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Evaluation of eight species of endemic trees from the state of Sonora in agricultural land

Evaluación de ocho especies de árboles endémicos del estado de Sonora en suelo agrícola

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RESUMEN

El cambio en el uso del suelo y factores como, sobre pastoreo, periodos largos de sequía y agricultura intensiva han provocado que los agostaderos de Sonora pierdan más de la mitad de su potencial productivo. La recuperación de suelos deteriorados es gradual y a largo plazo, por lo que urge implementar programas de rehabilitación en estas áreas. De acuerdo con los resultados, en lo que respecta a la altura, no se presentaron diferencias significativas de algunas especies, tales como: palo verde c., palo fierro y mezquite con valores de 37.11 a 45.56 cm, con respecto al resto de las especies (palo verde a., palo blanco, tepehuaje, palo verde h. ATZ y *Ceiba tésota*), con valores de 90.6 a 112.7 cm. En cobertura aérea no se mostró diferencias significativas, en palo blanco, palo fierro y *ceiba tésota* con coberturas de 390.3 a 4394 cm^2, excepto las especies de palo verde c., palo verde a., tepehuaje, mezquite y palo v. h ATZ con coberturas de 3111 a 10068 cm^2. Por último, en lo que respecta a la cobertura del tallo, no se presentaron diferencias significativas entre las especies de palo verde c., palo verde a., tepehuaje, palo fierro, mezquite, palo v. h ATZ y *Ceiba tésota* con tallos de 0.5592 a 3.0356 cm^2, excepto el palo blanco con 12.0480 cm^2. Es posible que estas especies a los 6 meses de su establecimiento en áreas agrícolas abandonadas puedan rehabilitar áreas en corto plazo.

Palabras clave: plantas nativas, altura, cobertura, tallo.

ABSTRACT

The change in land use and factors such as overgrazing, long periods of drought and intensive agriculture have caused that Sonora's pastures lose more than half of their productive potential. The recovery of deteriorated soils is gradual and long-term so, that it is urgent to implement rehabilitation programs in these areas. According to the results, with respect to height, there were no significant differences between some species such as: palo verde c., palo fierro and mesquite with values of 37.11 to 45.56 cm, with respect to the rest of the species (Palo verde a., palo blanco, Tepehuaje, palo verde H. ATZ and *Ceiba tésota*), with values of 90.6 to 112.7 cm. In aerial coverage, there were no significant differences, in palo blanco, palo fierro and *Ceiba tésota* with covers of 390.3 to 4394 cm^2, except for the species of palo verde c., palo verde a., tepehuaje, mesquite and palo v. h ATZ with coverage from 3111 to 10068 cm2. Finally, as regards stem coverage, there were no significant differences between the species of Palo verde c., Palo verde a., Tepehuaje, Palo Fierro, Mesquite, Palo v. h ATZ and *Ceiba tésota* with stems of 0.5592 to 3.0356 cm^2, except the palo blanco with 12.0480 cm^2. It is possible that these species, 6 months after their establishment in abandoned agricultural areas, can rehabilitate areas in the short term.

Keywords: native plants, height, coverage, stem.

INTRODUCTION

In Sonora, livestock and agricultural production are important activities because they generate foreign currency to our country for the quality products that it exports. The state has an open surface dedicated to the cultivation of 758,600 ha; of which 694,200 ha are irrigated and the rest, 64,400 ha of rain (SAGARHPA, 2016); vegetables, grains and fruits are produced in these areas. The factors that affect the crops in the study area are: scarce water, soil salinity, low rainfall and high temperatures. These factors generate a low yield and its subsequent abandonment, generating islands of heat. The growth of the region's population, economic difficulties, international indebtedness and a decrease in the per capita productivity of food have contributed to a greater demand for agricultural land, and as a consequence deforestation, indiscriminate use increases of agrochemicals, the marginal production of the slopes, the erosion of the soils and the deterioration of the basins and the water sources (Gallego *et al*., 2012).

