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Article

Efecto de la corta de matarrasa en la diversidad de la regeneración arbórea en Durango, México

Effect of clearcutting on tree regeneration diversity in *Durango*, Mexico

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Resumen

Con el propósito de incrementar la producción y productividad de los bosques en el estado de Durango, se realizaron cortas a matarrasa en rodales naturales de *Pinus* y *Quercus* que fueron sustituidos por plantaciones con dos especies de *Pinus*. El objetivo de este trabajo fue evaluar el efecto de las cortas de matarrasa con plantaciones inmediatas en la diversidad arbórea de la regeneración. El estudio se realizó en tres plantaciones comerciales dentro del ejido La Ciudad, Pueblo Nuevo, Durango; en cada una se establecieron 20 sitios de 150 m^2 en donde se registró la especie y el diámetro a la base de cada brinzal. Para comparar la diversidad de las plantaciones con la de los rodales adyacentes, que representan la condición original, se ubicaron diez sitios de 0.1 ha en los que se identificó la especie y se midió el diámetro normal de cada árbol presente. Para evaluar la diversidad alfa y beta se utilizaron los índices de riqueza, abundancia proporcional de *Shannon*-*Wiener*, similitud de *Jaccard* y *Sörensen*, así como el valor de importancia ecológica. Los cambios significativos en la riqueza y diversidad, se compararon con un análisis de rarefacción; el cual mostró cambios significativos en la riqueza de especies en una de las tres plantaciones, mientras que la diversidad evidenció diferencias significativas en dos de ellas, con respecto a los rodales adyacentes. Las cortas de matarrasa con plantación inmediata mantienen la riqueza de especies, pero modifican la diversidad.

Palabras clave: Bosques de pino, cortas totales, índices de dominancia, índices de similitud, plantaciones forestales, rarefacción.

Abstract

In order to increase the forest production and productivity in *Durango* State, clearcuttings with plantations of two pine species were made in natural stands of *Pinus* and *Quercus* species. The objective of the present study was to evaluate the effect of clearcuttings with plantations in the diversity of tree regeneration. This study was carried out in three commercial plantations in the *Ejido La Ciudad Pueblo Nuevo, Durango*. Twenty plots of 150 m^2 were established at each plantation where the species name and diameter al the base of each individual sapling were recorded. In order to compare the diversity of the regeneration against natural stands that represent the original diversity that sustained the clearcutting areas, ten plots of 0.1 ha were located in the neighboring stands to register species name and diameter al breast height of each individual. Alfa and beta diversity as well as structure were evaluated using species richness, Shannon-Weiner, Jaccard, Sörensen and species importance value indexes. Rarefaction analysis was used to compare species richness and diversity. The rarefaction analysis indicated significant changes in species richness in one of the three plantations; diversity was significantly different in two of the three plantations in regard to the adjacent stands. Clearcutting tends to keep species richness and to modify species diversity.

Key words: Pine forest, clearcutting, dominance index, similitude index, forest plantations, rarefaction analysis.

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Introduction

The study of the causes and effects of natural and man-made forest disturbances are important to develop sustainable management strategies. The current characteristics of a specific habitat are the product from natural and induced events that have occurred in the past (Kneitel, 2010), which have modified the diversity, composition and structure of the forests under management (Kuuluvainen, 2002; Hernández *et al.*, 2013).

When management systems are adopted for the formation of regular forests, the aim is to increase the production and productivity of wood, and the structure and diversity of tree species are simplified (Castellanos *et al*., 2008). This has been considered as one of the main factors that have promoted the changes and the reduction of ecosystem functions, as well as the limitation of the level of productivity of a site on a spatial and temporal scale (Monárrez *et al*., 2018).

Regardless of the desired structure (regular or irregular), forest management must consider the production of goods and services in a sustainable way. The main challenge is the management and use of forests and forest lands, conserving biological diversity, productive and regeneration ability through the application of forestry treatments (Aguirre, 2015).

In particular, the clearcutting regeneration method with immediate plantations promotes the renewal of the stand with fast-growing species, thus improving the richness and diversity of trees (Návar and González, 2009). However, in addition to the presence of the planted species, the spontaneous establishment of all the tree species that were there before the application of such cutting may arise, either through seed stored in the ground or from neighboring trees to the cutting area, as well as the vegetative reproduction capacity of some of them (Smith *et al.,* 1997).

This forestry practice included in forest management programs has been carried out in the *Pinus* and *Quercus* forests in the state of *Durango* and has impacted the biodiversity of woods at a local and regional scale (Corral *et al*., 2005; Solís *et al*., 2006). Therefore, the objective of this research study was to assess the effect of clearcutting on tree diversity of commercial forest plantations in the *La Ciudad ejido, Pueblo Nuevo, Durango.*

Materials and Methods

Study area

The climate is semi-cold subhumid with rains in summer with average annual temperature between 5 °C and 12 °C, the temperature of the coldest month varies between -3 °C and 18 °C with a percentage of winter precipitation between 5 and 10.2 % (García, 1973). The Edaphological Chart Series II indicates that the soil is classified as Regosol (INEGI, 2010) and the arboreal vegetation is composed by species of the *Pinus* and *Quercus* genera (Soil Use and Vegetation Chart Series VI).

