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Afforestation with the Purpose of Restoring the Protected Natural Area "Cerro del Punhuato", Morelia, Michoacán

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Abstract: During the last decade in the State of Michoacán Mexico, green spaces, recreation areas and the quality of the environment have been lost due to anthropogenic activities, which have impacted the sustainability in the forestry sector. This proposal was established in the Protected Natural Area of Cerro del "Punhuato", in the municipality of Morelia, Michoacán, Mexico, in the period 2009-2010 an essay that studies the establishment of a plantation of ***Pinus michoacana Martínez***, in four treatments, health and soil temperature. The plantation was carried out in an area of one hectare, divided in four treatments in a quarter of a hectare per treatment. Subsequently, an analysis was carried out by species between ***Pinus pseudostrobus lind***. ***Pseudostrobus*** and ***Pinus michoacana Martinez*** throughout the plantation. Survival rate, health and soil temperature were analized as key factors for the establishment of the plantation. Significant differences were found between the variables studied. In the established plantation pest attacks were found by defoliating insects and sap-sucking insects, where a sanitary siege was established by using a slightly toxic emulsifier insecticide. The analysis of the survival rate, health and soil temperature showed significant differences among the different species, where the species of ***Pinus michoacana Martinez*** adapted better to the conditions and highlights that the analysis of soil temperature was a determinant factor in the establishment of the plantation. This analysis is fundamental in the development of restoration of area due to the failed forestation attempts where society shows interest in the recovery of green spaces through the active participation of academic groups, educational institutions, civil society organizations and society.

Key words: afforestation, restoration, survival

1. Introduction

At the global level the main objective is the conservation and preservation of natural resources since the different types of vegetation that exist in the world are of vital importance for the development of the human race, because of this, new projects and strategies are proposed every day for the restoration of soil, by means of forestation and reforestation in some areas that have been designated for the establishment, regeneration or production of native vegetation and/or representative of the areas in which they are found, such is the case of the Cerro del Punhuato.

To date, the calculations of restoration through forestation and reforestation, as well as the loss of forest area in Mexico have been subjective and lack a statistical base.

In these conditions it's necessary to urgently implement, effective and efficient actions to increase the forest area and attempt to protect the soil, the harvesting of rainwater and maintain the diversity of climates, to increase soil fertility and productivity as rector of the conservation and restoration of ecosystems.

Finally, reforestation and afforestation is the option to recover degraded areas through actions such as

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watershed protection and restoration for the subsistence of the species, as well as the conservation and preservation of the natural protected areas [8].

Based on the above information in the protected natural area known as "Cerro del Punhuato", municipality of Morelia, where we find a high degree of ecological disturbance, no presence of soil and little vegetation, an afforestation was carried out for the purpose of restoring the area with favourable species such as *Pinus michoacana* and *Pinus pseudostrobus* since both, adhere to the environmental requirements of the surrounding environment, the aim was to increase the vegetation area, the reduction of soil erosion, the generation of soil and increased uptake of water, offering new alternatives for planting in order to know which factors have a significant influence on its successful establishment, and in this way achieve a greater survival of the plant and increase the forest area in the site, being a strategic space for the generation of environmental services that directly benefit the society, scientific activities and the environment [12].

There are various techniques that can be used to promote ecological restoration and the interaction with the participation of society to hopefully establish parameters to increase survival of the plantations and increase the interest of the people. This research proposes the following:

Planting trees to increase the forest area in the "Cerro del Punhuato" will encourage citizens to participate in order to generate greater interest from society in the environment and actions that benefit the increase of vegetation area. In environmental issues, it's suggested that as a result of greater vegetation, soil loss will be reduced and gradual regeneration of soil will begin. The regeneration of soil and increase of vegetation will increase rainwater harvesting [5].

2. Objective

Perform an experimental plantation to restore a Protected Natural Area with two species of pine, to determine which is the best in terms of health and survival rate in the "Cerro del Punhuato", Morelia, Michoacán.