The recovery of degraded soils has been favored by not contemplating the introduction of native plants; with this type of actions, degraded soils are recovered and erosion avoided; it will also allow the recharge of water tables. Mc Caughey-Espinoza *et al*., 2019), used native trees for the rehabilitation of quarries, obtaining satisfactory results; the trees used were mesquite (*Prosipis juliflora*) (Sw.) DC.), palo fierro (*Olneya tesota* A. Gray), palo verde azul (*Cercidium floridium* (Benth. ex A. Gray) S. Wats. and palo verde chino *Cercidium microphyllum* (Torr.) Rosse & J. The ecological restoration of a desertified land affected by severe erosion is a long-term process that requires an exhaustive analysis of structure, composition and functioning (Mongil *et al*., 2015).

Due to the aforementioned, it is important to implement actions that allow changing the environment of the disturbed area, for better conditions to establish ecosystems that were lost, generating life of flora and wild fauna; as well as minimizing global warming (Mc Caughey-Espinoza *et al*., 2019).

The objective of this work was to evaluate the establishment and development of eight native shrubby species in the state of Sonora, on an agricultural land with a drip irrigation system.

MATERIAL AND METHODS

The research was developed in the Experimental Agricultural Field of the Department of Agriculture and Livestock of the University of Sonora, located in Hermosillo, Sonora, Mexico, in the coordinates, 29 ° 00'48 " North Latitude and 111 ° 08'07 " West longitude, at 150 meters above sea level; in the zone an average temperature of 23 ° C is presented. The soil has a sandy loam texture, and the irrigation water presented an electrical conductivity of 0.57 dSm^{-1} and a pH of 7.29.

Selected area

In order to know the response of different species to the competition of water, nutrients and light; the evaluation was carried out on a plot of 20 X 20 m. The plants studied were planted at a distance between rows of 1.6 m and a distance between plants of 0.3 m.