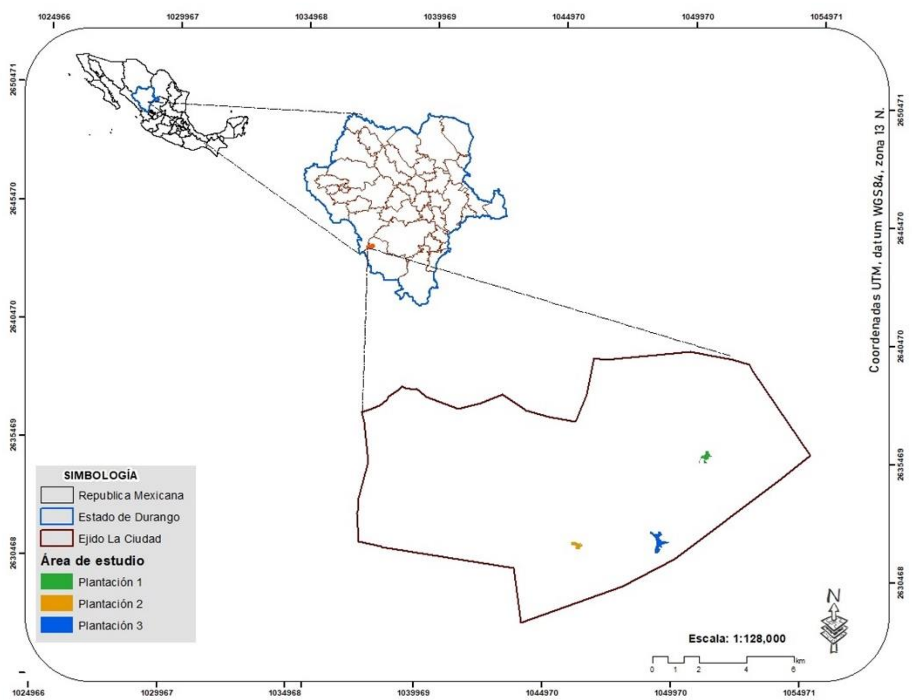


Figure 1. Location of the studied plantations at the *ejido* and state context.

Sample selection

Sampling considered the selection of three areas in which mulch cuttings were applied with immediate planting in the summer of 2010 and the adjacent stands (RA) with tree vegetation established naturally and that represent the conditions that existed within the plantation areas before the application of clearcuttings. The species only planted at spacing of 3 × 3 m were *Pinus cooperi* Blanco and *Pinus durangensis* Martínez (50 % for both species), from nurseries in the study region, with one year of age, which are the species with the highest growth and economic value in the region. The plantation areas were named: plantation 1 (P1), with an area of 10.29 ha, plantation 2 (P2) with 12.45 ha and plantation 3 (P3) with 9.43 ha. Starting from the center of each plantation and in the direction of the cardinal and subcardinal points, 20 circular sites of 150 m^2 were located at a distance of 25 m between them (60 sites).

In order to evaluate the changes that occurred in the tree diversity of the plantations, a comparison was made of it with the vegetation of the RA, which were called RA1, RA2 and RA3. In function of the same directions of the plantations towards the RA, ten sites of 0.1 ha (30 sites) were located within each one.

At both the plantation and RA sites, all trees were identified by genus and species. In the case of the plantations, the diameter at the base was measured with a Truper™ Caldi-6MP caliper and for the RA the normal diameter at the height of 1.30 m with a Haglöf Mantax 59722 caliper, as the RA had regular diametric structures, with ages close to the forestry shift and, therefore, there is little presence of shoots.

Data analysis

From the information on the number of new species per site, the accumulated richness curves were obtained, to justify that the sampling effort was enough and included most of the species present both in the plantations and in the RAs (Dzib *et al.*, 2014).

The description and comparison of the alpha diversity of the plantations and the RAs was carried out with the species richness indexes (*S*) and the Shannon-Wiener diversity index (H). The species richness index was defined as the total number of species present within each plantation and adjacent stand, while H 'was estimated from the sum of the multiplications of the proportions of the abundances of each species (pi) by the logarithm natural (ln) of these proportions:

$$H' = -\sum pi(\, ln\, pi) \quad (1)$$

To evaluate the occurrence of significant changes in *S* and H' between each plantation and its adjacent stand, considering the latter the one that represents the natural conditions of the forest, a rarefaction analysis was made from the number of species and abundances per sample, using the Estimates 9.1.0 program (Colwell and Elsensohn, 2014). Through a Monte Carlo simulation process, this method estimates an average and variance of *S* or H' for each sample size and, thereby, generates confidence intervals, which allow statistical comparisons to be made at a desired level of significance (0.05 % for this study) to the minimum sample size recorded (Gotelli and Colwell, 2011). In this study, the minimum of samples was obtained in the RA (10 sites) compared to the plantations (20 sites).

