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Impacto ecológico de la reforestación con la especie arbustiva *Atriplex canescens* (Pursh) Nutt. en un matorral desértico micrófilo.

Ecological impact of reforestation with the shrub species *Atriplex canescens* (Pursh) Nutt. in a desert microphile scrub.

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RESUMEN

El presente trabajo muestra los resultados de un primer monitoreo sobre un área revegetada de matorral desértico micrófilo en el Desierto Chihuahuense, para conocer estructura y composición de la comunidad arbustiva, con el propósito de identificar cambios de la comunidad a 10 años posteriores a la revegetación con *Atriplex canescens (costilla de vaca*), sobre suelos somero y profundo, evaluando: 1) Diversidad de especies (DE); 2) Valor de importancia de las especies (IVI); Abundancia relativa (*Ar*), Dominancia relativa (*Dr*) y, Frecuencia relativa (*Fr*). La revegetación se aplicó sobre aclareos con curvas a nivel utilizando un diseño de bloques completamente al azar incluyendo 5 repeticiones con transectos de 50m^2. Posteriormente, se determinó que existe una disminución en la Diversidad de Especies (DE) de 20.44% en suelo somero y de 12.21 en suelo profundo, en comparación a los grupos testigo. Para Valor de Importancia (IVI), destacan en suelo somero *Parthenium incanum* y *Atriplex canescens* con 99.23 y 45.57, respectivamente y, en suelo profundo *P. incanum* y *A. constricta* con 98.53 y 46.21, respectivamente. Se observó una diferencia significativa (P ≤ .05) en relación a tipo de suelo. En conclusión, *Atriplex.canescens* muestra valor de Importancia (IVI) con alta viabilidad para ser utilizada en ecosistemas del desierto Chihuahuense (México).

Palabras clave: monitoreo, revegetación, diversidad, ecosistema, arbustivas.

ABSTRACT

Present work shows the results obtained from an screening on a revegetated area of desert scrub in the Chihuahua Desert, to know the structure and composition of the shrub community to identify changes 10 years after revegetation with *Atriplex canescens* (Costilla de Vaca), on shallow and deep soils, evaluating: 1) Species Diversity (DE); 2) Value of importance of the species (IVI); Relative Abundance *(Ar)*, Relative Dominance *(Dr)* and, Relative Frequency *(Fr)*. The practice was applied on thinning with level curves using a randomized block design with 5 repetitions with 50m^2 transects. Subsequently, it was determined that there is a decrease in Species Diversity (DE) of 20.44 in shallow soil and 12.21 in deep soil, compared to control groups. For Value of Importance (IVI), they stand out in shallow soil *Parthenium incanum* and *Atriplex canescens* with 99.23 and 45.57, respectively, and in deep soil *P. incanum* and *A. constricta* with 98.53 and 46.21, respectively. A significant difference (P≤0.05) was observed in response to type of soil. In conclusion, *Atriplex canescens* shows an interesting Important Value (IVI), which determines its viability of their application in ecosystems with similar characteristics.

Keywords: monitoring, revegetation, diversity, ecosystem, shrublands.