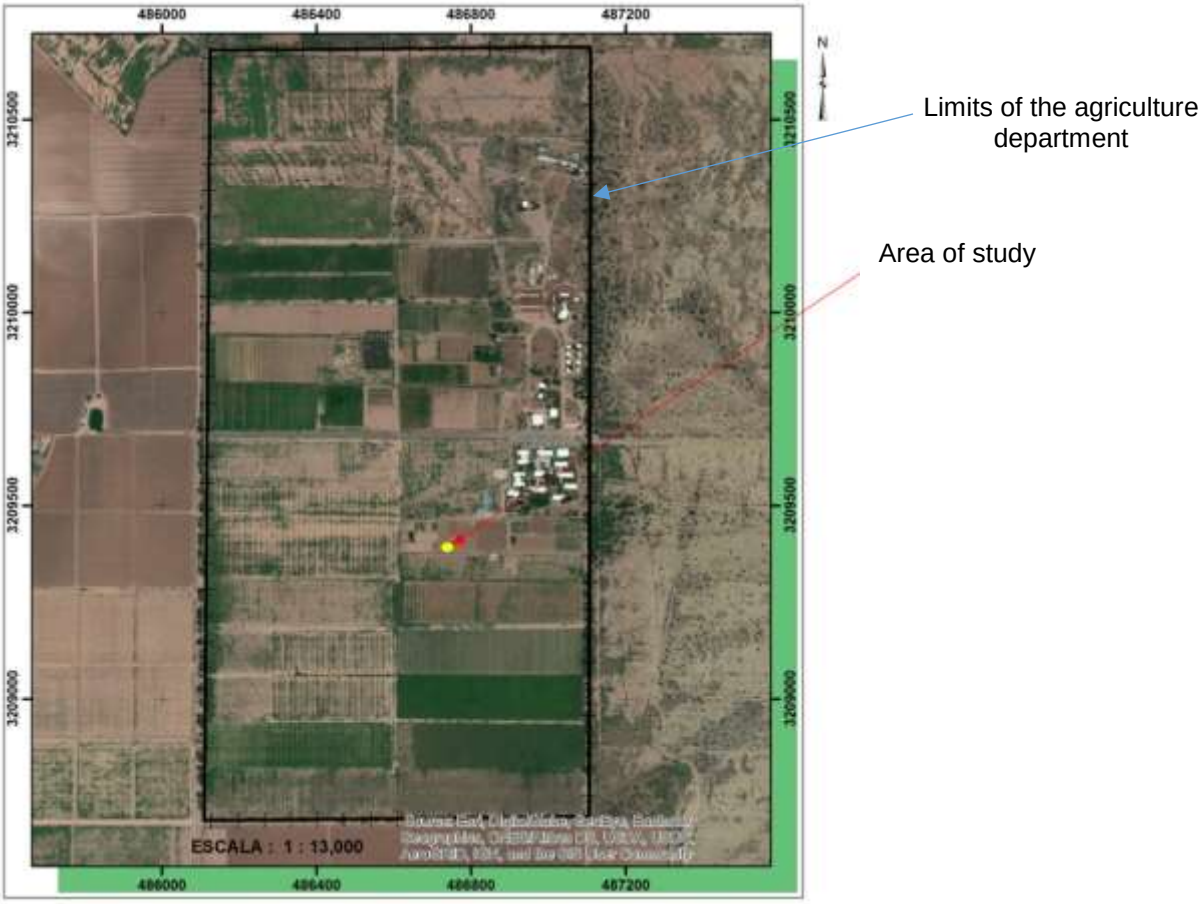

Figure 1.- Geo-referenced map of the location of the study area (ARCGIS, 2014).

Species under study

Seeds of eight tree species (table 1) were collected from the region and different pre-germination treatments were carried out, such as chemical, physical and mechanical, to ensure their germination. Seeds were planted in the study area in the month of June 2018.

Distribution of the species in the study area

The species used for this study were selected, taking as a first criterion their status as a key species for the state of Sonora; that is, adapted species for these ecosystems; also the versatility of these species in adapting to grow in different agronomic conditions

(edaphological, nutrimental, their potential for germination and adaptation) (Mc Caughey-Espinoza *et al*., 2017).

For the distribution of the species in the study area, one groove per species was considered; these plants were 6 months old; 10 specimens were used per species.

Table 1.- List of tree species under study

Groove	Common name	Scientific name
1	Tésota palo verde	*Acacia occidentalis* Britton & Rose
2	Palo verde azul	*Cercidium Floridium* (Benth. ex A. Gray) S. Wats.
4	Palo blanco	*Ipomea arborescens* Humb. & Bonpl. ex Willd.
6	Palo verde chino	*Cercidium microphyllum* (Torr.) Rosse & J.
9	Tepehuaje	*Lysiloma watsonii* Rose
10	Palo fierro	*Olneya tésota* A. Gray
11	Mezquite	*Prosopis velutina* Wooton
12	P. v. h. AZT	*Cercidium hybrid*

Application of irrigation

It is worth mentioning that in the months of July, August and September, no irrigation was applied, since at this time there were rains. The irrigation lamina that was applied was 10.0 cm^3 per week, from the end of September to November, with the purpose of creating a small moisture bulb and keeping the plants with the minimum amount of water, and in turn (propitiate or stimulate) the generation of roots to ensure their adaptation and survival with the least amount of water possible.

Parameters to evaluate

In this study some dasometric measurements (height, air cover and stem cover) were evaluated 6 months after its establishment. According to the adaptation and development of the plants in these semi-desert environments, it was considered appropriate to evaluate each of the plants according to their capacity for development and establishment. Measurements of stem cover, cover diameter and height were made for each individual; considering a single measurement. The stem diameter was measured at the base of the stem; the diameter of coverage was obtained when measuring the crown of the plants; for this, a tape measure was used and the values were expressed in cm^2.

$$A = \pi r^2$$

Experimental design

To carry out this work, a completely randomized block design was used, considering 10plants per species; an analysis of variance of the dasometric data (height, area and stem coverage) was performed; using the Tukey-Kramer mean test with an alpha of 0.05%, these analyzes were carried out using the statistical package JMP 5.0.1 (JMP, 2002).

RESULTS AND DISCUSSION

In these results two groups were formed, those that had a height close to 1 meter in height and those that were below 0.50 meters, presenting a rapid growth contrast of one group of trees with respect to another.

When analyzing the data, there were no significant differences (P <0.05), palo verde ATZ presented 112.7 cm, tepehuaje 112.2 cm, téstate 97.4 cm, palo blanco 97.3 cm and palo verde azul 90.6 cm, except with the species of palo fierro, palo verde c. and mesquite presented values of 37.11 to 45.5 cm. (Figure 2, Table 2).

The species studied, according to their physiological characteristics presented a positive growth, especially palo fierro, because it is considered a slow growth species; it behavior was better than those of palo verde, including mesquite. The height of the plants in relation to their establishment shows that the plants adapted to the site.