Similitude indexes

To evaluate the level of species replacement, originated by the application of clearcutting with plantations against the RA, the qualitative similitude indexes of Jaccard (I_j) and Sörensen ((I_s) were applied.

$$I_j = \frac{c}{a+b-c} \quad (2)$$

$$I_s = \frac{2c}{a+b} \quad (3)$$

Where:

a = Number of species in the plantation

b = Number of species in the adjacent stand

c = Number of species common to both areas

The range of values of both indices goes from zero when there are no shared species, up to one, when the two sites share the same species. The I_j measures differences in the presence or absence of species, while the I_s relates the number of species in common in regard to all the species found in the two areas (Magurran, 1988).

Importance Value Index

The species importance value index (IVI) was estimated to evaluate the existence of structural changes in the species composition as a consequence of the application of the slaughterhouse cut with plantation. The IVI, developed by Curtis and McIntosh (1951), consists of adding the relative values of density (Ab_r), dominance (D_r) and frequency (F_r). This synthetic structural index is mainly oriented to rank dominance by species in mixed stands (Sánchez *et al.,* 2018). According to Alvis (2009), the general expression of the IVI is the following:

$$IVI = Ab_r + D_r + F_r \qquad (4)$$

Where:

Abr = Ratio of the number of trees per species (n_i) over the total number of trees of all species (n).

$$Abr = \frac{n_i}{n} \times 100 \qquad (5)$$

Dr is equal to the basimetric area of each species (AB_i) over the total basimetric area of the species (AB).

$$Dr = \frac{AB_i}{AB} \times 100 \quad (6)$$

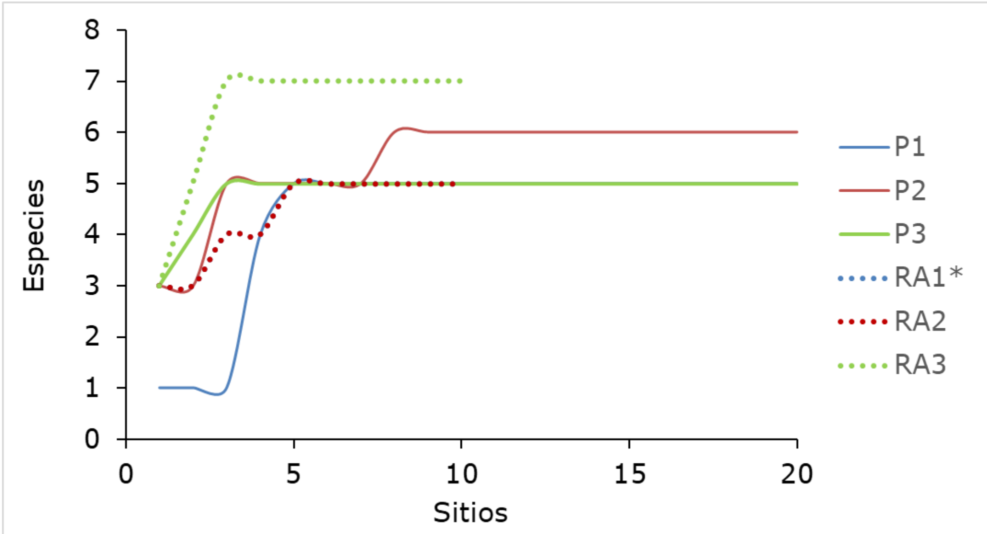
Fr is the ratio of the number of sites in which each of the species is present (F_i) over the sum of the number of sites in which all the species are present (F).

$$Fr = \frac{F_i}{\sum F} \times 100 \quad (7)$$

Results and Discussion

Richness and diversity

The number of species in a community is an expression by which a quick and easy estimate of diversity is obtained (Jiménez, 2000). Figure 2 shows the starting point of the upper asymptote of the species accumulation curves, deducing that the sample size was sufficient to record the richness of species present in the plantations and in the adjacent stands (Magurran, 2004).



*RA1 curve cannot be appreciated as it is identical to RA2.

Figure 2. Species accumulation curves from the sampling of the three plantations and adjacent stands.