INTRODUCTION

The expansion of the human population has disturbed the native environments, putting at risk the biological diversity due to the growing disturbed areas, bringing with it an increase in the pressure on the natural resources (Gutiérrez, 2008, Aguirre *et al*., 2012), being currently the conservation of biological diversity one of the goals of ecosystem management in an ecologically sustainable sense. In turn, shrubs were considered as competing plants for reforestation and replanting programs, when in reality they are facilitating species for the establishment of species in diverse environments (Freckleton *et al*., 2009; CONABIO, 2012). Currently, there is a history of conducting various scientific studies related to shrub species, studies on the analysis and measurement of biomass (Muñoz-Reyes, 2011), damage by meteorological factors, relationships between vegetation and physical factors (Boyd and Davies, 2010), composition and structure (Molina *et al*., 2013; Alanis *et al*., 2013); studies of woody species under different management (Pequeño-Ledezma *et al*., 2012; Jiménez *et al*., 2013). On the other hand, Mora *et al*. (2013) carried out an investigation to determine the effect of livestock on the natural scrub, determining finally that the effect of livestock grazing stimulates a low similarity between the species of the area studied compared to the control ecosystem. The purpose of the present work was to carry out the first monitoring to evaluate the effect of the revegetation practice with *Atriplex canescens* (ie, "costillas de vaca") on the community of shrub species present in the study area in order to determine the presence of negative effect on the populations of the representative species of the community within a period of ten years after its implementation. Finally, the results obtained show that there is no significant difference in the treated ecosystem compared to the control ecosystem, determining in turn the viability of *Atriplex canescens* in the shrub community as an option for the increase of forage production in ecosystems similar to the study area. The reason why only the shrub layer was evaluated, is because they are species with a more constant presence in the ecosystem of interest, since grasses are more ephemeral species that may or may not be present at the time of monitoring (at 10 o'clock) years of applying the practice of revegetation given their inter-specific relationships derived from the phenomenon of plant succession and their strong dependence on the climatic precipitation prevailing in the ecosystem of interest, however it is pertinent to mention that the present is the first of three monitoring they will be carried out in the community of interest with an interval of 10 years in order to obtain more precise information about the ecological impact of the practice in question.

MATERIAL AND METHODS

The present monitoring was carried out in the "El Halcón" Experimental Ranch located in the northeast of Zacatecas state, in Villa de Cos municipality, Zacatecas, under the coordinates 23 ° 27 '36 "LN and 102 ° 10' 14" LO ; at an altitude of 1,975 m a.s.l (Google Earth, 2011), considered the southern end of the Chihuahuan Desert (Granados-Sánchez *et al*., 2011). This ecosystem is characterized for being an overgrazed area due to the management to which it has been subjected over the last decades, showing a high presence of shrub species and to a lesser degree of perennial growing herbaceous. The vegetation that is present is of the type "Desert Microphyllous scrublands”", coexisting the species *Atriplex canescens, Parthenium incanum, Acacia constricta, Larrea tridentata, Lycium berlandieri, Salvia ballotaeflora*, among others. According to the Koeppen classification of 1962, the climate of the region is defined as type BW with an average annual temperature of 17.5 ° C (Patton, 1962). The annual rainfall amounts to 357.8 mm on average during the last decade. The soil is of the litosol type, and shows a shallow sandy loam arable layer (Alanís-Rodríguez *et al*., 2015), once the "A" horizon is exceeded, the parent rock is found, sampling a slope that fluctuates from 0.50 to 0.75 percent.

For the initial execution of the test, *A. canescens* seedlings were used, which were established under structures for water harvesting (level curves) with distances between plants of 1.5 m, being established in strips of 15 m of amplitude in one surface of 22 hectares. The information coming from the plots was used to determine the quantitative evaluation of shrub species.

Investigation methodology

The basic idea of the study lies in the realization of monitoring at 10, 20 and 30 years from the execution of the aforementioned practice in order to analyze the impact of the same on the ecosystem based on the analysis of the shrub community. The management history of the ecosystem in question is based on seasonal grazing during the growing season (rainy season), during the last three decades, this management corresponds to a continuous grazing, since only in the dry season cattle were excluded.

The density used was determined from a sampling carried out in a paddock adjacent to the experimental unit, which shows a density of 500 individuals of *A. canescens* per hectare under seasonal grazing conditions and with similar soil conditions.

The individuals used for the test were 8-month-old seedlings and had an average height of 27 cm in their aerial portion. The seedlings were developed in the nurseries dependent on SEDAGRO - Government of the State, located in Mazapil Municipality, Zacatecas, Mexico.

For the preparation of the sowing bed, a pre-cleaning was carried out with total elimination of the present vegetation, this was done on strips at level corresponding to two thirds of the total surface and a width of 15 m with the construction of curves or borders at the level of 30 cm on average.

Once the conditions of saturation of water in soil were presented, after a 25mm rainfall event for a period of 2.5 hours, depressions were made with 1.5 "metal bars and a depth of 20 cm in order to carry out placing the root balls extracted from the germination trays. Once the seedlings were placed, a little pressure was applied in order to allow the contact of the secondary roots with the natural soil in order to facilitate the conductivity of water and nutrients. The distance between plants was 1.5 m. The planting season was the month of September.

