD default group weightings (McCune & Grace 2002)

Finally, Indicator species analysis (ISA) was used to see if there was any variation in species composition across fire severity and to better understand the relationship between fire effects and environmental conditions with Monte Carlo technique to test for statistical significance; this is useful to contrast species across two or more groups (McCune and Grace, 2002). Indicator species analysis is a complement of MRPP. Dufrêne and Legendres (1997) method was used to calculate species indicator, with environmental differences in groups, and gives values of relative abundance of species inside a group. The relative frequency of those species in each group and an indicator value, based on combining the values for relative abundance and relative frequency, were given by PCORD.

Species size

Management after fire is a huge discussion nowadays, with managers having to choose between reforestation after fires--the technique followed in the last decades—to help natural regeneration or letting natural regeneration occur without reforestation and checking if it is enough to satisfy the economical and ecological demand, taking into account the importance of ecological necessities that society is starting to recognize. Therefore, size was studied using saplings between 2.54 and 20 centimeters of diameter at breast height (DBH), finding which ones were the biggest and which species are the most representative. Seedlings were measured in a different way, as a result of how data was collected, seedlings data correspond to count data of presence of regenerate, and a measure of height of each regenerate and classified as height class (DBH<2.54cm). The procedure was to take, for each subplot, the highest value of height, that would represent the largest seedling regeneration in that subplot.

To determine if the size reached a good value, Multiresponse permutation procedure (MRPP) and Pairwise Comparison were done to study subplots in pairs, matched head to head with each other, and determine which one is preferred. The one with higher value will be the best pair.

RESULTS

1. *Abundance of species*

Tree regeneration abundance was calculated for both seedlings and saplings, as the total of regenerate founded in each subplot. Abundance was calculated using a Generalized linear mixed model (GLMM). First, including both fire periods. second, with results for each fire period, finding the better variables that were affecting each fire period along fire succession. Manual stepwise selection was done to determine which variables were significant with post fire tree regeneration

A total of 168 observations in 42 sites were used to estimate GLMM for regeneration. Table 3 provides coefficients for the significant predictor variables and random error terms for estimating the probability of tree regeneration. Every combination with fire severity in each fire period was statistically significant and had a positive impact with tree regeneration. On the other hand, basal area is negative correlated, there is an increase in regenerate when basal area is lower.

Table 3. *Descriptive statistics for predicting regenerate abundance in all subplots for 22 and 10 years since fire.*

Coefficients	Estimate	Std. Error	Z value	Pr(>|z|)
Intercept	7.49485	0.37262	20.11	<0.001 ***
Basal area	-0.00951	0.00351	-2.71	0.0068**
Comb 10L	2.58415	0.54441	4.75	<0.001***
Comb 10M	1.73901	0.53625	3.24	0.0012**
Comb 22H	1.61687	0.54895	2.95	0.0032**
Comb 22 L	1.18417	0.55178	2.15	0.0319*
Comb 22 M	2.56534	0.55838	4.59	<0.001***
Comb O	0.95495	0.58469	1.63	0.1024

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "·" 1

Note: Comb 10L: combination of 10 years since fire and low severity fire; Comb 10M: combination of 10 years since fire and moderate severity fire; Comb 22H: combination of 22 years since fire and high severity fire; Comb 22L: combination of 22 years since fire and low severity fire; Comb 22M: combination of 22 years since fire and moderate severity fire and Comb O: old growth.

All predictor parameter estimates are significant at $P < 0.05$.

Random group intercept was (1|plot)

Negative binomial dispersion parameter was used to check overdispersion, being 1.3567 with a standard error of 0.15492, although the value of the parameter is higher than 1, for community data the value of 1.3567 is accepted, and solve the overdispersion problem. An approximation of overdispersion parameter was used to check if the data is still overdispersed, ratio value was 0.7349970. Boxplot for post fire regeneration is shown in Appendix 1, Figure 4 there is not big differences in regeneration post fire across fire severities, although is lower in high severity fires, in 2002 fire period, because of the presence of subplots without regeneration.

Because of the presence of subplots without live basal area, post fire regeneration was used without taking in account these subplots. In this case, just basal area was statistically significant, with a negative effect in post fire tree regeneration (Table 4, Appendix 1 Figure 5). After remove subplots where there is no basal area, combination of fire severity and years since fire, is not significant anymore. Value of negative binomial dispersion parameter, to check overdispersion in the data, was 1.6747 with a standard error of 0.20533.

Table 4. *Descriptive statistics for predicting regenerate abundance, in presence of basal area*

Coefficients	Estimate	Std. Error	Z value	Pr>(|z|)
Intercept	9.39309	0.24001	39.14	<0.001***
Basal area	-0.01186	0.00322	-3.69	<0.001***

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "·" 1

In those locations without live basal area, regeneration is statistically significant, with percentage of basal area mortality, linked with the combination of fires effects (Table 5). In Appendix 1 Figure 6, the graph shows boxplots for 6 combinations between fire severity and years since fire, and the relationship with regeneration. In Umpqua fires, there is no difference in the amount of regeneration between severities, included in high severity class that is the one with more subplots without basal area. During the second fire period, moderate severity shows more regeneration.

Table 5. *Descriptive statistics for predicting regenerate abundance.*

Coefficients	Estimate	Std. Error	Z value	Pr (>|z|)
Intercept	-9.6839	5.8133	-1.67	0.0728·
% Basal area mortality	0.1735	0,0593	2.93	0.0034**

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "·" 1

It is important to have an idea of variables that affect regeneration in both fire periods. First, 2002 Umpqua fires show a high relationship with fire severity (Table 6), in 96 observations in 24 plots, showing that fire effects are still important in regeneration of tree species after 10 years. All of them are statistically significant with a positive impact in regeneration except old growth. In this case, the value for the parameter to estimate negative binomial dispersion is 1.1744 with a standard error of 0.17653, lower that the one founded with both fire periods estimated together. The value for the ratio is 0.7057276. In Appendix 1 Figure 7, the figure shows boxplots for every fire severity, there is no difference between low and moderate severity and old growth, although high severity fires have lower values of regenerate.

Table 6. *Descriptive statistics for predicting regenerate abundance in all subplots for 10 years since fire.*

Coefficients	Estimate	Std Error	Z value	PR(>|z|)
Intercept	7.485	0.341	21.97	<0.001***
Comb 10L	2.189	0.478	4.58	<0.001***
Comb 10M	1.431	0.478	2.99	0.0028**
Comb =	0.255	0.478	0.53	0.5938

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "·" 1

Second, for 22 years, basal area is statistically significant with tree regeneration, showing the same trend that was previously mentioned. With 12 years of difference, fire severity is no longer significant for tree regeneration (Table 7). Overdispersion parameter had a value of 1.737319 with a standard error of 0.2618, with that value overdispersion is considered solved. The value for the ratio, in this case, is 0.7313250.

Table 7. *Descriptive statistics for predicting regenerate abundance in all subplots for 22 years since fire.*

Coefficients	Estimate	Std. Error	Z value	Pr(>|z|)
Intercept	9.17604	0.30911	29.69	<0.001***
Basal area	-0.01153	0.00354	-3.25	0.0011**

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "·" 1

Table 8 shows the main predictor of regenerate in subplots where basal area was founded. In this case, basal area was a significant predictor for regenerate. Overdispersion parameter value was 1.693 with a value for standard error of 0.29397 and ratio of 0.9139969. Distribution of post fire regeneration related with live basal area is in Appendix 1 Figure 8.

Table 8. *Descriptive statistics for predicting regenerate abundance for 10 years*

Coefficients	Estimate	Std. Error	Z value	Pr(>|z|)
Intercept	9.42982	0.32038	29.43	<0.001***
Basal area	-0.01271	0.00474	-2.68	0.0074**

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "·" 1

After 22 years, basal area is still the most significant variable that affects post fire regeneration, following the same trend observed previously. Overdispersion parameter is 1.7373 with a standard error of 0.2618, and ratio of 0.7313250 (Table 9).

Table 9. *Descriptive statistics for predicting regenerate abundance in all subplots for 22 years since fire.*

Coefficients	Estimate	Std. Error	Z value	Pr(>|z|)
Intercept	9.17604	0.30911	29.69	<0.001***
Basal area	-0.01153	0.00354	-3.26	0.0074**

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "·" 1

Subplots without basal area, in 2002 fire period, are statistically significant with percentage of basal area mortality (Table 10). Post fire regeneration after high severity fire in Umpqua National Forest, is the most representative case of subplots without basal area. A total of 21 subplots have no basal area, 20 of them in high severity, in spite of that, regeneration is not compromise (Appendix 1 Figure 9). On the other hand, in Willamette National Forest fires, just one subplot in the sample has no basal area, in moderate severity.