Within the study area (plantations and adjacent stands), a total of eight species were recorded, distributed in the *Pinus, Quercus, Juniperus* and *Arbutus* genera. Between P3 and RA3 the greatest difference of species (two species) was detected, while P2 and RA2 differed only by one species, and no differences were found between P1 and RA1 (Table 1). In general terms, the total species richness recorded in this research is greater than the seven recorded by Hernández *et al.* (2013) for the forests of *Chihuahua*. In a similar way, Návar and González (2009) calculated 7 to 7.8 species average in areas without forestry treatment (0 % removal) in a study carried out in temperate forests of *Durango*. Likewise, they determined a gradual decrease in the number of species as the percentage of removal from the basal area increased, which was calculated up to 5.7 species on average with the clearcutting treatment (100 % removal).

Table 1. Present species in the plantations and adjacent stands in the *Pueblo Nuevo* region, *Durango*.

No.	Species	P1	P2	P3	RA1	RA2	RA3
1	*Arbutus xalapensis* Kunth	1	1	1	0	0	1
2	*Juniperus deppeana* Steud.	1	1	1	1	1	1
3	*Pinus cooperi* Blanco	1	1	1	1	1	1
4	*Pinus durangensis* Martínez	1	1	1	1	1	1
5	*Pinus engelmannii* Carr.	0	0	0	1	1	0
6	*Pinus leiophylla* Schiede ex Schltdl. & Cham.	0	0	0	0	0	1
7	*Quercus rugosa* Nee	0	1	0	0	0	1
8	*Quercus sideroxyla* Humb.& Bonpl.	1	1	1	1	1	1
	Total number of species	5	6	5	5	5	7

P1 = Plantation 1; RA1 = Adjacent stand 1; P2 = Plantation 2; RA2 = Adjacent stand 2; P3 = Plantation 3; RA3 = Adjacent stand 3; 1 = Present; 0 = Absent.

The rarefaction curves indicate that the species richness of P3 is significantly lower than that of RA3. This agrees with the studies by Corral *et al.* (2005) and Vásquez-Cortez *et al.* (2018) coincided in the argument that the number of species that are shared can decrease in an area when carrying out forestry treatments. The curves of P1 and P2 with their adjacent stands indicate that the richness of species tends to maintain significantly the same number of taxa compared to the adjacent stands (Figure 3). In this sense, Leyva-López *et al.* (2010) and Hernández *et al.* (2013) pointed out that the application of intensive felling to promote regeneration (parent trees) does not only guarantee the establishment of the renewal of trees of the genus selected as parent tree, because within the intervened areas there are other species with different regeneration mechanisms. In this study, not only planted species of *Pinus* were established in both P1 and P2, but also the emergence of other pine species was confirmed.

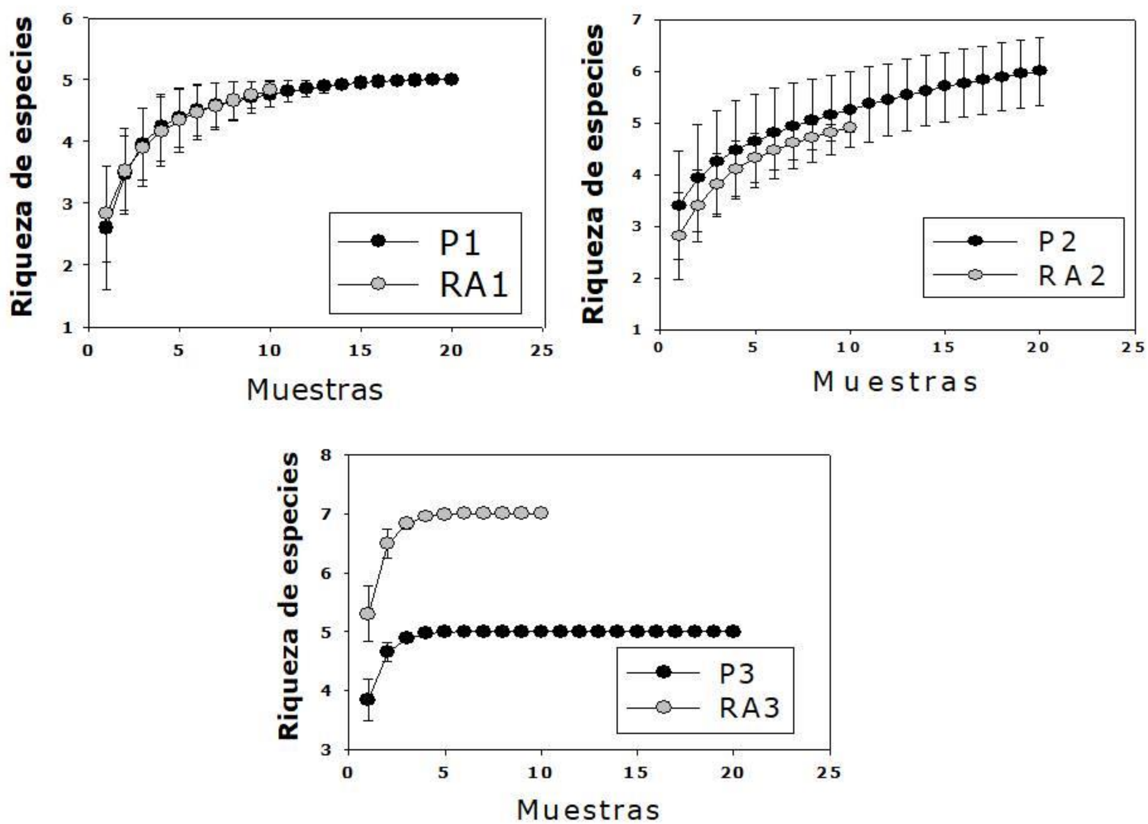


Figure 3. Rarefaction graphics constructed for species richness (95 % confidence).