The study area was reserved from the moment of planting until the month of July next year (10 months), time in which the established population showed an average height of 80 cm. Afterwards, the cattle were introduced, which used the species in a moderate way, going on to reserve the month of September so as not to use the bushes. From the second year, livestock grazing continued on the area each rainy season.

The individuals of *A. canescens* present in the control in shallow soil were found 31 and in the case of the control in deep soil 20 individuals per hectare.

Regarding the management of the study site, it is necessary that before the start of the trial, the area was excluded and once the individuals were transplanted, the establishment was expected, for which no additional treatment was applied. After the mentioned precipitation event, there were no rains in what remained of that year. The next rainfall was observed in the month of February with a 15 mm event and later until June. It is worth mentioning that the representative species of the shrub layer were taken into account, as faithful indicators of ecological degradation, due to their longevity, a factor that will allow us to obtain reliable information at 10, 20 and 30 years of observation to determine the impact generated.

Variables of study

Diversity of species:

The Shannon index (Shannon, 1949; Spellerberg and Fedor, 2003) was used to determine the diversity of species, which is obtained under the following formula:

$$H' = -\sum_{\mathrm{i}-1}^{S} \mathrm{p} \, * \mathrm{In}\,(\mathrm{Pi})$$

Where: H' = Diversity
S = Number of species present
In = Natural logarithm
pi = Proportion of species ni/N
ni = individual number of species
N = Total number of individuals.

Value of importance of the species or Specific Weight (PE): This parameter takes into account, the relative abundance (*Ar*), relative frequency (*Fr*) and the relative dominance (*Dr*) of the species present in the stand (Magurran, 1989) from the following formulas:

$$Ar = \frac{\mathrm{n}}{\mathrm{N}} * 100$$

$$Dr = \frac{\text{area of canopy of specie i}}{\text{area of total canopy}} * 100$$

$$Fr = \frac{\text{number of appearance of a species}}{\text{Total number of observations}} * 100$$

Given the previous equations, we can determine the Specific Weight of the indicator species in the ecosystem, which is determined through the following formula:

$$PE = \sum \sum_{\mathrm{i}}^{Fr} . \sum_{\mathrm{i}}^{Ar} . \sum_{\mathrm{i}}^{Dr} .$$

This equation includes the results of relative abundance (*Ar*), relative frequency (*Fr*) and relative dominance for each species in particular.

RESULTS AND DISCUSSION

Diversity of species

In relation to the Shannon index for both communities with shallow soil (table 1), it was found that the diversity of species is higher in the control ecosystem (1,355), compared to the restored ecosystem (1,078) with a differential of 21.45 %. For the communities with deep soil (Table 1), it was determined that the diversity is higher for the control (1.015), compared to the restoration (0.891) with a differential of 13.22%. Individually, for the case of the site restored in shallow soil, the most outstanding species was found to be *Parthenium incanum* (0.236), followed by *Atriplex canescens* (0.198). In the case of the community restored in deep soil, *Parthenium incanum* (0.190) stood out, followed by *Acacia constricta* (0.153).

Table 1. Diversity of species in the revegetated community (Shannon´s index)

		Shallow soil		Deep soil	
Nu.	**Species[1]**	**Treated area**	**Control**	**Treated area**	**Control**
1	*P. incanum*	0.236	0.314	0.190	0.237
2	*L. tridentata*	0.134	0.213	0.133	0.201
3	*S. ballotaeflora*	0.094	0.190	0.069	0.134
4	*A. constricta*	0.148	0.189	0.153	0.168
5	*L. berlandieri*	0.144	0.253	0.106	0.212
6	*J. dioica*	0.124	0.168	0.089	0.046
7	*A. canescens*	0.198	0.028	0.151	0.016
		1.078	1.355	0.891	1.015

1) Parthenium. incanum, Larrea tridentata, Salvia ballotaeflora, Acacia constricta, Lycium berlandieri, Jatropha dioica, A. canescens

The fact of working only with the seven mentioned species obeys to suggestions of committee of thesis based on the species that resulted with a frequency greater than 5 % in the sampling count by plots.

Importance Value of Species

The indicators related to the value of importance of the species (IVI) (table 2) in the ecosystem restored in shallow soil, show that *Parthenium incanum* presents the highest values (99.2), followed by *Atriplex canescens* (45.6).