Table 10. *Descriptive statistics for predicting regenerate abundance in all subplots for 10 years since fire.*

Coefficients	Estimate	Std. Error	Z value	Pr(>|z|)
Intercept	-9.7066	5.8307	-1.66	0.0960·
% Basal area mortality	0.1732	0.0594	2.91	0.0036**

Significant codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 "·" 1

Total of regenerate mean in trees ha^{-1} (±1 SE) across fire severities is shown in Appendix 1 Figure 10. In 10 years, low severity has the biggest amount of regenerate (18426±22183.24), followed for moderate severity (8328±7400.99). After 22 years, moderate severity has the best results in total regeneration (18227±19128.39), followed by high severity (10198±16555.05), a change in regenerate distribution occurs with 12 years of difference. Values of total regenerate per hectare are shown under the graph.

2. *Species composition*

Two fire periods were taking in account in this study, (a) 1987-1991 and (b) 2002. During these periods, significant areas of the forest in Willamette National Forest and Umpqua National Forest were impacted by wildfires. Nonmetric Multidimensional Scaling (NMS) ordination analysis, using Sorensen distance measure, was used to perform total tree regeneration, with seedlings and saplings.

First, Willamette National Forest fires got a 3-dimensional solution, with 66 itinerations and a stress value of 12.400, this value is related with the sample size. Interpretation of values of final stress, using Clarke´s stress formula, that said that values between 10-20 could get a good ordination, although values at the upper end suggest mislead results. Most part of ecological community data appears between 10 and 20 values of stress, in this case, a value in the lower half of this range, like 12.400, is considered satisfactory. On the other hand, 10 years since fire also get a 3-dimensional solution with 62 iterations and a value of stress of 13.174 that, like in the other case, it is satisfactory for the data. In table 11, the 3-dimensional ordination in both fires are shown, 22 years since fire had a cumulative R squared of 0.878 and 10 years since fire 0.870.

Table 11. *Coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space*

R squared	**Increment**		**Cumulative**	
Axis	22 years	10 years	22 years	10 years
1	0.402	0.416	0.402	0.416
2	0.285	0.272	0.687	0.688
3	0.191	0.182	0.878	0.870

Species regeneration and environmental data was used to check the ordination by NMS. On one hand, 1991 fire period with environmental correlations in all of the 3 axes (Appendix 1. Table 2). Axis 1 shows a strong relationship with both environment and fire variables, being environmental variables such as northing (r= -0.679) and latitude (r= -0.679) the stronger negative correlations, that means that farther north, in wetter places, post-fire regeneration decrease. Live trees per hectare showed the most important fire effects correlations, with a positive correlation of r= 0.468 for live trees per hectare, in a subplot level. Axis 3 has a slightly different correlation values in relationship with axes 1, but with a positive correlation with live quadratic mean diameter (r=0.325) and live trees per hectare (r=0.136) in a subplot level.

On the other hand, 2002 fire period shows different correlations, in axes 1, there is a negative correlation with live trees per hectare, and live basal area (r=-0.625, r=-0.620), and a positive correlation with percent of basal area mortality (r=0.608) and slope (r=0.530). Axis 3 has a correlation with environmental variables, such as northing, easting and latitude (r= 0.114, r= 0.132, r=0.114). Axis 2 has the same trend as axis 1, with a slightly different correlation values (Appendix 1 Table 3). Axis 1 and 3 had the most important correlation with environmental variables. Table 12 confirms that those ones were the main axis to make NMS ordination plots.

Table 12. *Increment and cumulative R-squared were adjusted for any lack of orthogonality of axes*

Axis	**r**		**Orthogonality,% = 100(1-r^2)**	
	22 years	10 years	22 years	10 years
1 vs. 2	-0.217	0.302	95.3	90.9
1 vs. 3	0.175	-0.020	96.9	100.0
2 vs. 3	-0.263	-0.086	93.1	99.3

NMS also gives information of species correlation in the 3-dimensional axis. In Umpqua fires, the most abundant species, correlated with axis 1, were *Abies concolor*, *Pseudotsuga menziesii*, *Thuja plicata* and *Tsuga heterophylla*, partial shade, to shade tolerant species. Axis 2 is related to *Calocedud decurrens*, a shade intolerant specie, and axis 3 to *Arbutus enziesii* Push, partial shade tolerant species (Appendix 1 Table 4). A different situation was found 22 years since fire, axis 1 is correlated with *Abies concolor* and *Acer macrophyllum* Purhs, both partial shade tolerant, axis 2 and 3 had more shade tolerant species, like *Calocedud decurrens*, *Thuja plicata* and *Tsuga heterophylla* (Appendix 1 Table 5).

In NMS ordination plots (Appendix 1, Figure 11 a) for Umpqua National Forest, vectors indicate the direction of correlations between axis and environmental variables. An overlap between fire severities appears related with moderate severity fires and high and low severity groups. Variables related with fire effects are the most correlated in this case, percentage of basal area mortality tends to be an important variable, in the high severity group. Old growth, on the other hand, had a slightly similarity with moderate severity group.

After 22 years (Appendix 1 Figure 11 b), there are no differences between high and moderate severities. In spite of an overlap with low severity group, this one is lower that then one in Umpqua fires. Old growth has a relationship with every fire severity, specially moderate and high. Environmental variables were more correlated with groups than fire effects.

MRPP was used to evaluate differences in community vegetation in environmental space to stratify the information across time where groups were (4=old growth, 3= moderate severity, 2= low severity, 1= high severity). A total of 96 sites and 10 species in both fire periods were studied, using Sorensen distance, the same one used to calculate nonmetric multidimensional scaling.

The average within group distance (Table 13) shows that, in Umpqua fires, group 2 (low severity) is the most dispersed. In Willamette fires, the highest value appears in old growth, but since the study is focused in the effect of fire in post-disturbance regenerate, low severity fires got the higher dispersion within groups, related with fire effects. On the other hand, the lowest value of dispersion, in Umpqua fires are high severity and moderate severity on the other fire period.

Table 13. *Average within group distance calculated from Sorensen distance in 22 and 10 years since fire.*

Average within groups distance		
Group	Sorensen	
	22 years since fire	10 years since fire
4	0.552	4.166
3	0.399	3.813
2	0.529	4.767
1	0.419	3.444
Average	0.475	4.047

The agreement statistic A, describes homogeneity within groups compared to a random expectation chance, between regeneration communities and years since fire (McCune & Grace 2002). Willamette fires are highly significant (A=0.137, p<0.001).

On the other hand, Umpqua fires are also highly significant (A=0.149, p<0.001). Values of A over zero show more homogeneity within groups than the ones expected, with a value of A=1 and delta=0, all species are identical within groups. The strength of the relationship between regeneration communities is more significant by 10 years since fire. These results reveal a higher similarity between tree regeneration within groups in 10 years since fire (Table 14).

Table 14. *Summary statistics for MRPP for 22 and 10 years since fire*

Summary statistics							
Years	Observed delta	Expected delta	Variance delta	Skewness delta	T	A	p
22	0.475	0.549	0.214E-04	-0.806	-16.101	0.137	<0.001
10	4.047	4.758	0.790E-03	-0.716	-25.271	0.149	<0.001

Indicator species analysis (ISA) was used to determine species. High severity class, in 10 years since fire, is associated with *Abies concolor* (IV=33.2, p>0.001) and *Thuga plicata*, although this specie is not a strong indicator for this group (IV= 42.0, p=0.0578). Low severity fires are associated with *Arbutus menziesii* Pursh, *Pinus lambertiana*, *Pseudotsuga menziesii* and *Tsuga heterophylla* (IV= 16.6, p=0.0374, IV=33.9, p<0.0001, IV= 32.5, p<0.001, IV=42.0, p<0.001), there are other species that appears to be associated to this group, but they are not strong indicators, that are *Calocedrud decurrens* and *Taxus brevifolia* (IV=24.7, p=0.0768 and IV=13.9, p=0.0950). Old growth, group is most associated with *Acer macrophyllum*, although those species are not strong indicators of this group (IV=10, p=0.0724). Indicator species analysis hasn't shown any specie associated with group 3 or moderate severity, in 10 years since fire (Appendix 1, Tables 6 and 7).

In Willamette fires, high severity class is strongly associated with *Abies concolor* and *Castanopsis chrysophylla* (IV= 47.9, p<0.001 and IV=20.8, p=0.0024), it is also associated with other three species, that are not strong indicates of high severity, *Pinus lambertiana*, *Taxus brevifolia* and *Tsuga heterophylla* (IV=5.6, p=0.6161, IV=9.3, p=0.2034, IV=20.8, p=0.3317).

On the other hand, moderate severity fires are strongly associated with *Arbutus menziesii* Pursh, *Calocedrud decurrens* and *Pseudotsuga menziesii* (IV=31.5, p<0.001, IV=34.4, p<0.001, IV=32.7, p<0.001). Species like *Acer macrophyllum* and *Thuja plicata* Donn, are associated with this group, although they are not strong indicators (IV=23.1, p=0.0052, IV=21.9, p=0.0712). Indicator species analysis for this group has no species associated with two of four groups, 2 (low severity) and 4 (old growth) (Appendix 1, Table 8 and 9)

Species composition in both fire periods is shown in (Appendix 1, Figure 12), where percentage of presence of species is shown, there is a change in species community distribution across severities and years since fire, where *Pseudotsuga menziesii* is the most common specie, with a change in it distribution, in 12 years of difference. Species like *Calocedrud decurrens*, *Thuja plicata* Donn and *Tsuga heterophylla* persist across fire severity with a different distribution in both fire periods. Species like *Cornus nuttallii* (a) and *Castanopsis chrysophylla* (b) are linked to specific conditions and are founded just in one of the periods.