3. Material and Methods

In Morelia, Michoacán, Mexico, a trial of two species of the genus *Pinus*, in the Protected Natural Area known as "Cerro del Punhuato", an Ecological Preservation Area, which has a program of management and is under the supervision and care of the government of the state of Michoacán, Mexico, to whom a petition was requested in order to carry out the research.

The experimental site is located in an area of 01-00-00 has. or 10.000 m² of land, in which there are herbaceous and shrub species, some trees, as shown in, the latter introduced or exotic species, which present some shortcomings.

The site has an approximate slope of between 77° and 41°, there is abundant presence of stones, exposed soil and low permeability to the subsoil.

Later the experimental site was divided in four treatments or plots which were classified as follows (Fig. 2), plot 1 has a steep slope between 73° and57° and there is a high degree of disturbance; Plot 2 The slope is soft and ranges from 56° to 41° with a high degree of disturbance; plot 3 has a steep slope between 77° and 50° Low Disturbance; plot 4 has a gentle slope of 47° to 42° and low disturbance (Table 1).

In (Fig. 3), we observe the distribution of the plantation, where the squares represent trees of

Fig. 1 Experimental site for carrying out afforestation.

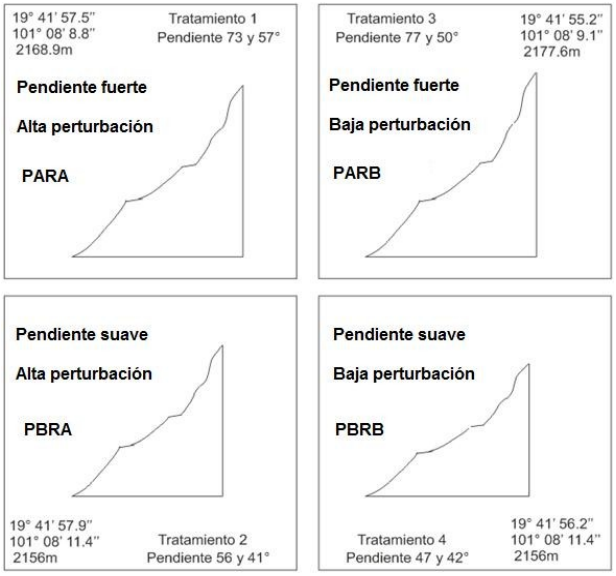

Fig. 2 Outline of the delimitation of the plots and experimental treatments, as well as the slope representative and nomenclature of each of the treatments.

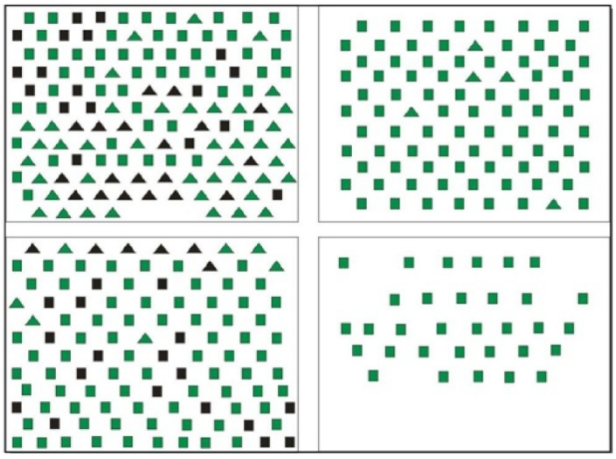

Fig. 3 Distribution scheme for the stablishment of the plantation by treatment.

Table 1 Characteristics of the slope, soil conditions, degree of disturbance and nomenclature of treatment.

Site	Degree Slope	Disturbance	Nomenclature
Plot 1	(73° to 57°) Steep	High	PARA
Plot 2	(56° to 41°) Soft	High	PBRA
Plot 3	(77° to 50°) Steep	Low	PARB
Plot 4	(47° to 42°) Soft	Low	PBRB

Pinus michoacana and triangles represent trees of *Pinus pseudostrobus* [7].

The first species considered for this plantation, is the *Pinus michoacana Martinez*. Also known as Lazio pine. A native of Mexico and with a geographical distribution of the 16°35' and 21°15' north latitude and 92°15' and 102°05' West longitude. As a particular feature it establishes in slopes of pine forests and Encino Oak Tree forests [6].