It is worth mentioning that the results obtained from the species under study show their development in another context, starting from their sowing and existing conditions of nutrients, organic matter and the possibility of having humidity nearby. According to Mc Caughey-Espinoza *et al*., (2019). The five important factors that should be considered are: use of plants in the region, availability of water, soil type, nutrients, transplant season and protection of wildlife or domestic.

In this study, these conditions were fulfilled that favored sowing, survival and development of the species, and in this way help the self-regeneration of a damaged or transformed ecosystem to the presence of soil; whose objective is to fight for the structure, functioning (recovering ecosystem services), diversity and dynamics of the historical and indigenous ecosystem (Hobbs and Norton, 1996, Ehrenfeld, 2000, Kremen and Ostfeld, 2005, Cadotte *et al.,* 2011).

Aerial coverage

The foliar development of the species under study, can be observed in Table 1, that palo v. h. ATZ had the highest aerial coverage with 10068.3 cm², followed by mesquite with 5626.1 cm² and tepehuaje with 4394.1 cm²; in the medium-sized ones there is palo blanco, palo verde chino and palo verde azul; Lastly, those with the lowest coverage were the ironwood with 1624.0 cm² and ceiba tésota with 390.3 cm². With respect to aerial coverage, tree species, such as palo verde chino, palo verde azul, tepehuaje, mesquite and hybrid palo verde ATZ, did not show significant differences (P <0.05), compared to the rest of the tree species under study. (Table 2 and figure 3).

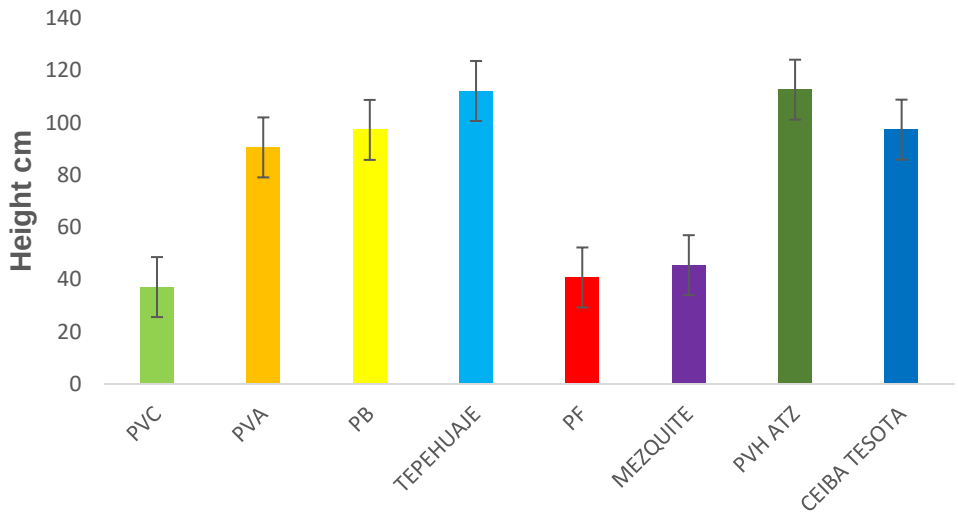

Figura 2.- Promedio de la altura en cm de cada una de las especies en estudio

The aerial coverage presented by the species was very accepted, since these results indicate that these plants can have perimeters of 98.77 to 307.87 meters, and would ensure having canopies that generate organic matter, water absorption and shelter for animals. The leaf area is strongly related to the level of interception of light, transpiration and net photosynthesis in the crown, varying with respect to environmental conditions, in which a stand is developed, taking into account the age and time of year (Amponsah *et al*., 2005; Smethurst *et al*., 2003; Simioni *et al*., 2004; Jerez *et al*., 2005).

Table 2.- Comparison of the averages of height, aerial coverage and stem

Species under study	Height cm	Aerial coverage cm²	Stem coverage cm²
Palo v. c.	**37.11±10.8934 b**	**3595.6±2009.8 a**	2.5910±1.28610 b
Palo v. a.	90.6 ±31.8615 a	**3111.9±2150.8 a**	1.3462±0.87666 b
Palo blanco	97.3±19.8609 a	2384.5±2633.8 b	**12.0480±5.92797a**
Tepehuaje	112.2 ±50.2589 a	**4394.1±3654.1 a**	2.4017±2.01900 b
Palo fierro	**40.8 ±8.8919 b**	1624.0±1076.9 b	0.5592±0.25760 b
Mezquite	**45.5 ±14.8343 b**	**5626.1±2793.8 a**	1.1215±0.32621 b
Palo v. h. ATZ	112.7±31.0557 a	**10068.3±12742.8 a**	3.0356±2.44005 b
Ceiba tesota	97.4±4.2479 a	390.3±75.3 b	2.2808±0.34153 b

Means with equal letters indicate that there are no significant differences (P <0.05). The data presented are the average of the 10 plants per species.