3. Species size

MRPP gives names of groups for 1:high severity, 2: low severity and 3: moderate severity. Table 15 gives the distance calculated from Sorensen, the same one used to check species composition. The highest value in both years is on group 2 (low severity), what means that is the most dispersed group.

Table 15. *Average within group distance calculated from Sorensen distance.*

	Sorensen distance	
Group	22 years	10 years
1	0.37497745	0.52583942
2	0.59729038	0.67739636
3	0.38992964	0.48747570
Average	0.45385474	0.56357049

Chance correlated within group agreement (A), was studied in Table 16 for both study cases, for 22 years (A=0.12729, p<0.001) and for 10 years (A=0.14229, p<0.001), the highest value of A is founded in 10 years after fire, what means that trees, in terms of size, are more similar within this year. Umpqua National Forest burned mainly as very low, to low severity fires (Table 1), with higher number of individuals that survive fire through the landscape, and create conditions where shade tolerant species can regrow better than intolerant species.

Table 16. *Summary of statistics*

Summary statistics							
Year	Observed	Expected delta	Variance delta	Skewness delta	T	A	P
22	0.45385	0.591880	0.2988E-04	-0.93632	-13.1725	0.12729	<0.001
10	0.56357	0.668835	0.3703E-04	-0.95057	.15.6388	0.14229	<0.001

To determine what pair of subplots was more similar to each other, table 17 gives values for a Pairwise comparison. In Umpqua fires, the highest value of A was founded in 3vs1 (moderate severity with high severity) with a statistical significant value of A= 0.175780, p<0,001, what means that this groups are more similar each other in terms of size. In Willamette fires, the highest significant value of A is also between moderate severity with high severity, with A=0.148841, p<0.001, so there is more similarity between this groups. Total size distribution is represented in Appendix 1 Figure 13, the biggest species that were found were Sugar pine (17.17 ± 1.53), Incense cedar (13.95 ± 3.84) and Pacific yew (13.70 ± 3.54).

Table 17. *Pairwise comparisons in 22 and 10 years post fire*

	T		**A**		**p**	
	22 years	10 years	22 years	10 years	22 years	10 years
2 vs. 3	0.38866	-6.1496	-0.0039	0.0655	0.57424	0.00031
2 vs1	-11.268	-2.5158	0.1225	0.0264	0.00014	0.02552
3 vs1	-13.199	-15.593	0.1488	0.1757	0.00001	0.00001

Seedlings

The highest value of size in seedlings was measured as the biggest high class founded in a subplot, considering it the biggest tree that can be founded. Table 18 shows height classes across fire severity in both years, values represented the total of 24 subplots for each plot, and the most representative for each one. Except moderate severity in 2002, where the biggest tree was founded in height class 4 (100-150cm), the rest of the values show that the biggest trees where founded in the highest class, with trees higher that 200 cm. Species representative of height class with a measure bigger than 200 cm were, mainly, Douglas-fir, Western redcedar and Western hemlock.

Table 18. *Values of count data for the biggest height classes*

Severity	H1	H2	H3	H4	H5	H6
02HS	0	3	4	3	2	13
91HS	0	0	0	3	1	19
02LS0	0	7	6	3	3	4
91LS	2	5	6	2	1	10
02MS	0	16	7	1	0	0
91MS	0	0	0	1	2	21

Note: height classes are H1 (0-10cm); H2 (10-50cm); H3 (50-100cm); H4 (100-150cm) H5 (150-200cm) and H6 (>200cm)

DISCUSSION

The aim of this study was to determine tree natural regeneration, following different conditions of fire severity, in order to satisfy the economical and ecological demand of managers and society. This research was focused at the dry-west side of Oregon's western hemlock/Douglas-fir forest, in two fire periods, 22 years since fire at Willamette National Forest, and 10 years since fire at Umpqua National Forest, that used to burn as mixed-severity regime, even if now there is a change in fire distribution, with more frequent high severity fires. Perry et al., (2011) discuss that, forest that burn within this fire severities, were formed by large and very large fire tolerant species, even with a dense canopy overstory.

Wildfires studied in Umpqua National Forest burned mainly as very low, to low fire severities, followed by mixed severity fires, creating patches of even aged stands, and only a 5-12% of the surface is affected by high severity fires (Table 1), that kill overstory canopies and replace species composition restoring successional stages. Pre-fire composition plays an important role in regeneration after fire disturbances. Umpqua National Forest (Appendix 1, Figure 2) shows a greatest variance in species inside and outside fire borders, with presence of climax species like White-fir, Douglas-fir and Western hemlock distributed across the landscape. Western hemlock/Douglas fir forests form a plant association broadly distributed in Southwest Cascades Range in Oregon.

Conditions 10 years after fire, in Umpqua National Forest, results in a highest conifer regeneration in terms of abundance, more important in low and moderate severity fires with average of 18426 and 8328 trees/ha, consequence of the most abundant relic mature species, that survive the fire, and work as the main seed source. On the other hand, there is a lack of regeneration in high severity replacing fires where most part of live basal area was killed by fire, and seed resources are limited (Bonnet et al., 2005, Schoennagel et al., 2004), with an average density of 2832 trees/ha. The same results of post fire conifer abundances were given by Crotteau et al. (2013) and Turner et al. (1997).

The overview of conditions for 10 years since fire shows a relationship with fire severity, increasing post-fire regeneration across severities. There is a significant effect of live basal area in regeneration abundance, since overstory in very low, to low severity fires, besides patched moderate severity, produce high shade conditions, given the opportunity of seedlings adapted to this environment to establish. Although the relationship between post-fire regeneration abundance, and basal area, is negative, this trend is slight. High severity fires where taking in account separately, in such a way that those subplots affected by this severity, do not have presence of live basal area, and their regeneration were related with pre-fire basal area.

Post-fire tree composition exhibits an influence with live trees per hectare, and live basal area, and a reduction of species composition with greatest values of these variables, resulted of shade conditions in low severity fires, that favor the establishment of shade tolerant species, as the ones present at the survival overstory. On the other hand, there is a positive influence with pre-fire basal area, affecting high severity subplots. The post-fire environment may favor individual species, or abundance of individual specie. Fire severity alone is not enough to explain post-fire species abundance but shows an interaction with species composition similar found by Beckage and Stout (2000).

NMS dispersion output revealed that there is a higher dispersion of tree composition in subplots affected by low severity fires, and lowest values of dispersion were founded in high severity fires, that homogenize the landscape, where just Douglas-fir and Incense cedar showed up, as in Crotteau et al. (2013).

Analysis of species regeneration revealed that Douglas-fir has the highest presence throughout severities, with mean in trees/ha (± SE), (1935±2623.14) in high severity, (6708±6506.08) in moderate severity, and (7875±6999.28) in low severity, and it is associated with Incense cedar (4322±13846.88), Western hemlock (2923.33±7369.75) and White fir (1784±3775.8) in low severity fires that was the most extended severity in Umpqua wildfires. Douglas-fir is an off site colonizer, seeds can be carried by wind during the first and second post-fire year more important in years with heavy seed crops and can survive substantial heating and scorch without died (Hofmann, 1924). Tsuga and Thuja have been excluded of high and moderate sites, because of environmental conditions (light, humidity and temperature).

Post-fire environmental conditions can be checked with the presence of species that were found as indicator of those communities. Surprisingly, White fire is an indicator of high severity stands this specie is an aggressive shade tolerant tree and can reproduce abundantly under Douglas-fir shade being a component in ecosystems in Western hemlock/Douglas fir forest. Three species are indicators of low severity 10 years since fire, in Umpqua National Forest, Douglas-fir, that is a shade tolerant specie in dry forest of Southwest Cascades Range and may achieve climax in Southeast to Southwest facing slopes in those drier forest, Sugar pine, shade tolerant specie that coexist with Douglas-fir, and Pacific madrone, associated with hot, dry lowland within Douglas-fir and Western hemlock forest.

A second study was given in Willamette National Forest fires, primarily Warner Creek. Pre-fire communities were greatly covered by Western hemlock, with presence of Douglas-fir, White-fir and Silver/Mountain hemlock. Very low and high severity disturbances were the most representative in 1991 wildfires, with a 26.8 and 34.2% of area burned respectively. This situation is the origin of a high impact of mixed severity fires in post-fire disturbance regeneration and can be related with the idea that high severity fire regimes or stand replacing fires are associated a higher elevations, and low severity regimes, with low elevation across the burned area.