The other species that account with the necessary requirements to be able to settle on the site is the *Pinus pseudostrobus Lindl*. var. *pseudostrobus*, commonly known in the state of Michoacán as ortiguillo pine or white pine, native to Mexico, Honduras and Guatemala, which is distributed geographically between the 17°15' and 29°15' north latitude and 92°05' and 108°35' West longitude, frequently found in pine forests and pine-oak forests, however it cannot be ruled out its use in restoration of degraded soils [7].

Table 2 Summary of the main historical climate factors in the site.

Climate data						
Average temperature (°C)	2003	2004	2005	2006	2007	2008
	19	18.4	19.1	18.9	18.3	18.8
Relative humidity (%)	59	62	58	56.4	54	56.1
Total insolation (hrs)	1834.6	1699.4	1867	1732.6	1697.1	1667.1
Evaporation total (mm)	2657.56	2634.44	2886.31	2625.09	2713.56	2801.5
Total Rain (mm)	1007.7	1073.7	843.5	923.1	725.5	616.9

Fig. 4 *Pinus michoacana Mart.* specimen, healthy.

Fig. 5 ***Pinus pseudostrobus*Lindl.specimen, healthy.**

The development of the strains was carried out with 40 cm. in length, width and depth, (Fig. 6) in the experimental site.

The plantation was carried out in the month of September 2009, (since this year was atypical in its rainy season) according to the physiography of the ground and respecting the existing vegetation with a distribution of, 3 meters apart, the final distribution.

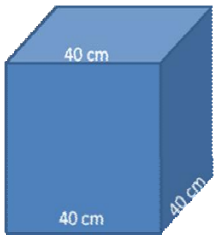

Fig. 6 Strain scheme.

Table 3 Species established in the plots, by species and proportion.

Treatment	Species	# of established species	Ratio %
Plot 1	*P.michoacana*	74	55
	P.pseudostrobus	59	45
Plot 2	*P.michoacana*	89	83
	P.pseudostrobus	18	17
Plot 3	*P. michoacana*	83	95
	P.pseudostrobus	5	5
Plot 4	*P. michoacana*	32	100
	P.pseudostrobus	0	0

Then and given the inequality of specimens per species in each of the treatments we proceeded to perform a random analysis (with the SAS software), to select 32 individuals per plot of *Pinus michoacana*, then a new random analysis was carried out to choose 74 individuals of *Pinus michoacana* to evaluate the general level in the plantation *Pinus pseudostrobus*.

For six months, the evaluations were performed every 45 days, counting the survival rate and monitoring the health [2] of each species.

The general analysis used in the case of *Pinus michoacana* is the following:

$$Yij = \mu + Pi + PRijRj + + Eij$$

While in the case of analysis by species (*Pinus michoacana vs Pinus pseudostrobus*) is the following:

$$Yij = \mu + If + Eij$$

Statistical analysis consisted of analysis of variance (ANOVA) and a comparison of means using the Tukey test, carried out with the variables of soil temperature, health and slope since they are regarded as variation factors that may affect the survival of the trees. For ANOVA the GLM procedure was used (general linear model), as well as the The Tukey test for average statistical analysis of comparison of the SAS statistical package [13].

Subsequently a hypothesis test was done using an F-Snedecor test. As shown below:

Hypothesis testing.

Ho = T1 = T2 = T3 = T4 VS has = T1 ≠ T2 ≠ T3 ≠ T4

Decision Rule:

If F calculated > F tabulated

Reject Ho. otherwise accept.

Word, Access and Excel from the Microsoft Office package were used for the handling and processing of data.

The (Fig. 7), shows the amount of living and dead trees for each of the species chronologically, according to the months in which assessments were carried out.