In Figure 4 it is observed that there is no overlap in the confidence intervals in the Shannon proportional diversity index between the P2 and P3 plantations with their respective adjacent stands, which shows that there are significant differences between the forest diversity of these plantations and its adjacent stands. While between P1 and RA1 no significant changes were observed, indicating that both species richness and their proportion were similar.

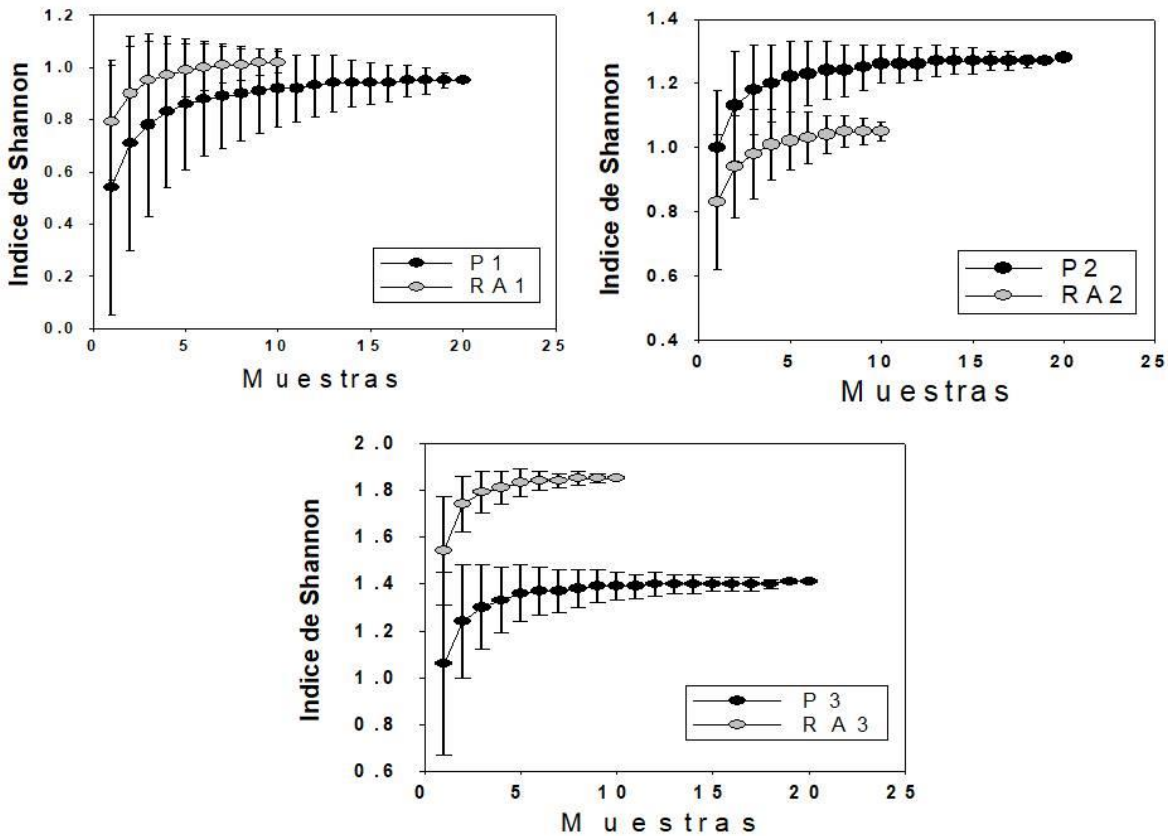


Figure 4. Rarefaction graphics constructed for the Shannon-Wiener proportional diversity (95 % confidence).

For P2 and its RA, the rarefaction curves based on species richness did not confirm significant differences (Figure 3). However, if they existed for H'. This characteristic coincides with that mentioned by Del Río *et al*. (2003) and Hernández *et al*. (2013), who recognized that the periodic application of forestry practices, although they can maintain the richness of tree species, tend to change the proportional abundance of the number of individuals of each of the species and, with it, the diversity.

Similtude indexes

When evaluating the similarity of the species present in the plantations with the adjacent stands, the Jaccard and Sörensen indexes supported the fact that the species composition between P3 and RA3 has greater similitude (five species in common) compared to the other plantations and its adjacent stands, which were less similar (Table 2).