After 22 years subplots burned by mixed severity fire present the greatest value of abundance, with an average of 18227 trees/ha, followed by high severity fires, with and average of 10198 trees/ha, and low severity with 5417 trees/ha. Mixed severity fires are an intermediate disturbance between high and low severity fire regimes, and interactions between top-down forcing by climate and bottom-up shaping by topography (Perry et al., 2011). Fire creates conditions conductive to tree regeneration, as competing vegetation is reduced and total available growing space increase, that also depends on fire severity, being mixed severity fires the most complex disturbance, since they create a spatial mosaic of fire severity patterns and are extended across moisture variation. These mixed conifer forests were defined by Zenner (2005) as the "successional/gap processes" pathway where Douglas-fir dominate in every condition and a successional replacement by Western hemlock and Western redcedar is necessary to complete structural development.

Abundance distribution at this point is related with basal area, as the main variable affecting post-fire regeneration abundance, with a slight negative relationship with abundance of species, at this point, species that cannot grow in shade (full or intermediate shade intolerant species) reduce in abundance, as a result of the canopy closure. A study focused on 11 years post-fire regeneration in Warner Creek fire, was carried out by Larson and Franklin (2005), showing a positive correlation between basal area and seedling density, mainly related with Tsuga and Thuja, although it seemed a confounding factor in this example.

Not surprisingly, after 22 years, species composition is related with the historical mixed conifer Western hemlock/Douglas fir of Southwest Cascades Range. Mean values (±1 SE) for main species across severities, Douglas-fir (5720±9091.45) in high severity, (2527±3325.67) in low severity and (3566±5763.96) in moderate severity, Western hemlock, in high severity (3566±5763.96), Western redcedar in moderate severity (2435±4905.97), and Incense cedar, in moderate severity (4686±9276.38), are the most common species (Figure 15). Douglas-fir was found in high densities in every fire severity, although communities are more related to environmental conditions, in this particular case Western hemlock and Western redcedar are two of the most shade tolerant species growing in mixed conifer forest with Douglas-fir in low severity stands, pattern that can be due to local conditions like a mosaic of shade to light sites, which facilitates coexistence (Connell, 1978). In Oregon's Cascades Range, this mixed conifer forest define the climax community. Incense cedar in moderate severity subplots grows with Douglas-fir and, although it is shade tolerant it needs part of light to achieve its best status being a good indicator of mixed severities where both light and shade conditions coexist. After 22 years since Warner Creek fire shade tolerant conifer species dominate in high severity stands, with a great proportion of Douglas-fir and Western-hemlock. These results showing a change with Larson and Franklin (2005), where Tsuga and Thuja densities were low, because of stressful environmental conditions.

Environmental variables started to be important in relationship with post-fire tree composition; Northing and Latitude have a negative correlated with community composition. A change in dry conditions, favorable for mixed conifer forest in Oregon's Southwest Cascades Range reduce the number of species that can successfully grow, and wet conditions are negatives for them. Ordination plots (Appendix I Figure) give an overlap between high and moderate severity communities and low severity composition is also linked with every fire severity and old growth, this trend coincide whit what I founded in species composition. At this point, it is clear than low severity communities present the most dispersed composition related with fire disturbances.

Size was studied in two different parts, saplings and seedlings, and was done as a general study in all fire severities, and sites together. MRPP was done for saplings, to understand its distribution. In Umpqua and Willamette National Forests, the most dispersed distribution of size within groups was found in stands affected by low severity, and these results are agree with the ones found in species composition, within severities, low severity has more species and more variability in sizes. High severity communities, in Umpqua fires, has a homogeneous size, these stands are primarily dominated by Douglas-fir and Sugar pine. On the other hand, post-fire regenerate size within years is less dispersed in Umpqua fires, resulting in a bigger dispersion within groups, but groups are similar between them. Although the biggest saplings are Sugar pine, Incense cedar and Pacific yew in a general study of Umpqua and Willamette National Forest, the species more representatives in terms of abundance are Douglas-fir, Western redcedar and Western hemlock, very shade tolerant, climax species, that will dominate the forest canopy in the future.

CONCLUSIONS

Future conditions in the Western of the United States are linked with the effects of fire suppression during the 19th century, with an increase in fuel loads, and more important large fires, and climate change conditions, that may create a change in fire frequency and severity, and a shift in species composition and abundance in post-fire communities. Those conditions should be taking in account for post-fire management, commonly related with post-fire logging and reforestation. Nowadays, as a result of the increase on the number of fires, a change in their intensity and a decrease of economical resources, reforestation is starting to be questioned as the best management tool to help natural regeneration.

Post-fire landscapes are considered a starting point of secondary succession and, although there is a widespread idea that natural regeneration after these disturbances are not enough to return forests to their pre-fire situation, this study show that, 10 years since fires, in Umpqua National forest, and 22 years since fires, in Willamette National Forest, communities are related to those pre-fire conditions in both years since fire, so the lost of species specially those ones economically important in the area is not a problem, and fire by itself is not strong enough to produce a change in composition. Regeneration establishment across landscape is related by fire effects in some of the stands, and also by environmental variables.

Regeneration is highly abundant in every severity, and forest tend to be recovered after fire, although the success vary by time since fire, and sites affected by high severity fires in Umpqua National Forest, present the lowest amount of regeneration, in spite of that, the proximity of mature stands and sites with high density of survival trees will be expected to be a resource of seedlings for the future forest. Determine the size of regenerate helps to create an idea of how the future forest can grow, the biggest species in the regeneration stage, and what managers can expect.

These results mean that unmanaged stands are productive, with natural regeneration that recover the space by itself, and artificial reforestation is not necessary to improve the reestablishment of the forest. Following a disturbance, pioneer species will become establish in open areas and without any disturbance, these species will be replaced by seral species, leading ultimately to a plant community comprised of climax species so, let the forest regrow naturally reduce the loss of species, since there is no change in forest succession and a change in environmental conditions will not change species abundance or composition.