In the analysis of variance for the survival rate significant differences were found with regard to disturbance (D = 0.0003), where we found that the sites

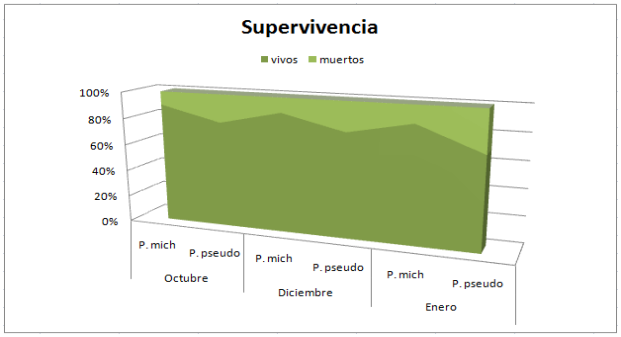

Fig. 7 Chronological graph of plantation survival.

Table 4 Variable survival analysis of *Pinus michoacana* in treatments.

Fuente de variacion	Grados de libertad	Suma de cuadrados	Cuadrado medio	F	P
Pendiente	1	0.000	0.000	0.00	1.0000
Perturbacion	1	1.531	1.531	0.00	<0.0001
Pendiente* perturbacion	1	0.000	0.000	0.00	1.0000
Error	124	13.937	0.112		

with high degree of disturbance had the highest mortality rate, unlike sites with a lower degree of disturbance where mortality rate was lower. The slope had no inference in survival because it does not show significant differences.

The following results were obtained from the tests:

Table 5 Hypothesis test for the variable survival of *Pinus michoacana* in treatments.

Fuente de variacion	Grados de libertad	Suma de cuadrados	Cuadrado medio	F	P
Pendiente	1	0.000	0.000	0.00	1.0000
Perturbacion	1	1.531	1.531	13.62	0.0003
Pendiente* perturbacion	1	0.000	0.000	0.00	1.0000
Error	124	13.937	0.112		

In the hypothesis test we note that the disturbance is a significant factor in the survival rate (P = <.0001), we can observe that the slope and the interaction of the slope and the disturbance does not show significant differences in survival rate.

There are significant differences for the variable health in disturbance (P = 0.0031,), since the greater the degree of disturbance on the site, the greater the number of dead specimens, while the lower the degree of disturbance, the less number of specimens attacked by pests. The effect of the slope is not significant as it doesn't show differences, while the effect of the slope and disturbance show significant differences (P = 0.0101).

In the hypothesis test for health we note that the effect of the slope (P = 0.8556) and the effect of disturbance (P = 0.4546) show no significant differences, but not in the case of the interaction between the slope and the disturbance (P = 0.0101).

In Fig. 8, we can see that there are no significant differences in survival rate and health. In the case of soil temperature there are significant differences with regards to the slope because the temperature of soil on the gentle slopes (A) is where *P.michoacana* establishes better, while steep slopes (B) are a limiting factor for the temperature on the establishment of *P.pseudostrobus.*

In Fig. 9, we can see that for the variable survival rate, there are significant differences between sites with high degree of disturbance (B) and sites with low degree of disturbance (A), where the sites with a low

Table 6 Analysis of variance for the variable health of *Pinus michoacana* in treatments.

Fuente de variacion	Grados de libertad	Suma de cuadrados	Cuadrado medio	F	P
Pendiente	1	0.070	0.070	0.36	0.5475
Perturbacion	1	1.757	1.757	9.09	0.0031
Pendiente* perturbacion	1	1.320	1.320	6.83	0.0101
Error	124	23.968	0.193		

Table 7 Hypothesis test for the variable health of *Pinus michoacana* in treatments.

Fuente de variacion	Grados de libertad	Suma de cuadrados	Cuadrado medio	F	P
Pendiente	1	0.070	0.070	0.05	0.8556
Perturbacion	1	1.757	1.757	1.33	0.4546
Pendiente* perturbacion	1	1.320	1.320	6.83	0.0101
Error	124	23.968	0.193		

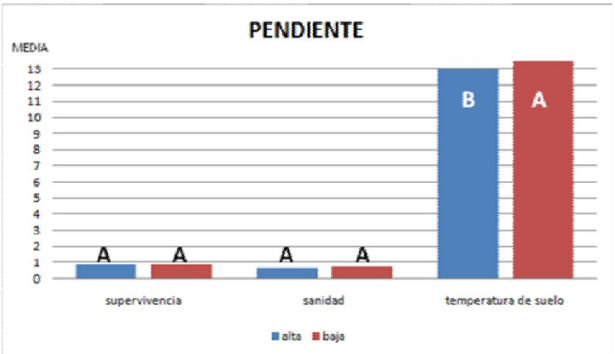

Fig. 8 The Tukey test (α = 0.05) for the effect of the slope, in the variables of survival, health and soil temperature for the establishment of *P. michoacana*.