Agroforestry studies have shown that a large proportion of the bound N can be transferred to associated non-legume plants (Crews and Peoples, 2005); "however, the processes that explain these interactions between tree species when they are associated, have not been fully elucidated" (Moyer-Henry *et al*., 2006). Mixed plantations have the potential to

increase biomass production and carbon sequestration (Resh *et al*., 2002, Binkley *et al*., 2003, Bauhus *et al*., 2004); as well as other benefits, among them the improvement of soil fertility and nutrient cycling (Binkley *et al*., 2000); This often happens when there is a distribution of resources, whether superficial (light) or underground (water or nutrients) (Casanova *et al*., 2007).

It can be said the species used in this study "that require little water to meet their needs. But, even so, the availability of water for the establishment and growth of the species is very important, since they are in their wild state, they are of slow growth; together with the grazing of wild or domestic animals, low rainfall, immoderate pruning practices and forest fires; what causes a stress in the plants, damaging them, being able to arrive at a given moment to die"(Mc Caughey-Espinoza *et al*., 2017).

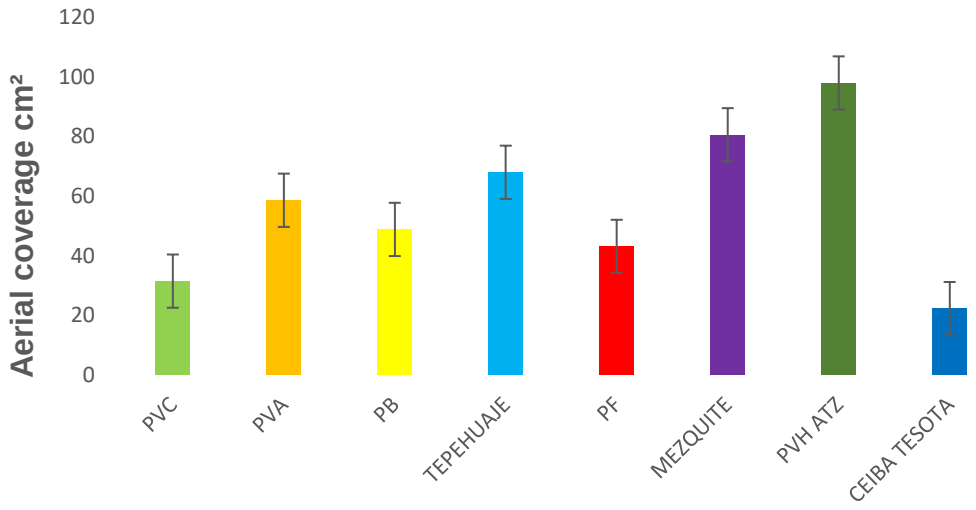

Figure 3. Average of the aerial coverage cm² of each of the species under study

Stem coverage

The support of the plants is balanced by the development of their roots, this allows having trees with desired characteristics of good size (height), aerial coverage (cup) and of course have a stable stem that may be able to maintain the weight, sustain before winds and heavy rains. The development of aerial coverage of these species under study can be seen in Table 2 and Figure 4.

The palo blanco showed significant differences with the rest of the species under study, showing a stem coverage of 12.0480 cm², followed by hybrid palo verde ATZ 3.0356 cm², el palo verde chino 2.5910 cm², tepehuaje 2.4017 cm², tésota 2.2808 cm² and finally find palo verde azul 1.3462 cm², mesquite 1.1215 cm² and palo fierro 0.05595 cm². Given the characteristics of each species that have fibrous or succulent stems, there is clearly a significant difference between the palo blanco and the rest of the species, with the palo

blanco being a tree with a more succulent stem, generating more moisture absorption and turn the stem to swell.