Table 2. Similitude indexes of the plantations and their adjacent stands.

P *vs* RA	I_J	I_S
1	0.66	0.80
2	0.57	0.72
3	0.71	0.83

P = Plantation; RA = Adjacent stand; I_J = Jaccard similitude index; I_S = Sorensen similitude index.

Of the total number of species rerecorded in the study area, *P. durangensis, P. cooperi, Quercus sideroxyla* Humb.& Bonpl. and *Juniperus deppeana* Steud. are present both in the plantations and in the RAs (Table 1). In regard to the species registered in the areas treated with cuttings, most of the individuals of *P. durangensis* and *P. cooperi* come, mainly, from the plantation, while *Q. sideroxyla, Q. rugosa* Née, *J. deppeana* and *Artus xalapensis* Kunth sprouted by seeds contained in the soil or by vegetative reproduction. In this sense, the similarity of species as well as the difference in the number of them can be explained from the establishment and development strategies that each species shows in response to the kind and degree of disturbance to which it was exposed (Leyva-López *et al.,* 2010).

On the other hand, Hernández *et al.* (2013) determined that as the forest mass prospers after being intervened, a smaller number of species are shared, but their richness in the forest is maintained. This coincides with this study, although the similarity between P2 and RA2 was 0.57 for I_j and 0.72 for I_s, the difference between these areas was only one species, and for P2 and RA2 the similarity was I_j = 0.66 and I_s= 0.80; however, the same number of species was observed, while between P3 and RA3 there was a greater difference in richness (2 species) but the similarity was greater than for the other areas.

Importance Value Index

If RAs are considered as the original condition and that it was modified by the plantations, it is observed that *P. cooperi* remained as the species with the highest IVI in P2 and RA2; in the same way, *P. durangensis* did not undergo changes in the IVI between P3 and RA3, but in P1 it displaced *P. cooperi* from RA1 with the highest IVI. In contrast, the absence of *P. engelmannii* Carr. and *P. leiophylla* Schiede ex Schltdl. & Cham. stands out in the plantations with respect to their adjacent stands where they were present (Table 3).

J. deppeana did not undergo considerable modifications in the IVI in any of the plantations. *Q. sideroxyla* increased its IVI position in the three plantations and *A. xalapensis* emerged in P1 and P2, but was not identified in their RA (Table 3).

In general, it would be expected that only the species of *P. durangensis* and *P. cooperi* would be observed in the plantations in the same proportion as they were plants (50 % for each species). However, it is important to mention that both these species and other native ones can emerge spontaneously by seed deposited in the soil before and during cutting, seed from adjacent stands or the vegetative way, from the new conditions that arise in each area. Based on the above, Oliver and Larson (1996) and Leyva-López *et al*. (2010) mentioned that the presence of a greater or lesser number of species within the studied areas is due to the capacity of each of them to reproduce or regenerate in a vegetative, as well as its vulnerability to the level of disturbance, stress and competition. Furthermore, Vásquez-Cortez *et al.* (2018) recognized that the areas surrounding the clearcuttings can limit the dominance of the plants and the loss of tree and shrub diversity.

Table 3. Ecological Importance Value Index of the species.

Species	**P1**	**RA1**	**P2**	**RA2**	**P3**	**RA3**
Arbutus xalapensis Kunth	51.98	0.00	31.34	0.00	37.46	48.72
Juniperus deppeana Steud.	50.98	75.97	75.99	84.37	60.07	50.63
Pinus cooperi Blanco	17.14	116.84	92.39	119.51	56.55	43.57
Pinus durangensis Martínez	130.18	47.80	39.65	51.56	91.17	52.28
Pinus engelmannii Carr.	0.00	21.64	0.00	17.63	0.00	0.00
Pinus leiophylla Schiede ex Schltdl. & Cham.	0.00	0.00	0.00	0.00	0.00	29.10
Quercus rugosa Née	0.00	0.00	1.95	0.00	0.00	30.94
Quercus sideroxyla Humb.& Bonpl.	49.70	37.74	58.64	26.90	54.72	44.72
Sum	300	300	300	300	300	300

P1 = Plantation 1; RA1 = Adjacent stand 1; P2 = Plantation 2; RA2 = Adjacent stand 2; P3 = Plantation 3; RA3 = Adjacent stand 3.

In regard to *Juniperus*, Rzedowski (1981); Bakker *et al.* (1996) and Biondi and Ferrante (2004) mentioned that this genus has the ability to colonize degraded places and is part of secondary vegetation; these trees are early onset and their presence is associated with disturbances caused by human activities. This suggests a possibility of greater repopulation and development of the genus when the level of competition and shade are significantly reduced by silvicultural interventions. In a similar way, Leverkus *et al.* (2014) stated that *Quercus* species re-sprout very favorably in burned and degraded areas, which gives them resilience to the forests they comprise.