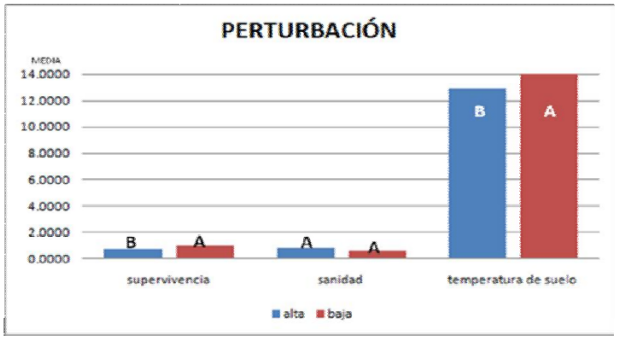

Fig. 9 The Tukey test (α = 0.05) for the effect of the disturbance, in the variables of survival rate, health and soil temperature for the establishment of *P. michoacana.*

degree of disturbance is where there's a lower incidence of mortality of *P.michoacana*. For the health variable we note that there are no significant differences. In the case of soil temperature there are significant differences in the effect of the disturbance because the temperature of soil in sites with little disturbance (A) is where *P.michoacana* settles better, and the sites with high disturbance (B) are a limiting factor for the effect of temperature on the establishment of *P.pseudostrobus.*

In Fig. 10 we can see the effect of the treatments in the variable survival rate, there are significant differences between the treatments PARA, PBRA, (B) and PBRB, PARB, (A), respectively. With regard to the health variable PARA, PBRA, (A) and PARB, PBRB (B), there are significant differences between these as well. For soil temperature the treatment PARA (c) shows significant differences, compared to the other three treatments, while the PBRA and PARB treatments (B), don't show significant differences between them but it does show significant differences with the other two treatments and treatment PBRB (A), there are significant differences with the other three treatments, where the treatment with a gentle slope and low disturbance in which *P. michoacana* plant settles best.

The obtained results by species, consist in the assessment of *Pinus michoacana* and *Pinus pseudostrobus* in the plantation which evaluates the establishment of both species

In the variance analysis significant differences were found in survival rate in the establishment of both species (P = 0.0037). *Pinus michoacana* had the greatest survival rate.

In the case of the health variable, in the variance analysis, we found significant differences (P = 0.0486), in which the species with the least number of individuals with pest attack was *Pinus michoacana*.

In the variance analysis for the variable soil temperature, we found that there are significant differences (P = 0.4781).

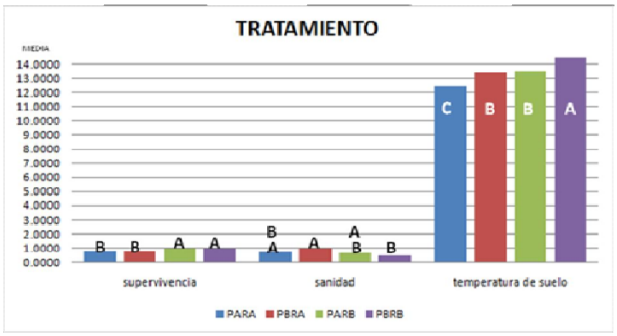

Fig. 10 The Tukey test (α = 0.05) for the effect of the treatment, in the variables of survival rate, health and soil temperature for the establishment of *P.Michoacana.*

Table 8 Variance analysis for the variable survival rate for the assessment of the establishment of *Pinus michoacana* and *Pinus pseudostrobus* in the plantation.