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APPENDIX 1. FIGURES AND GRAPHICAL REPRESENTATIONS

METHODS

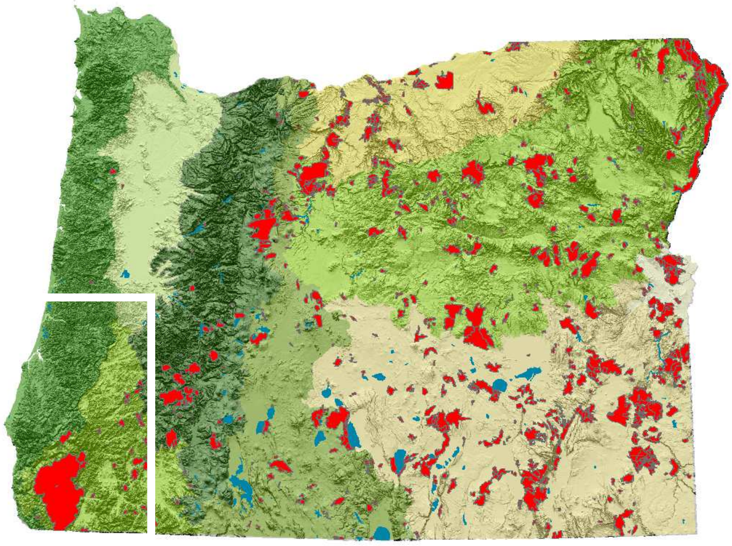


Figure 1. *(a) Recent Large Fires of Oregon*

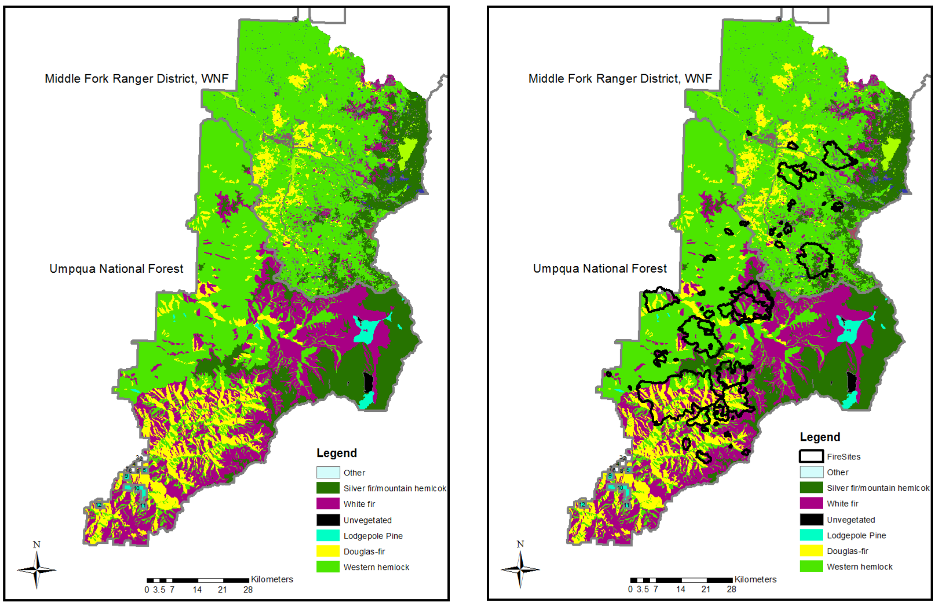
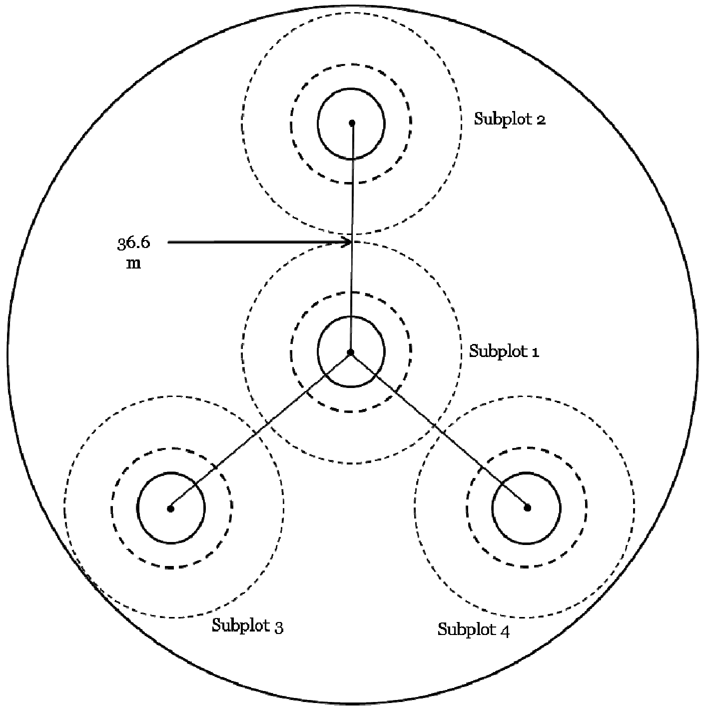


Figure 2. *(a) Dominant Forest Vegetation (b) Dominant Forest Vegetation with fire places*



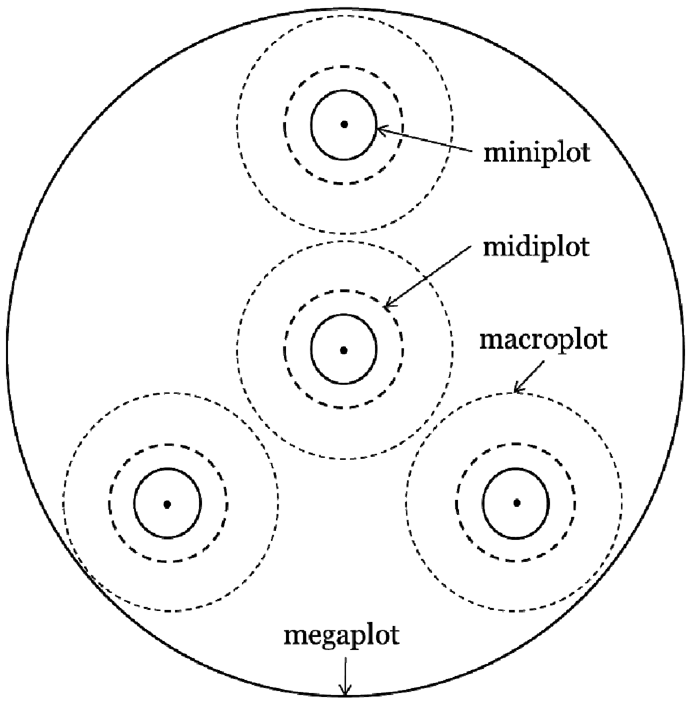
1 – ha Megaplot footprint (radius = 56.4 m)

Subplot 1 - at Megaplot center

Subplot 2 - center at random azimuth 36.6 meters from Megaplot center

Subplot 3 - plus 240 degrees from random azimuth of subplot 2 and 36.6 meters from Megaplot center

Subplot 4 - plus 120 degrees from random azimuth of subplot 2 and 36.6 meters from Megaplot center



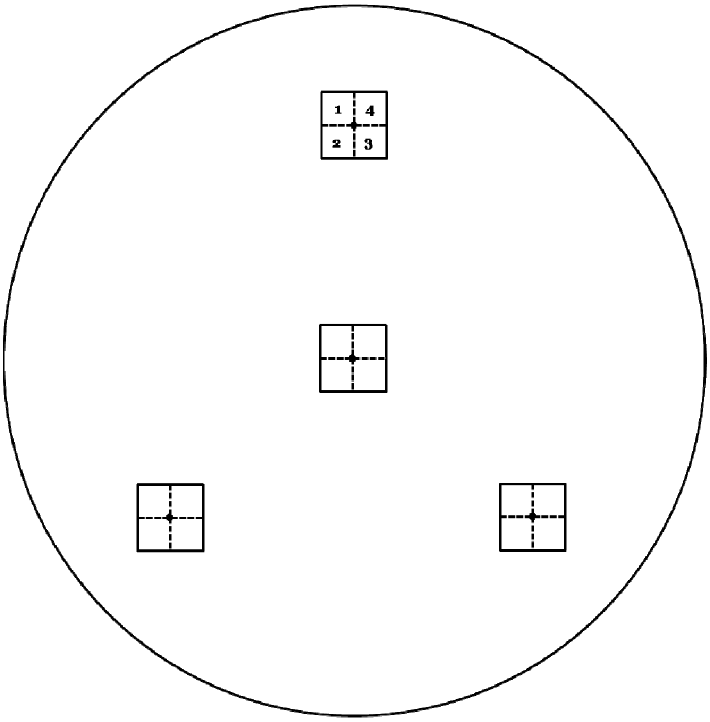
Subplot Measurements

Miniplot (2.54-10cm DBH)
5.64 meter radius
Species, height, DBH, crown ratio

Midiplot (10 – 40 cm DBH)
8.92 meter radius
Species, height, DBH, crown ratio

Macroplot (>40cm – 70cm DBH)
17.84 meter radius
Species, height, DBH, crown ratio

Megaplot (>70cm DBH)
56.42 meter radius
Species, height, DBH, crown ratio



Tree Regeneration (all trees <2.54cm DBH and smaller)
Tally regeneration by species and 10cm height class. Within tree miniplots

Figure 3. *Plot design (a) Plot layout (b) Tree sampling and saplings(c) Tree regeneration*

Table 1. *Distribution of plots across fire severity and old growth.*

Fire severity classes	**10 years Post-fire**	**22 years Post-fire**
Low Severity	6 intensive plots	6 intensive plots
Moderate Severity	6 intensive plots	6 intensive plots
Hight Severity	6 intensive plots	6 intensive plots
Mature Old Growth (reference group)	6 intensive plots	

RESULTS

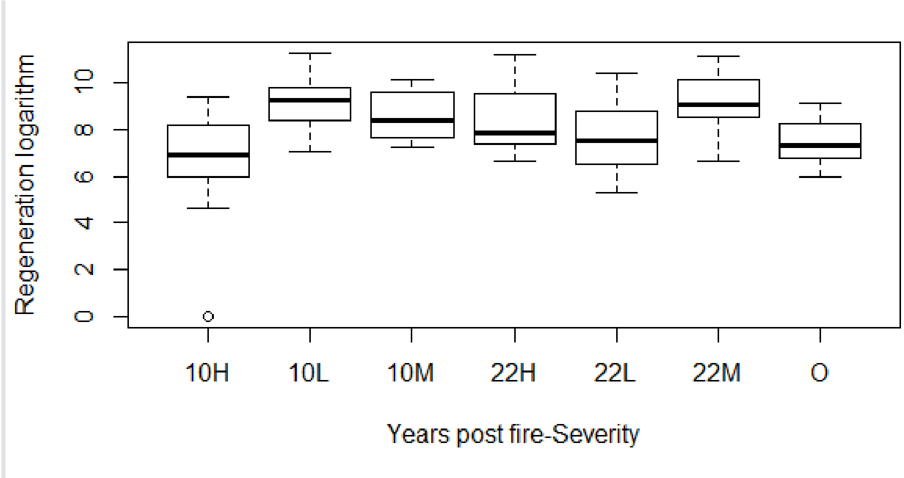


Figure 4. *Boxplot for post fire regeneration*

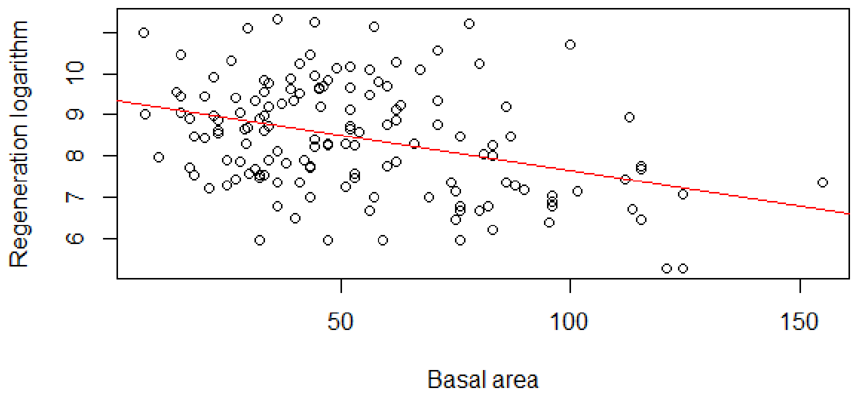


Figure 5. *Post-fire regeneration abundance as a function of basal area*

Figure 6. *Boxplot for post fire regeneration, in logarithm scale, for those subplots*