On the other hand, although there is little information on the regrowth capacity of *Arbutus* after cutting, a high incidence of new specimens was observed in the study area. In this regard, Díaz-Hernández *et al*. (2014) confirmed a high probability of *Arbutus* regrowth in an area with disturbance caused by a forest fire.

Conclusions

The results of this study support the conclusion that clearcuttings with plantations carried out in mixed forests can keep species richness; however, diversity is significantly affected in two of the three plantations with in regard to their adjacent stands.

Despite the fact that all tree species were completely removed in the cuttings and only specimens of *P. durangensis* and *P. cooperi* were planted, the similarity of species between the plantations and the adjacent stands is high, due to the spontaneous emergence from other native species present before felling and under the influence of neighboring stands. This allowed the importance value index of the species to maintain a similar structure, hierarchy and dominance between the species of the plantations and the adjacent stands.

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Yadira Yesenia Guevara Fisher: data collection at the field, data capture and analysis and writing of the original manuscript; Francisco Cruz Cobos: data collection at the field, data and statistical analysis, interpretation of results and review of the manuscript; Francisco Javier Hernández: data and results analysis and review of the manuscript; Juan Abel Nájera Luna: statistical analysis and review of the final manuscript; Francisco Cruz García: interpretation of results and review of the manuscript; Gerónimo Quiñonez Barraza: data analysis, interpretation of results and review of the manuscript.

References

Aguirre C., O. A. 2015. Manejo forestal en el siglo XXI. Madera y bosques 21:17-28. Doi:10.19136/era.a4n12.1114.

Alvis G., J. F. 2009. Análisis estructural de un bosque natural localizado en zona rural del Municipio de Popayán. Biotecnología en el Sector Agropecuario y Agroindustrial 7(1):115-122. http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S1692-35612009000100013&nrm=iso (3 de mayo de 2020).

Bakker, J. P., E. S. Bakker., E. Rosén G., L. Verweij and R. M. Bekker. 1996. Soil seed bank composition along a gradient from dry alvar grassland to Juniperus shrubland. Journal of Vegetation Science 7(2):165-176. Doi:10.2307/3236316.

Biondi, E. and L. Ferrante. 2004. Demographic and spatial analysis of a population of *Juniperus oxycedrus* L. in an abandoned grassland. Plant Biosystems 138(2):89-100. Doi:10.1080/11263500412331283735.

Castellanos B., J. F., E. J. Treviño G., Ó. A. Aguirre C., J. Jiménez P., M. Musalem S. y R. López A. 2008. Estructura de bosques de pino pátula bajo manejo en Ixtlán de Juárez, Oaxaca, México. Madera y bosques 14(2):51-63. https://doi.org/10.21829/myb.2008.1421212.

Colwell, R. K. and J. E. Elsensohn. 2014. EstimateS turns 20: statistical estimation of species richness and shared species from samples, with non-parametric extrapolation. Ecography 37(6): 609-613. Doi: 10.1111/ecog.00814.

Corral R., J. J., O. A. Aguirre C., J. Jiménez P. y S. Corral R. 2005. Un análisis del efecto del aprovechamiento forestal sobre la diversidad estructural en el bosque mesófilo de montaña «El Cielo», Tamaulipas, México. Investigación Agraria. Sistemas y Recursos Forestales 14(2):217-228. https://dialnet.unirioja.es/servlet/articulo?codigo=1223634 (3 de mayo de 2020).

Curtis, J. T. and P. McIntosh R. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology 32(3):476-496. http://www.jstor.org/stable/1931725 (3 de mayo de 2020).

Del Río. M., G. Montero., F. Montes e I. Cañellas. 2003. Revisión: Índices de diversidad estructural en masas forestales. Investigación Agraria Sistemas y Recursos Forestales 12(1):159-176. https://www.researchgate.net/profile/Miren_Rio2/publication/28061992_Indices_de_diversidad_estructural_en_masas_forestales/links/0deec51c3fa0f63666000000.pdf (3 de mayo de 2020).

Díaz-Hernández, D., R. Rodríguez-Laguna, D. A. Rodríguez-Trejo, O. A. Acevedo-Sandoval y C. C. Maycotte-Morales. 2014. Tolerancia al fuego de *Alnus arguta* (Schl.) Spach. y *Arbutus xalepensis* Kunth, en Singuilucan, Hidalgo. Revista Iberoamericana de Ciencias 1(7):103-112. https://www.researchgate.net/publication/292996332 (3 de mayo de 2020).

Dzib C., B., C. Chanatasig V. y N. A. Gonzalez V. 2014. Estructura y composicion en dos comunidades arboreas de la selva baja caducifolia y mediana subcaducifolia en Campeche, México. Revista Mexicana de Biodiversidad 85(1):167-178. Doi:10.7550/rmb.38706.