Fuente de variacion	Grados de libertad	Suma de cuadrados	Cuadrado medio	F	P
Especie	1	1.461	1.461	8.68	0.0037
Error	152	25.584	0.168		
Total	153	27.054			

Table 9 Variance Analysis to evaluate health in the establishment of *Pinus michoacana* and *Pinus pseudostrobus* in the plantation.

Fuente de variacion	Grados de libertad	Suma de cuadrados	Cuadrado medio	F	P
Especie	1	0.785	0.785	3.95	0.0486
Error	152	30.207	0.198		
Total	153	30.993			

Table 10 Variance analysis for the variable soil temperature for the assessment of the establishment of *Pinus michoacana* and *Pinus pseudostrobus* in the plantation.

Fuente de variacion	Grados de libertad	Suma de cuadrados	Cuadrado medio	F	P
Especie	1	1.272	1.272	0.51	0.4781
Error	152	382.517	2.516		
Total	153	383.790			

Subsequently a comparison analysis of the averages using the Turkey test found the following:

As we can see in the variable survival rate doesn't show significant differences between the species being *P. michoacana* the one that established better.

With the above findings of the reforestation, it's considered that the plantation has a high level of survival rate in spite of the steep slope that exists on the site, as well as high disturbance, whereas in a trial of *Pinus ponderosa* in a level plane and hillside site, where the survival rate was 3% on the level plane, while in the slopes the survival rate was higher [14].

In the case of the plantation in the Cerro del Punhuato the plants had no limitations during its establishment or by the altitudinal gradient, nor by the lack of soil in the upper parts of the slope of the hill

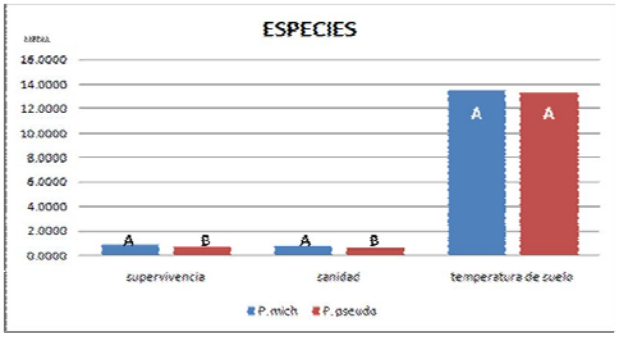

Fig. 11 The Tukey test ($\alpha = 0.05$) for the evaluation of the species, with the variables survival rate, health and soil temperature.

where the slope was steep and pronounced, contrary to reports [9], to examine the potential establishment of three species of the Cloud Forest *Fraxinus uhdeii lusitana*, *Magnolia* and *Quercus Salicifiolia*, under the canopy of *Pinus douglasiana*, where the different trends in mortality of seedlings, suggest that the survival in the top of the hillside is more limited due to the limited availability of water and light, not by the condition or nutrients of the soil.

From the results we can take that since slopes are less exposed to the sun there are lower temperatures [11], which is the case in the plantation in Cerro del Punhuato where the soil temperature where *Pinus michoacana* and *Pinus pseudostrobus* were planted showed significant differences, depending directly on the factors of the slope and the disturbance of the site [10].

In the analysis of the studied plants by species we found that the main limiting factor is the existing disturbance in the sites, where due to the conditions microorganisms survive long periods. The species that established the best was *Pinus michoacana* since it had the lowest mortality rate, as well as the lesser number of individuals attacked by insects, while *Pinus pseudostrobus* presented the lower survival rate and greater number of individuals with insect attacks. That *Pinus pseudostrobus* planted under good conditions presented a high rate of growth.

5. Conclusion

The survival rate depends directly on the degree of disturbance on the site, the greater the degree of disturbance the lower the survival rate, while the lower the degree of disturbance the greater the survival rate. [3]

The health of the species for its part will depend on the degree of disturbance as well as the climatic conditions of the site since both species require specific environmental conditions to be able to develop, such as soil and environmental moisture, where greater

amounts of disturbance exist is also where insects establish and develop better.