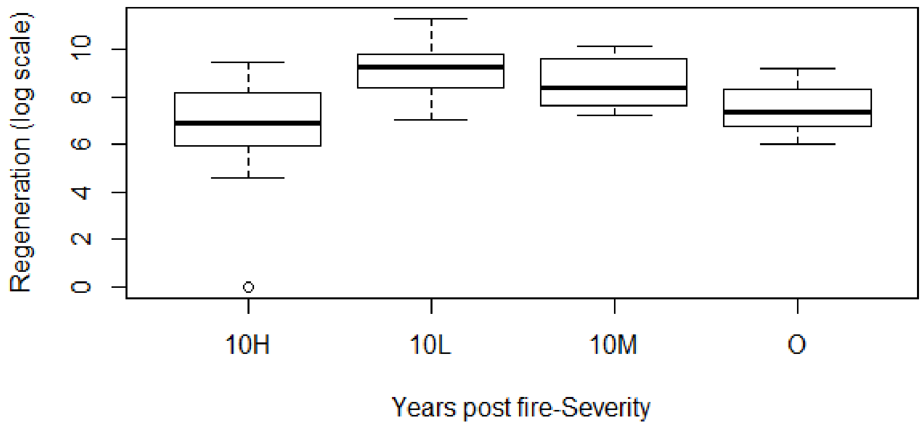


Figure 7. *Boxplot for post fire regeneration, in logarithm scale, for those subplots 10 years since fire*.

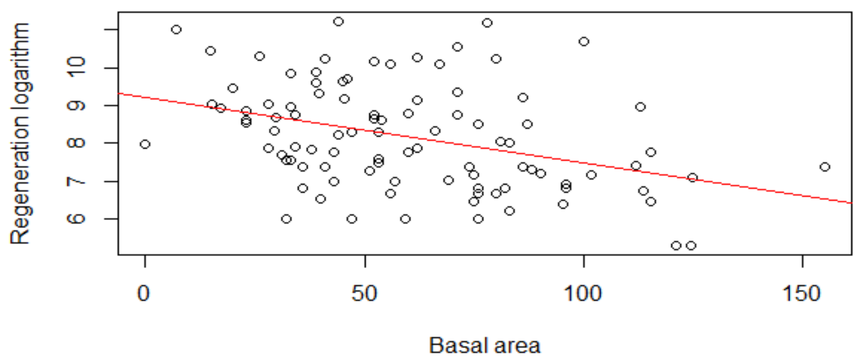


Figure 8. *Post-fire regeneration abundance in 22 years*

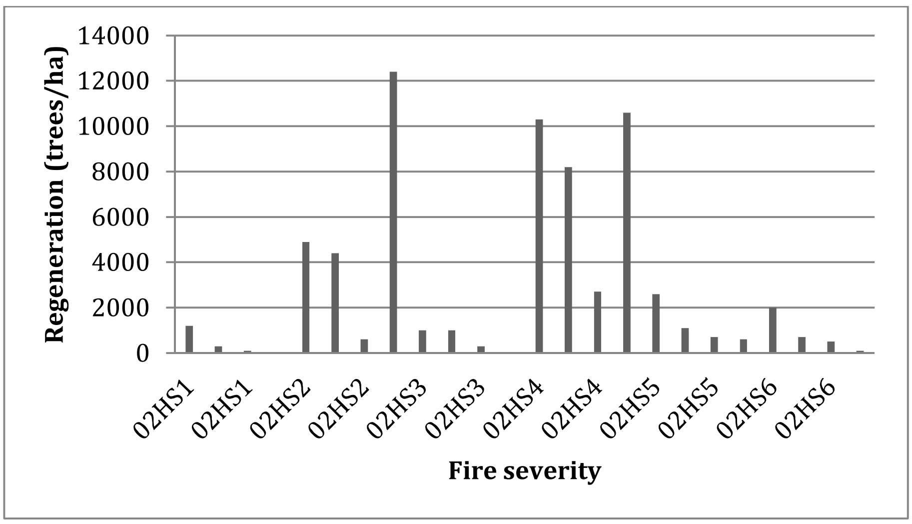


Figure 9. *Clustered column that compare regeneration in 2002 fire period in high severity fire*

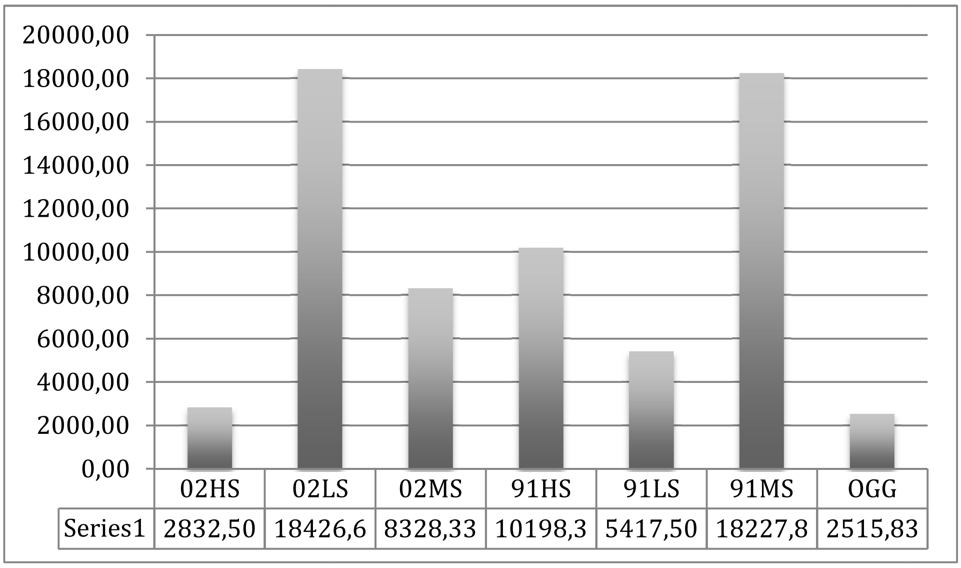


Figure 10. *Clustered column that compare average regeneration in trees across fire severity.*

Table 2. *Environmental correlations with ordination axes following Pearson and Kendall correlations 22 years since fire related to severity.*

	1			**2**			**3**		
Variable	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
SLiveQMD	-0.24	0.060	-0.19	0.062	0.004	0.052	0.325	0.106	0.212
SLiveTPH	0.468	0.219	0.169	-0.02	0.001	0.063	0.136	0.019	0.154
SLiveBA	0.160	0.026	0.059	0.000	0.000	0.047	0.166	0.027	0.149
S%BAMort	-0.22	0.051	-0.16	-0.07	0.005	-0.06	-0.31	0.098	-0.19
Aspect	-0.46	0.213	-0.17	0.004	0.000	0.039	0.069	0.005	0.143
Elevatio	0.302	0.091	0.200	-0.23	0.053	-0.15	-0.42	0.180	-0.26
Slope	-0.53	0.280	-0.37	0.296	0.087	0.202	-0.27	0.077	-0.22
HeatLoad	-0.52	0.274	-0.32	-0.01	0.000	0.076	0.040	0.002	0.119
Northing	-0.67	0.461	-0.36	0.018	0.000	0.110	-0.09	0.010	-0.06
Easting	-0.52	0.275	-0.08	0.096	0.009	-0.07	-0.11	0.013	-0.14
Latitude	-0.67	0.462	-0.36	0.017	0.000	0.110	-0.09	0.009	-0.06
PLiveBA	0.139	0.019	0.102	-0.04	0.002	0.008	0.154	0.024	0.100
PLiveTPH	0.588	0.345	0.200	0.015	0.000	0.077	0.184	0.034	0.136
PLiveQMD	-0.38	0.144	-0.30	0.190	0.036	0.043	0.248	0.061	0.179
P%BAMort	-0.36	0.130	-0.31	0.076	0.006	0.065	0.211	0.045	0.201

Table 3. *Environmental correlations with ordination axes following Pearson and Kendall correlations 10 years since fire related to severity*