García M., E. 1973. Modificación al sistema de clasificación climática de Köppen (para adaptarlo a las condiciones de la República Mexicana). UNAM. Instituto de Geografía. México, D. F., México. 246 p.

Gotelli, N. J. and R. K. Colwell. 2011. Estimating species richness. Biological diversity: Frontiers in measurement and assessment*. In:* Magurran, A. E.and B. J.McGill (eds.). Oxford University Press. Oxford, U.K. pp.39-54.

Hernández S., J., Ó. A. Aguirre C., E. Alanís R., J. Jiménez P., E. J. Treviño G., M. A. González T. y A. Domínguez P. 2013. Efecto del manejo forestal en la diversidad y composición arbórea de un bosque templado del noroeste de México. Revista Chapingo. Serie ciencias forestales y del ambiente 19(2):189-200. Doi:10.5154/r.rchscfa.2012.08.052.

Instituto Nacional de Estadística y Geografía (INEGI). (2010). Conjunto de datos vectoriales de la carta de Uso del suelo y vegetación. Escala 1:250 000. Serie IV (Continuo Nacional). Durango, Dgo., México. s/p.

Jiménez V., A. 2000. Las curvas de acumulación de especies y la necesidad de evaluar los inventarios biológicos. Revista Ibérica de Aracnología 8:151-161. https://ci.nii.ac.jp/naid/20001123750/#cit (3 de mayo de 2020).

Kneitel, J. M. 2010. Successional changes in communities. Nature Education Knowledge 3(10): 41. Doi:10.1890/09-1541.1.

Kuuluvainen, T. 2002. Introduction, disturbance dynamics in boreal forests: defining the ecological basis of restoration and management of biodiversity. Silva Fennica 36(1): 5-11. Doi: 10.14214/sf.547.

Leverkus, A., B. Castro J. y J. M. Rey B. 2014. Regeneración post-incendio de la encina en pinares de repoblación mediterráneos. Revista Ecosistemas 23(2): 48-54. Doi.: 10.7818/ECOS.2014.23-2.07.

Leyva-López, J. C., A. Velázquez-Martínez y G. Ángeles-Pérez. 2010. Patrones de diversidad de la regeneración natural en rodales mezclados de pinos. Revista Chapingo serie ciencias forestales y del ambiente 16:227-239. Doi:10.5154/r.rchscfa.2010.06.038.7

Magurran, A. E. 1988. Why diversity?. In Ecological Diversity and Its Measurement. Princeton University Press. Princeton, NJ, USA. pp.1-5. Doi:10.1007/978-94-015-7358-0_1.

Magurran, A. E. 2004. Measuring Biological Diversity. Blackwell Science Inc. Malden, MA, USA. 256 p.

Monárrez G., J. C., G. Pérez V., C. López G., M. A. Márquez L. y M. d. S. González E. 2018. Efecto del manejo forestal sobre algunos servicios ecosistémicos en los bosques templados de México. Madera y Bosques 24(2):1-16. Doi:10.21829/myb.2018.2421569.

Návar C., J. D. J. y S. González E. 2009. Diversidad, estructura y productividad de bosques templados de Durango, México. Polibotánica 27:71-87. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-27682009000100005&lng=es&tlng=pt (5 de mayo de 2020).

Oliver, C. D. and B. C. Larson. 1996. Forest stand dynamics: updated edition. John Wiley and Sons, New York, NY, USA.520 p.

Rzedowski, J. 1981. Vegetación de México. Ed. Limusa, México, D. F., México. 432 p.

Sánchez H., M. A., A. M. Fierros G., A. Velazquez M., H. M. De los Santos P., A. Aldrete y E. Cortez D. 2018. Estructura, riqueza y diversidad de especies de arboles en un bosque tropical caducifolio de Morelos. Revista Mexicana de Ciencias Forestales 9(46):131-156. Doi:10.29298/rmcf.v9i46.115.

Smith, D. M., B. C. Larson M., J. Kelty and P. M. S. Ashton. 1997. The practice of silviculture: applied forest ecology (vol. 9). John Wiley & Sons, Inc. New York, NY, USA. 537 p.

Solís M., R., O. A. Aguirre C., E. J. Treviño G., J. Jiménez P., E. Jurado y J. Corral R. 2006. Efecto de dos tratamientos silvícolas en la estructura de ecosistemas forestales en Durango, México. Madera y bosques 12(2):49-64. Doi:10.21829/myb.2006.1221242.

Vásquez-Cortez, V. F., R. Clark-Tapia, F. Manzano-Méndez, G. González-Adame y V. Aguirre-Hidalgo. 2018. Estructura, composición y dibversidad arbórea y arbustiva en tres condiciones de manejo forestal de Ixtlán de Juárez, Oaxaca. Madera y bosques 24(3): e2431649. Doi: 10.21829/myb.2018.2431649