Soil temperature is a factor that depends entirely on the degree of the slope, as well as the degree of disturbance in the site where the plant is set, since soil temperature will depend on the exposure of the plant.

With respect to the different degrees of slope, the two species can adapt to the different degrees of slope and can establish without risking the development of both species. [4]

The species with the highest survival rate is *P. michoacana*; which also showed a lesser number of specimens attacked by insects.

For its part, the *P. pseudostrobus* had a lower survival rate in the treatments, it also had the highest number of specimens attacked by insects.

The effect of the slope is not a limiting factor for the establishment of the species, however it depends on the temperature of the treatments because sun exposure is variable depending on the degree of inclination it presents.

For future reforestation projects in the Natural Protected Area "Cerro del Punhuato" we recommend establishing *P. michoacana* because of its greater survival rate.

The size and the age of the plant of *Pinus michoacana* is an essential factor for future research. When it exceeds 15 cm high, considering that it is a tufted plant it must be planted in containers with sufficient amounts of substrate for its establishment in the forest, ideally the container should have a capacity of 5000 cm^3, or 5 lts.

It is necessary to perform a health inspection, where the phytosanitary conditions of The Natural Area will be determined.

References

[1] H. Arias Red, Assessment of reforestation on diferents soils in the middle of the Basin of Mexico, *Earth* 10 (1992) 309-317.

[2] P. Bowler, Large scale Salvage of coastal sage scrub through transplantation, Department of Ecology and Evolutionary Biology, University of California, Irvine, CA, 2001.

[3] A. Camacho-Cruz, M. González-Espinosa, B. H. J. Wolf and J. H. D. de Jong, Germination and survival of tree species in disturbed forests of the Highlands of Chiapas, Mexico, *Canadian Journal of Botany* 78 (2000) 1309-1318.

[4] S. A. Carrillo and P. S. Cisneros, Summary of climatological data in 4 seasons of Michoacán, *Biological Scientific Journal* 3 (1995).

[5] A. Carrillo, Different treatment tests of ecological restoration in degraded areas of Cerro del Potosí, Galeana, Nuevo León, Mexico, master thesis, Linares, Nuevo León, Mexico, 2003.

[6] The National Forestry Commission (CONAFOR), Pinusdevoniana, available online at: http://www.conafor.gob.mx/National programs__forest/pronare/tabs 20%Technical/Pinus%20devoniana.pdf.

[7] The National Forestry Commission (CONAFOR), Pinuspseudostrobus, available online at: http://www.conafor.gob.mx/Nationalprograms__forest/pronare/tabs%20Techniques/Pinus%20pseudostrobus.pdf.

[8] O. Masera, Carbon Mitigation scenarios for Mexican Forests: Methodological considerations and results, *Interciencia* 20 (1995) (6) 388-395.

[9] A. Ortiz et al., Restoration of cloud forest tree species: Tree plantations under the canopy of Pinusdouglasiana in Sierra de Manantlán, 2001.

[10] A. Ramirez Contreras and D. A. Rodriguez Trejo, Effect of the quality of the plant, exposure and micro site in a plantation of Quercusrugosa, *Magazine Chapingo, Series Forestry Science and the Environment* 10 (2004) (1) 5-11.

[11] N. Ramirez-Martial, M. González-Espinosa and G. Williams-Linera, Anthropogenic disturbance and tree diversity in Montane Rain Forests GNI, Chiapas, Mexico, *Forest Ecology & Management* 154 (2001) 311-326.

[12] G. C. Rzedowzky and J. Rzedowsky et al., *Fanerogamica Flora of the Valley of Mexico* (2th. ed.), Institute of Ecology, A.C. and National Commission for the Knowledge and Use of the Biodivesity, Patzcuaro, Michoacán, 2001, p. 1406.

[13] SAS (Statistical Analysis System), *Version 9.1*, SAS Institute Inc., Cary, NC, USA, 2003, p. 943.

[14] L. Tejera and M. Davel. Establishment of Oregon Pine in Patagonia, *Technical Sheet: Patagonia Forest* 10 (2004) (2) 9-12.