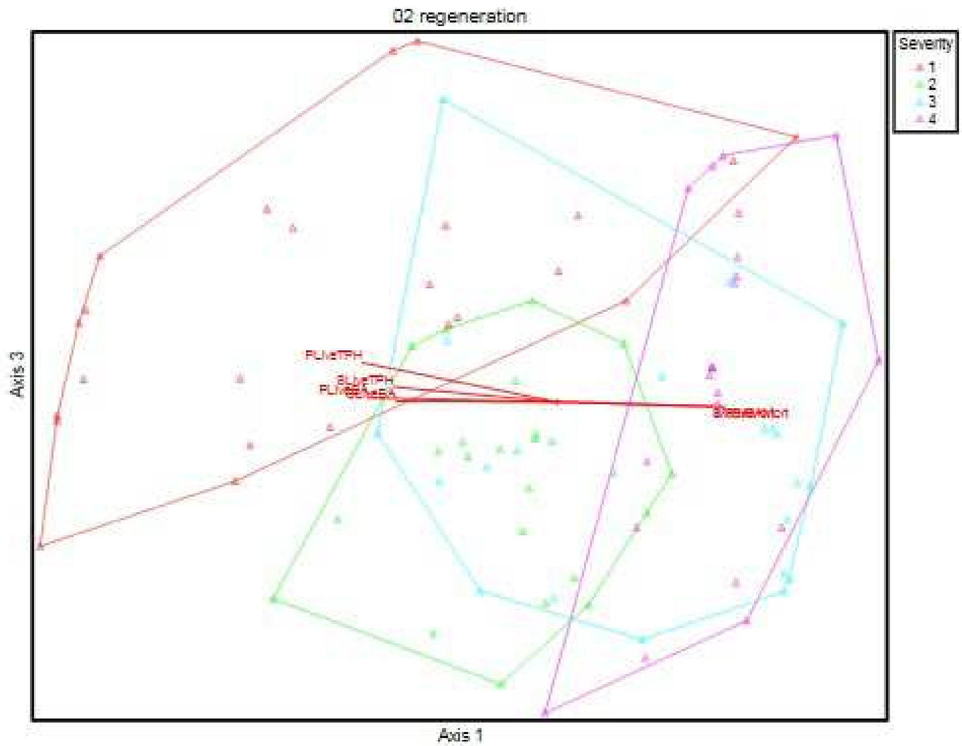
	1			2			3		
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
SLiveQMD	-0.01	0.000	0.005	-0.42	0.178	-0.25	-0.26	0.070	-0.20
SLiveTPH	-0.62	0.390	-0.47	-0.33	0.108	-0.31	0.189	0.036	0.047
SLiveBA	-0.62	0.385	-0.36	-0.48	0.234	-0.35	0.043	0.002	0.016
S%BAMort	0.608	0.369	0.398	0.483	0.234	0.280	-0.11	0.012	-0.06
Aspect	0.105	0.011	0.182	0.480	0.230	0.332	0.003	0.000	0.047
Elevatio	-0.13	0.017	-0.05	-0.01	0.000	0.038	-0.32	0.104	-0.19
Slope	0.530	0.280	0.370	0.063	0.004	-0.01	-0.24	0.059	-0.15
HeatLoad	0.074	0.005	0.135	0.217	0.047	0.116	-0.04	0.002	-0.01
Northing	-0.34	0.118	-0.06	-0.07	0.000	0.081	0.338	0.114	0.258
Easting	-0.18	0.033	-0.02	-0.29	0.084	-0.36	0.363	0.132	0.171
Latitude	-0.34	0.118	-0.06	-0.06	0.000	0.081	0.337	0.114	0.258
PLiveBA	-0.67	0.449	-0.43	-0.51	0.262	-0.37	0.095	0.009	0.082
PLiveTPH	-0.68	0.465	-0.47	-0.40	0.164	-0.31	0.308	0.095	0.135
PLiveQMD	0.089	0.008	0.097	-0.41	0.169	-0.17	0.026	0.001	-0.19
P%BAMort	0.634	0.401	0.430	.0533	0.284	0.349	-0.11	0.011	-0.09

Table 4. *Species correlations with ordination axes following Pearson and Kendall correlations 10 years since fire related to severity*

	1			2			3		
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
ABCO	-.556	.309	-.433	-.487	.237	-.362	.049	.002	.025
ACMA	.235	.055	.221	.015	.000	.012	.293	.086	.218
ARME	.124	.015	.091	-.152	.023	-.128	-.478	.229	-.423
CADE	.332	.110	.211	-.558	.311	-.417	.366	.134	.215
CONU	-.043	.002	-.035	-.129	.017	-.053	.033	.001	.005
PILA	.322	.103	.216	-.457	.208	-.375	-.550	.302	-.441
PSME	.494	.244	.087	.119	.014	-.132	-.432	.187	-.318
TABR	-.179	.032	-.188	-.321	.103	-.252	-.050	.003	-.055
THPL	-.422	.178	-.292	-.308	.095	-.253	-.002	.000	-.010
TSHE	-.694	.481	-.557	-.206	.042	-.139	-.255	.065	-.180

Table 5. *Species correlations with ordination axes following Pearson and Kendall correlations 22 years since fire related to severity*

	1			2			3		
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
ABCO	.736	.541	.582	-.226	.051	-.182	.058	.003	.023
ACMA	-.587	.344	-.489	.073	.005	.051	.161	.026	.134
ARME	-.197	.039	-.192	.137	.019	.102	.275	.076	.283
CACH	.368	.135	.281	.065	.004	.081	.116	.013	.113
CADE	-.102	.010	-.117	.698	.488	.533	.336	.113	.254
PILA	.182	.033	.164	.177	.031	.153	.159	.025	.100
PSME	-.450	.202	-.181	.065	.004	-.095	-.050	.002	.221
TABR	.210	.044	.186	-.174	.030	-.152	.128	.016	.132
THPL	-.016	.000	-.009	-.626	.392	-.466	.616	.379	.492
TSHE	.342	.117	.279	-.627	.393	-.489	.403	.162	.302



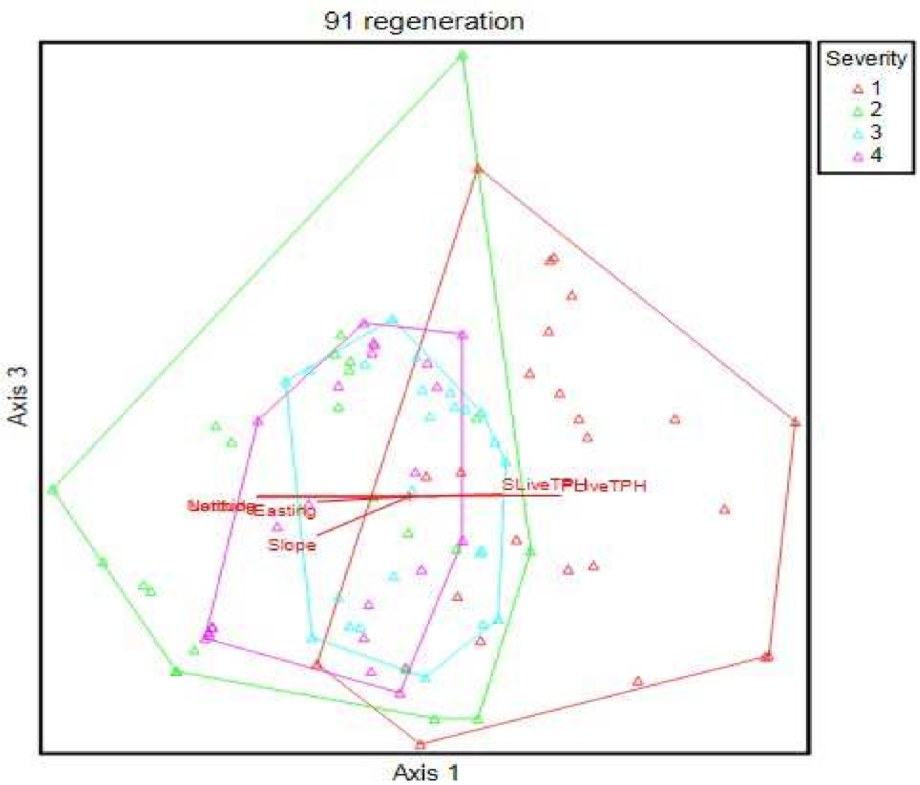


Figure 11. *NMS ordination plots for (a)10 and (b)22 years since fire. Groups are 1=old growth, 2= low severity, 3= moderate severity, 4= high severity*.