In deep soil (table 2), we have what *Parthenium incanum*, which has the greatest ecological weight (105.8), followed by *Acacia constricta* (46.2). In the case of the control in both soils, *Parthenium incanum* had the highest ecological weight (98.94), followed by *Larrea tridentata* (52.04), the rest of the species showed lower values.

Table 2 Value of importance (IVI) for the representative species of the ecosystem in shallow soil

		Shallow soil		Deep soil	
Nu.	**Species**	**Treated area**	**Control**	**Treated area**	**Control**
1	*P. incanum*	99.23	98.94	105.83	98.53
2	*L. tridentata*	41.08	50.89	44.32	52.04
3	*S. ballotaeflora*	21.80	23.25	19.84	23.17

4	*A. constricta*	39.51	47.96	46.21	47.72
5	*L. berlandieri*	36.89	44.28	34.68	40.67
6	*J. dioica*	15.92	8.77	10.58	10.26
7	*A. canescens*	45.57	25.91	38.54	27.62
		300	300	300	300

1) *Parthenium incanum, Larrea tridentata, Salvia ballotaeflora, Acacia constricta, Lycium. berlandieri, Jatropha dioica, Atriplex canescens.*

Relative abundance (*Ar*)

For the variable of relative abundance, for both communities with shallow and deep soil (table 3), it was determined that, in the restored area with shallow soil, the highest values were shown by *P. incanum* (4477 individuals per hectare), followed by *A. canescens* (482 individuals per hectare). In the case of the community restored in deep soil, the same tendency is observed, with *P. incanum* being the most abundant (6086 plants per hectare), followed by *A. constricta* (399 individuals per hectare). In the control area with shallow soil a greater abundance of *P. incanum* (3362 individuals per hectare) is observed, followed by *L. berlandieri* (683 plants per hectare) showing similarity in both types of soil for these species.

Table 3 Relative abundance (*Ar*) for the representative species in the restored ecosystem expressed in number of individuals per hectare

		Shallow soil		Deep soil	
Nu.	**Species**	**Restoration**	**Control**	**Restoration**	**Control**
1	*P. incanum*	4477	3362	6086	5200
2	*L. tridentata*	264	502	325	575
3	*S. ballotaeflora*	159	417	131	307
4	*A. constricta*	305	412	399	430
5	*L. berlandieri*	293	683	236	628
6	*J. dioica*	235	344	185	73
7	*A. canescens*	482	31	392	20

Species frequency

For the variable of relative frequency, in both communities with shallow and deep soil (table 4), it was found that, in the area restored with shallow soil, the highest values were shown by *P. incanum* (100%), followed by *L. tridentata* (83%). In the case of the community restored in deep soil, *P. incanum* (100%) is observed, followed by *A. canescens* (84%). In the control area with shallow soil a greater frequency was observed for P. incanum (100%), followed by *L. berlandieri* (97%), and for the control in deep soil the maximum value for *P. incanum* was found (100%) and *A. constricta* (97%).

Table 4 Relative Frequency (*Fr*) for the representative species in the ecosystems of interest, expressed in percentage of appearance

		Shallow soil		Deep soil	
Nu.	Species	Restoration	Control	Restoration	Control
1	*P. incanum*	100	100	100	100
2	*L. tridentata*	83	94	80	96
3	*S. ballotaeflora*	57	76	61	67
4	*A. constricta*	56	92	90	97
5	*L. berlandieri*	73	97	71	93
6	*J. dioica*	58	60	41	39
7	*A. canescens*	79	13	84	43

Relative dominance

For the variable of relative dominance (*Dr*) (table 5), in both communities with shallow and deep soil (table 9), it was recorded that, in the restored area with shallow soil, the highest values were shown by *A. constricta* (90.00) m^2), followed by *A. canescens* (84.50 m^2). For the case of the community restored in deep soil *L. tridentata* (77.37m^2) followed by *A. constricta* (74.12 m^2) is observed In the control area with shallow soil a greater dominance of *L. tridentata* (64.75 m^2) is observed followed of *A. constricta* (60.87 m^2) and, for the control in deep soil, the maximum value was found for *A. constricta* (84.50 m^2) and, later *L. tridentata* (73.12 m^2).