Generally, agricultural soils present macros and micronutrients that accumulated over the years, as well as organic matter; these components will be suitable for the establishment and development of the plants.

In the present study good results were observed in the development of the evaluated species, although they were at a distance between them of 30 cm; therefore, the results of the variables evaluated are very promising to include these species in reforestation programs.

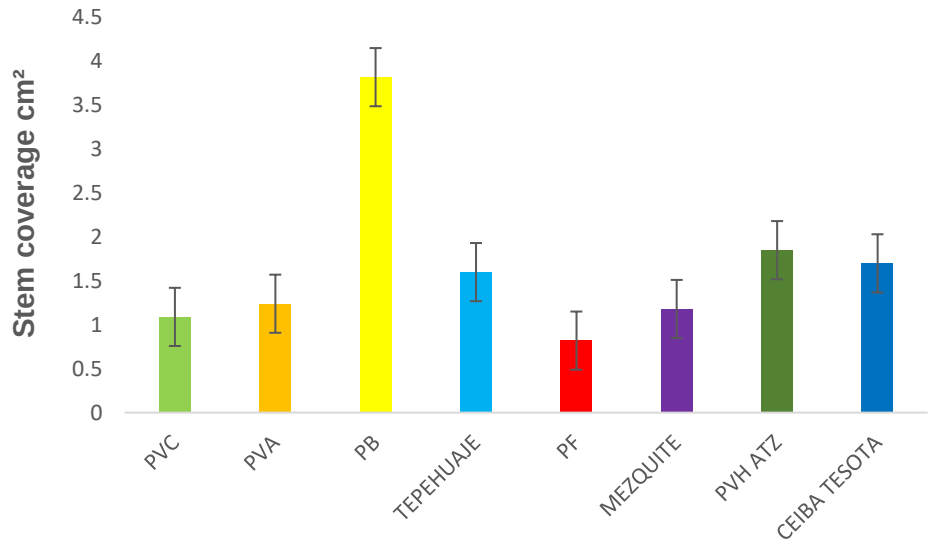

Figure 4. Average of the stem coverage cm² of each of the species under study

To contribute to the regeneration of abandoned fields, it is necessary to use native species, with low mortality percentages and resistant to dry and hot periods; coupled with viability, that increase soil fertility, effectively increasing plant coverage and controlling erosion; at the same time that they accelerate the succession (Padilla *et al*., 2004). The use of native species in reforestation programs is important for the recovery of abandoned agricultural lands; especially in arid areas, where conditions are unfavorable (Miranda *et al*., 2004). In several European and American countries, hydrological forest restoration is widespread, the hydrological service they provide to ecosystems has been developed (Brauman *et al*., 2007; Monterroso-Rivas *et al*., 2009; Benavides-Solorio *et al*., 2008), emphasizing the economic importance (López-Paniagua *et al*., 2007); as well as the meaning it has in the maintenance of these services, both for conservation (Manson, 2004), and the restoration of ecosystems.

The Commission of the European Communities (2002) points out that erosion and soil fertility represent a major threat to sustainable development, reduce the viability of

agricultural land and suggest that agricultural and forestry activities have a great impact on the organic matter of the soil (CCE, 2002). Therefore, the economic importance of soil resources is also indisputable, through the review of some studies of the economic valuation of soil and ecosystems (Silva and Correa, 2009).

Due to the scarce information that exists in the remediation or recovery of agricultural soils abandoned by different factors (precipitation, salinity, among others), with the use of native species; therefore, it is important to continue generating more research on the species found in these ecosystems, which may be viable for the remediation of degraded areas. The correlation that exists between the height, aerial coverage and stem, are of ecological importance; the stem is the firm base of the plants, this ensures a better root biomass; therefore, there will be better air coverage that provides more CO_2 and organic matter; finally, the plants will present a positive development.

CONCLUSIONS

It is concluded that tree species, such as: palo verde chino, palo verde azul, Tepehuaje, palo fierro, mesquite, palo v. h ATZ, palo blanco and ceiba; they presented a good adaptation and development according to the response of height, aerial coverage and stem coverage. It is possible that these species, 6 months after their establishment in abandoned agricultural areas, can rehabilitate areas in the short term. The aerial coverage of the plants was positive when presenting canopies with areas of more than 1 square meter. It is very important to carry out more research using other species that have the same or greater potential than the species used here.