Table 6. *Indicator values, in perdentage of perfec inditacion, in 10 years since fire.*

				Groups			
			Sequence	1	2	3	4
			Identifier	4	2	3	1
			N of items	24	24	24	24
Species	Avg	Max	MaxGrp				
1 ABCO	16	33	1	0	27	2	33
2 ACMA	3	10	4	10	0	1	2
3 ARME	7	17	2	5	17	4	0
4 CADE	15	25	2	9	25	15	10
5CONU	2	4	4	4	1	1	0
6 PILA	15	34	2	3	34	23	0
7 PSME	23	32	2	25	32	29	6
8 TABR	5	14	2	0	14	1	5
9 THPL	7	16	1	2	9	0	16
10TSHE	18	42	2	1	42	3	25
Average	11	23	-	6	20	8	10

Table 7. *Monte Carlo test of significance of observed maximum indicator values for species in 10 years since fire.*

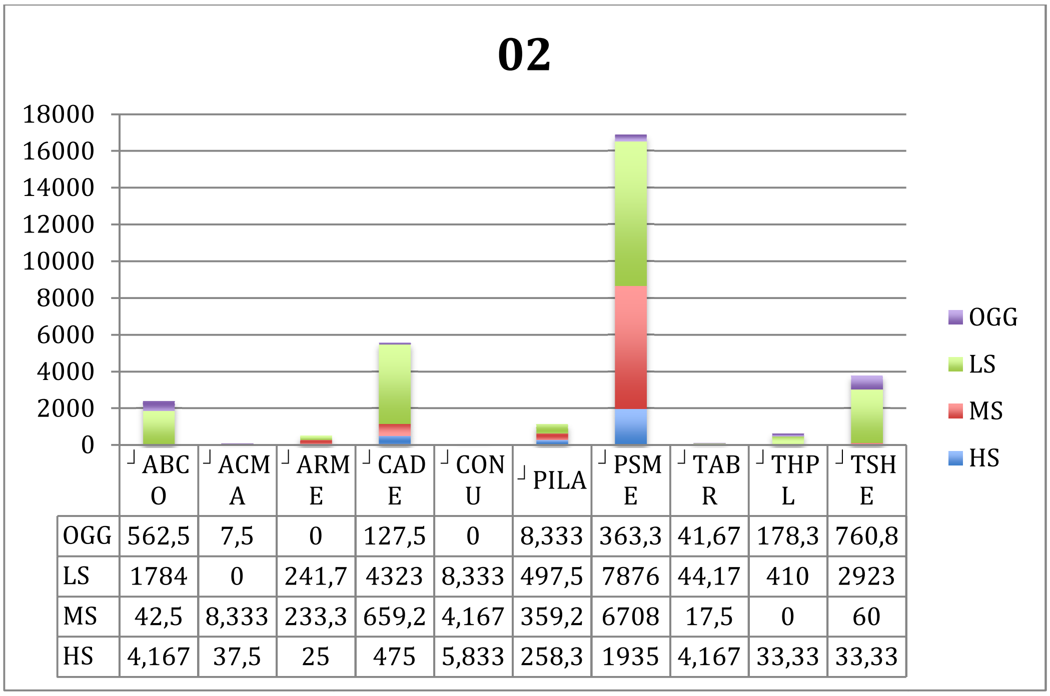
		IV from randomized groups		
Species	Observed indicator value (IV)	Mean	S.Dev	p
1 ABCO	33.2	16.3	3.41	0.0008
2 ACMA	10.0	6.2	2.94	0.0724
3 ARME	16.6	9.9	3.19	0.0374
4 CADE	24.7	20.0	3.07	0.0768
5CONU	3.8	4.9	2.61	0.8972
6 PILA	33.9	16.5	3.26	0.0004
7 PSME	32.5	25.6	1.73	0.0002
8 TABR	13.9	8.9	3.23	0.0950
9 THPL	15.7	9.8	3.16	0.0578
10TSHE	42.0	18.5	3.22	0.0002
Average	22.6	13.7	2.98	0.1238

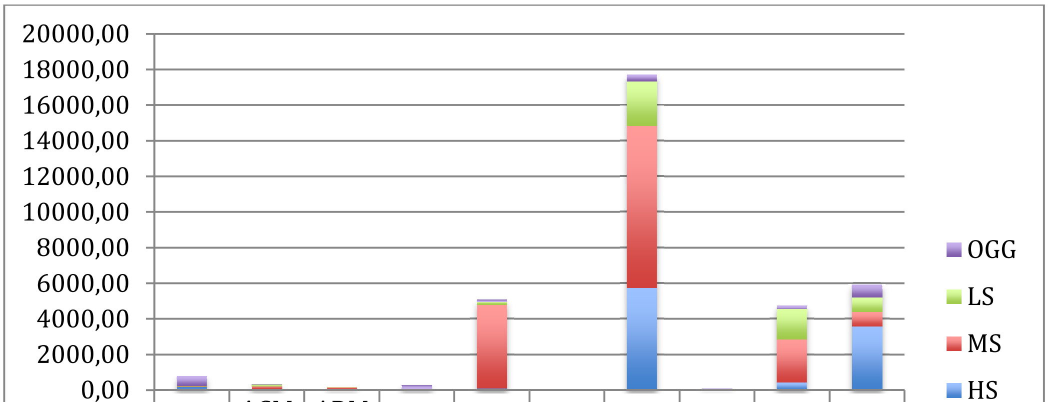
Table 8. *Indicator values, in perdentage of perfec inditacion in 22 years since fire.*

					Groups		
			Sequence	1	2	3	4
			Identifier	4	2	3	1
			N of items	24	24	24	24
Species	Avg	Max	MaxGrp				
1 ABCO	14	48	1	7	0	1	48
2 ACMA	10	23	3	0	18	23	1
3 ARME	8	32	3	0	0	32	0
4 CACH	5	21	1	0	1	0	21
5 CADE	14	34	3	2	6	34	12
6 PILA	2	6	1	0	1	0	6
7 PSME	23	33	3	30	23	33	6
8 TABR	3	9	1	2	0	1	9
9 THPL	11	22	3	8	9	22	6
10TSHE	14	21	1	13	9	14	21
Average	10	25	-	6	7	16	13

Table 9. *Monte Carlo test of significance of observed maximum indicator values for species in 22 years since fire.*

		IV from randomized groups		
Species	Observed indicator value (IV)	Mean	S.Dev	p
1 ABCO	47.9	13.4	3.32	0.0002
2 ACMA	23.1	11.7	3.22	0.0052
3 ARME	31.5	7.8	3.13	0.0002
4 CACH	20.8	6.2	2.93	0.0024
5 CADE	34.4	17.1	3.30	0.0006
6 PILA	5.6	4.3	2.77	0.6161
7 PSME	32.7	25.4	1.74	0.0002
8 TABR	9.3	6.2	2.96	0.2034
9 THPL	21.9	16.5	3.35	0.0712
10 TSHE	20.8	20.0	3.12	0.3317
Average	24.8	12.9	2.98	0.1231





	ABCO	ACMA	ARME	CACH	CADE	PILA	PSME	TABR	THPL	TSHE
OGG	562,5	7,50	0,00	225,0	127,5	8,33	363,3	41,67	178,3	760,8
LS	4,17	130,8	4,17	66,67	160,0	4,17	2527,	0,00	1701,	804,1
MS	35,00	179,1	141,6	0,00	4686,	0,00	9085,	12,50	2435,	808,3
HS	175,0	0,00	8,33	0,00	104,1	0,00	5720,	20,83	416,6	3566,

Figure 12. *Cluster column that compare species distribution across fire severity in (a) 10 and (b) 22 years since fire.*

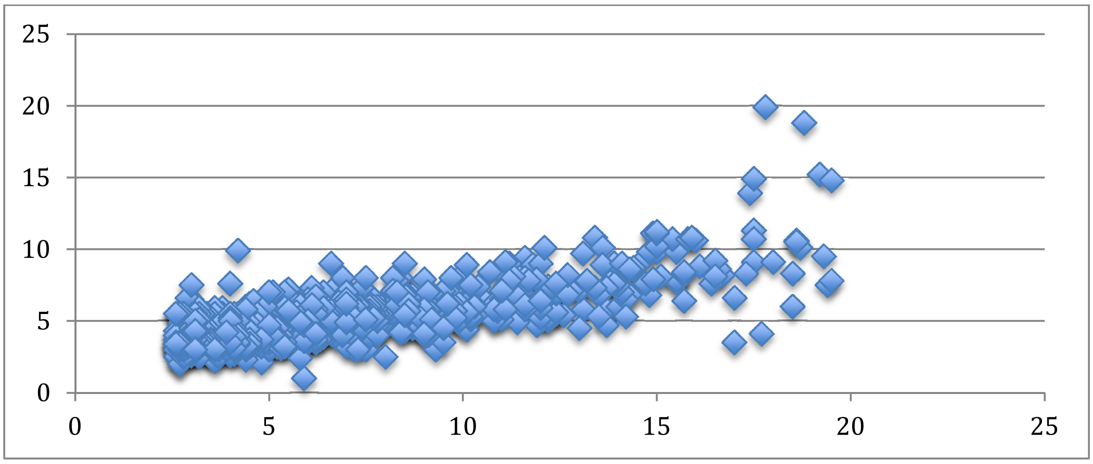


Figure 13. *Total saplings size*

Table 10. *Average and standard error of saplings size*

Species	Average	Standard error
ACMA	6.06	1.71
ARME	5.65	1.06
CACH	5.85	1.32
CADE	13.95	3.84
CONU	8.07	4.63
PILA	17.17	1.53
PSME	6.09	3.18
TABR	13.22	3.39
THPL	7.43	6.94
TSHE	5.12	2.88