Table 5 Relative dominance (*Dr*) of the representative species of the monitored ecosystem, expressed as a percentage

		Shallow soil		Deep deep	
Nu.	Species	Restoration	Control	Restoration	Control
1	*P. incanum*	28.50	22.5	26.00	30.00
2	*L. tridentata*	77.75	64.75	77.37	73.12
3	*S. ballotaeflora*	30.50	23.25	20.37	20.25
4	*A. constricta*	90.00	60.87	74.12	84.50
5	*L. berlandieri*	67.50	46.37	56.37	56.37
6	*J. dioica*	2.50	1.76	1.32	1.97
7	*A. canescens*	84.50	0.00	54.37	0.00

For the variable of relative dominance (*Dr*), in both communities with shallow and deep soil, it was recorded that in the restored area with shallow soil, the highest values were shown by *A. constricta* (90.00 m^2), followed by *A. canescens* (84.50 m^2). For the case of the community restored in deep soil *L. tridentata* (77.37m^2) followed by *A. constricta* (74.12 m^2) is observed In the control area with shallow soil a greater dominance of *L. tridentata* (64.75 m^2) is observed followed of *A. constricta* (60.87 m^2) and, for the control in deep soil, the maximum value was found for *A. constricta* (84.50 m^2) and, later *L. tridentata* (73.12 m^2).

In turn, *L. tridentata* and *A. constricta* show a similar trend over the rest of the species to that observed by Pequeño *et al*. (2012) who report a dominance marked with *Vachellia farnesiana* and *Prosopis glandulosa* on the rest of the community in the thorny scrub of

Tamaulipas, with 74% of absolute dominance, while 26% is divided among the remaining species.

For the case of the comparison between the communities studied, there has been a significant difference (P≤0.05) between soil types, as a response to the availability of nutrients. These results coincide with those obtained by Alanis *et. al.* (2008), who observed significant differences when comparing areas of thorny scrub with different management history. In relation to the diversity of species (DE), it was obtained that the values for the revegetated area turned out to be slightly smaller compared to their controls for both types of soil, however, as regards the species of interest (*A. canescens*), it was observed that it is the most favored species, with a differential of 707% and 943% for area treated in shallow and deep soil, respectively. For the variable of Importance Value of the species (IVI), it was determined that *Atriplex canescens* was the most relevant species, followed by *Parthenium incanum*, in relation to the rest of the species, they observed a slight decrease with the application of the treatment .

Analysis of variance for the total number of treatments and their controls in the communities under study

The results obtained in relation to the analysis of variance (table 6) show that there is a significant difference (P <.05) between blocks, and a highly significant difference (P <.01) for soil types (factor B), species (factor C) and the interactions between treatment vs species (A x C) and soil types vs. species (B x C) which shows the effect of the treatments and type of soil on the species that make up the community under study.

This allows us to assume that the difference found in soil types (factor B) is due to a greater availability of arable layer in deep soil, which results in a greater availability of nutrients and a greater development of the root system of the species in question. For the case of the statistical difference between species (factor C), it is inferred that this is derived from the presence of dominant species in the ecosystem such as the case of *P. incanum* over the rest of the community. In reference to the difference found between treatments and species (A x C), there are species that are more favored with the application of the practice in question such as *J. dioica* and *A. canescens*, since these are disclimax species, which respond to the generation of a disturbance and others that presented better development in the control plot, such as *A. constricta* and *L. berlandieri*. They maintain higher values in the control plots compared to the treated areas due to their capacity for development and propagation in low disturbed soils and which demonstrate a certain degree of compaction. For the interaction between soil types vs species (B x C), an effect similar to the previous interaction (A x C) is inferred since the soil depth favors species such as *P. incanum*, *A. Constricta* and *A. canescens* since they are species that develop better in deeper soils compared to the rest of the representative species of the ecosystem.

Table 6. Analysis of variance for the communities and treatments involved in the present study.