CITED LITERATURE

AMPONSAH I, Comeau P, Brockley R, Lieffers V. 2005. Effects of repeated fertilization on needle longevity, foliar nutrition, effective leaf area index, and growth characteristics of lodgepole pine in interior British Columbia, Canada. *Can. J. For. Res.* 35: 440-451.DOI: 10.1093/treephys/24.10.1099

ARCGIS. 2014. Source: Esri, DigitalGlobe, GeoEye, Earthstar Geografphics, CNES/Arirbus DS. USDA, USCS, AeroGRID, IGN, and the Gis User Community. Software 10.1

BAUHUS JV, Winden AP, Nicotra AB. 2004. Above–ground interactions and productivity in mixed–species plantations *of Acacia mearnsii* and *Eucalyptus globulus. Can. J. Forest. Res*. 34:686–694.https://doi.org/10.1139/x03-243

BENAVIDES-SOLORIO J, González-Guillén M, López-Paniagua C, Valdez-Lazalde R. 2008. Oferta hídrica de la cuenca forestal Tapalpa, Jalisco, orientada hacia los servicios ambientales. *Madera y Bosques*. 14(2):5-28. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-04712008000200002&lng=es&nrm=iso>. ISSN 2448-7597

BINKLEY D, Giardina C, Bashkin MA. 2000. Soil phosphorous pools and supply under the influence *of Eucalyptus saligna* and nitrogen–fixing Albizia facaltaria. *Forest. Ecology and Management*. 128:241–247. https://doi.org/10.1016/S0378-1127(99)00138-3

BINKLEY D, Senock R, Bird S, Cole T. G. 2003. Twenty years of stand development in pure and mixed stands *of Eucalyptus saligna* and N–fixing *Facaltaria moluccana. Forest Ecol. Managem*. 182:93–102 https://doi.org/10.1016/S0378-1127(03)00028-8

BRAUMAN KA, Daily GC, Duarte TK, Mooney HA. 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. *Annual Review of Environmental Resources.* 32:67-98. doi: 10.1146/annurev.energy.32.031306.102758

CADOTTE MW, Carscadden K, Mirotchnick N. 2011. Beyond species: functional diversity and the maintenance of ecological processes and services. *Journal of Applied Ecology* 48(5):1079-1087. https://doi.org/10.1111/j.1365-2664.2011.02048.x

CASANOVA LF, Ramírez AL, Solorio SFJ. 2007. Interacciones radiculares en sistemas agroforestales: mecanismos y opciones de manejo. *Avances en Investigación Agropecuaria.* 11(3): 41-52. ISSN: 0188-789

CCE. Comisión de las Comunidades Europeas. 2002. Hacia una estrategia temática para la protección del suelo. (En línea) Comunicación de la comisión al consejo, el Parlamento Europeo, el comité económico y social y el comité de las regiones. Brúcelas. Disponible en http//www.oei.es/salactsi/ue.htm. (Fecha de consulta septiembre 2008).

CREWS TE, Peoples MB. 2005. Can the synchrony of nitrogen supply and crop demand be improved in legume and fertilizer–based agroecosystems? *A review. Nutr. Cycl. Agroecosys*. 72:101–120. DOI: 10.1007/s10705-004-6480-1

EHRENFELD JG. 2000. Defining the limits of restoration: the need for realistic goals. *Restoration Ecology* 8(1):2-9 https://doi.org/10.1046/j.1526-100x.2000.80002.x

GALLEGO BURBANO E, Morales Velasco V, Vivas Quila N. 2012. Propuesta para el uso de Especies Arbóreas y Arbustivas Forrajeras en Sistemas Ganaderos en el Valle del Patía. *Biotecnología en el Sector Agropecuario y Agroindustrial.* 10(2):207 – 216. ISSN 1692-3561

HOBBS RJ, Norton DA. 1996. Towards a conceptual framework for restoration ecology. *Restoration Ecology*. 4(2):93-110. https://doi.org/10.1111/j.1526-100X.1996.tb00112.x

JEREZ M, Dean T, Cao Q, Roberts S. 2005. Describing leaf area distribution in Loblolly Pine trees with Johnson's SB function. *Forest Science.* 51(2): 93-101. https://doi.org/10.1093/forestscience/51.2.93