F. V.	G. L.	S. C.	C. M.	F.	P > F.
Blocks	3	1299568.0000	433189.343750	3.1417	0.029
Factor A	1	283816.0000	283816.0000	2.0618	0.151
Factor B	1	1167062.0000	1166072.0000	8.4212	0.005
Factor C	6	275863040.00	45977172.0000	334.0122	0.000
A x B	1	7352.0000	7352.0000	0.0534	0.813
A x C	6	4255352.0000	709225.3125	5.1523	0.000
B x C	6	6175880.0000	1029313.3125	7.4777	0.000
A x B x C	6	349160.0000	58193.332031	0.4228	0.862
Error	81	11149744.0000	137651.15625		
Total	111	300549984.0000			

C. V. 35.5636 %.

Table 7 shows the results of the comparison of means in shallow soil, within which it is highlighted that *P. incanum* with 4477 individuals per hectare, it is statistically different (P <.05) in shallow soil to its same species in the area witness. The rest of the species do not show significant differences between them for both communities, however, there is a noticeable decrease in the treated area compared to the control, which indicates that the treatment limited the diversity of the rest of the species in the ecosystem due to the removal of the original vegetation at the site with marginal soil.

Table 7: Comparison of means of the species in the treated area vs control with shallow soil (Tukey = 909.9111)

Nu.	Species	Restoration	vs Control
1	*P. incanum*	4477 a	3362 b
2	*L. tridentata*	264 a	502 b
3	*S. ballotaeflora*	159 a	417 b
4	*A. constricta*	305 a	412 b
5	*L. berlandieri*	293 a	683 b
6	*J. dioica*	235 a	344 b
7	*A. canescens*	482 a	31 b

Table 8: shows the results of the comparison of means of the species in the treated area vs control with deep soil, within which it is highlighted that *P. incanum* in deep soil and its control are statistically different (P <.05) with 6086 and 5200 plants per hectare, in turn,

the rest of the community, showed a tendency to decrease with the effect of the disturbance generated from the reference ecosystem.

Table 8: Comparison of means of the species in the treated area vs control with deep soil (Tukey = 909.9111)

Nu.	Species	Restoration	vs	Control
1	*P. incanum*	6086 a		5200 b
2	*L. tridentata*	325 a		575 b
3	*S. ballotaeflora*	131 a		307 b
4	*A. constricta*	399 a		430 b
5	*L. berlandieri*	236 a		628 b
6	*J. dioica*	185 a		73 b
7	*A. canescens*	392 a		20 b

CONCLUSION

The results derived from the determination of Species Diversity through the Shannon Index show that the diversity was greater in the control areas compared to the plots treated, as a response to the disturbance effect generated with the pre-clamp as well as the construction of curves At the level carried out for the implementation of *A. canescens* seedlings in the experimental area, however, when the comparison of means for treatments was carried out, it was determined that there is no significant difference between them. In turn revegetation with *A. canescens* in both types of soil does not impact the ecosystem under study, so its application is relevant to improve the increase in forage production and animal diversity, based on its forage and nutritional attributes.

The results derived from the determination of Species Diversity through the Shannon Index show that the diversity was greater in the control areas compared to the plots treated, as a response to the disturbance effect generated with the pre-clamp as well as the construction of curves At the level carried out for the implementation of *A. canescens* seedlings in the experimental area, however, when the comparison of means for treatments was carried out, it was determined that there is no significant difference between them. In turn Revegetation with *A. canescens* in both types of soil does not impact the ecosystem under study, so its application is relevant to improve the increase in forage production and animal diversity, based on its forage and nutritional attributes.

Despite observing a lower biodiversity in the treated areas, it is not pertinent to affirm categorically that the practice carried out negatively affects the ecosystem in question until obtaining the information of a second monitoring (at 20 years) or even a third measurement (a 30 years), data that will allow us to determine if a negative impact was actually generated on the populations present, since these species have life cycles that fluctuate between 15 and 25 years.

RECOMMENDATION

For productive purposes, it is pertinent to recommend the species *Atriplex canescens* (costilla de vaca) as an excellent forage alternative, especially for larger (bovine) and smaller ruminants (sheep and goats), in the northern Mexican grasslands located south of the Desert Chihuahuan, as long as no destructive practices of preparation of seedbed are carried out, trying to avoid soil erosion present in each ecosystem in particular.

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