JMP. 2002. The Statistical Discovery Software. SAS institute Inc.Ver. 5.0.1

KREMEN C, Ostfeld RS. 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. *Frontiers in Ecology and the Environment.* 3(10):540-548. https://doi.org/10.1890/1540-9295(2005)003[0540:ACTEMA]2.0.CO;2

LÓPEZ-PANIAGUA C, González-Guillén M, Valdez-Lazalde JR, De los Santos-Posadas HM. 2007. Demanda, disponibilidad de pago y costo de oportunidad hídrica en la cuenca Tapalpa, Jalisco. *Madera y Bosques.* 13(1):3-23. ISSN: 1405-0471

MANSON RH. 2004. Los servicios hidrológicos y la conservación de los bosques de México. *Madera y Bosques.* 10(1):3-20. ISSN 2448-7597 https://doi.org/10.21829/myb.2004.1011276

MC CAUGHEY-ESPINOZA DM, Ayala Astorga GI, Velázquez-Caudillo J, Anaya-Islas J, Canseco-Vilchis E. 2017. Creación de un jardín botánico y de árbol madre de arbustivas forrajeras nativas del estado de Sonora. *Rev. Idesia (Arica)*. 35(4):35-45. https://dx.doi.org/10.4067/S0718-34292017000400035

MC CAUGHEY-ESPINOZA DM, Ayala-Astorga GI, Burboa Zazueta MG, Ochoa Meza A, Retes López R. 2019. Uso de plantas nativas para la rehabilitación de canteras en Sonora. *Rev. Idesia (Arica).* Volumen 26 (4) https://dx.doi.org/10.4067/so718-34292018005002401

MIRANDA J, Padilla F, Pugnaire F. 2004. Sucesión y restauración en ambientes semiáridos. *Ecosistemas: Revista científica y técnica de ecología y medio ambiente*. 13 (1): 55-58. ISSN 1697-2473

MONGIL J, Navarro J, Díaz V. 2015. Esquema ecológico aplicado a una restauración forestal en cárcavas de la Sierra de Ávila (centro de España). *Madera y bosques*, *21*(1): 11-19. ISSN 2448-7597.

MONTERROSO-RIVAS AI, Gómez-Díaz JD, Tinoco-Rueda JA. 2009. Servicios ambientales hidrológicos bajo escenarios de cambio climático en el Parque Nacional “El Chico”, Hidalgo. *Madera y Bosques*. 15(2):5-26. <http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-04712009000200001&lng=es&nrm=iso>. ISSN 2448-7597.

MOYER–HENRY KA, Burton JW, Israel DW, Rufty TW. 2006. Nitrogen transfer between plants: A^{15}N natural abundance study with crop and weed species. *Plant. Soil*. 282:7–20. https://doi.org/10.1007/s11104-005-3081-y

PADILLA RUIZ F, Pugnaire de Idaola F, Marín R, Hervás Muñoz M, Ortega Oller R. 2004. EL uso de Especies Arbustivas para la Restauración de la Cubierta Vegetal en Ambientes Semiáridos. *Cuad. Soc. Esp. Cien. For*. 17: 103-10. ISSN: 1575-2410

RESH SC, Binkley D, Parrotta JA. 2002. Greater soil carbon sequestration under nitrogen–fixing trees compared with *Eucalyptus* species. *Ecosystems.* 5:217–231. DOI: 10.1007/s10021-001-0067-3

SAGARHPA. Secretaria de Agricultura, Ganadería, Recursos Hidráulicos, Pesca y Acuacultura. 2016. Programa de mediano plazo 2016-2018.http://sagarhpa.sonora.gob.mx/portal_sagarhpa/images/archivos/PMP/PMPAGRICOLA20162021.pdf

SILVA ARROYAVE SM, Correa Restrepo FJ. 2009. Análisis de la Contaminación del Suelo: Revisión de la Normativa y Posibilidades de Regulación Económica. *Semestre Económico.* 12(23):13-34. ISSN 0120-6346

SIMIONI G, Gignoux J, Le Roux X, Appé R, Benest D. 2004. Spatial and temporal variations in leaf area index, specific leaf area and leaf nitrogen of two co-occurring savanna tree species. *Tree Physiology* 24: 205-216. https://doi.org/10.1093/treephys/24.2.205