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Restoration of Rangelands Invaded by *Amelichloa clandestina* (Hack.) Arriaga & Barkworth after 12 Years of Agriculture Abandonment (Coahuila, Mexico)

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Abstract: Abandonment of agricultural land is currently one of the main land use changes in developed countries. This change has an impact at the economic level and from the point of view of conservation. Therefore, recovering these areas after abandonment is, in many cases, necessary for ecological restoration, especially as they can be invaded by exotic or dominant species, preventing recovery of the original plant species community. The objective of this study is to examine changes in plant species richness and composition after the application of different treatments to eliminate *Amelichloa clandestina*, a species that dominates pastures abandoned 12 years ago in an area located in northern Mexico. The area is a semi-desert grassland dominated by buffalo grass *Bouteloua dactyloides*. We used different eradication techniques such as burning, herbicides, and clipping. Although the treatments had significant effects on species richness and composition and resulted in a relative reduction of the target species, the abundance of *Amelichloa clandestina* was still substantial. Burning is effective, favoring the increase of species richness and provoking a lower presence of *A. clandestine* but with a dominance of annuals. The most important impact on the total cover of *A. clandestina* is shown by the herbicide treatment. However, monitoring of these areas will still be required to consider the long-term impact and success of treatments.

Keywords: biodiversity; DCA; species richness; restoration

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1. Introduction

Urbanization and the abandonment of agricultural land are currently among the main changes in land use in developed countries [1] and can lead to loss of diversity and cultural values [2,3]. Moreover, a further increase in land abandonment is anticipated in the near future [4].

In general, the cessation of extensive farming in the developing world has led to a substantial increase in dry grasslands and dwarf shrublands in marginal lands [5]. Such changes in vegetation patterns may be an indication of the onset of desertification in arid areas. However, in some cases, positive aspects can arise from land abandonment such as changes in vegetation cover, affecting water availability and soil properties [6,7]. The abandonment of traditional agricultural lands in some areas often leads to fields that require restoration. Indeed, intensive agriculture in the past and rapid environmental change are hindering original plant community recovery. Thus, the restoration of these abandoned fields should be considered a requirement [8,9].

After abandonment, the dominance of some species (including exotic species) may alter patterns of vegetation recovery in disturbed sites [9], even where native species have enough propagules to recolonize through natural dispersal [10–12]. Thus, management through different tools is required to restore, to some degree, the ecological processes of the plant community (native species, regeneration, species richness, etc.) [13,14].

In this study, we evaluated an area that after 12 years of agriculture abandonment has been completely dominated by Mexican needlegrass (*Amelichloa clandestina*), unpalatable for vertebrate grazers and native to northern Mexico. This species has been expanding across abandoned fields in northern Mexico and Texas [15]. Changes after agriculture abandonment are evident in many aspects, and the most relevant are related to erosion, changes in nutrients, and alteration of ecological processes such as species richness and maintenance [16,17]. Therefore, the objective of this study is to examine changes in plant species richness and composition after the application of different treatments to eliminate a species that dominates pastures due to agriculture abandonment. Elimination was conducted through chemical methods, clipping, and burning to evaluate the restoration possibilities of these management tools. We hypothesized that burning would increase species richness due to the clearing of the biomass and nutrient incorporation through mineralization, while herbicide and clipping would have a more significant effect on the *A. clandestina* cover due to elimination after six months of treatment application.

The study of agriculture abandonment has potential management and environmental implications (species conservation, control of invasive species, etc.) that can be considered relevant to avoid land degradation.

2. Materials and Methods

2.1. Study Site

The study was carried out at the Los Angeles ranch, located 34 km south of Saltillo, Coahuila, Mexico, between 25°04′12″–25°08′51″ north latitude and 100°58′07″–101°03′12″ west longitude; the mean altitude is 2150 m (Figure 1). The climate according to García [18], using the climate formula (BWhw (x′) (e)), is semi-arid, with cool winters, average annual temperature between 18 and 22 °C, and average annual rainfall of 450 to 550 mm, distributed mainly in the summer. The soils are of alluvial origin, deep with well-defined profiles and horizons; they are brown and light reddish-brown in color. The soil type is Calcaric Feozem [19]. The study area is surrounded by a native semi-desert grassland dominated by buffalo grass *Bouteloua dactyloides* (Nutt.) Columbus, with other dominant grasses as *Muhlenbergia phleoides* (Kunth) Columbus, *M. arenicola* Buckley, and the forb *Dyschoriste linearis* (Torr. & A. Gray) Kuntze. With an isolated distribution, we can find shrubs of the species *Opuntia engelmanii*, Salm-Dyck, *Cylindropuntia imbricata* (Haw.) F.M. Knuth, and *Buddleja scordioides* Kunth.

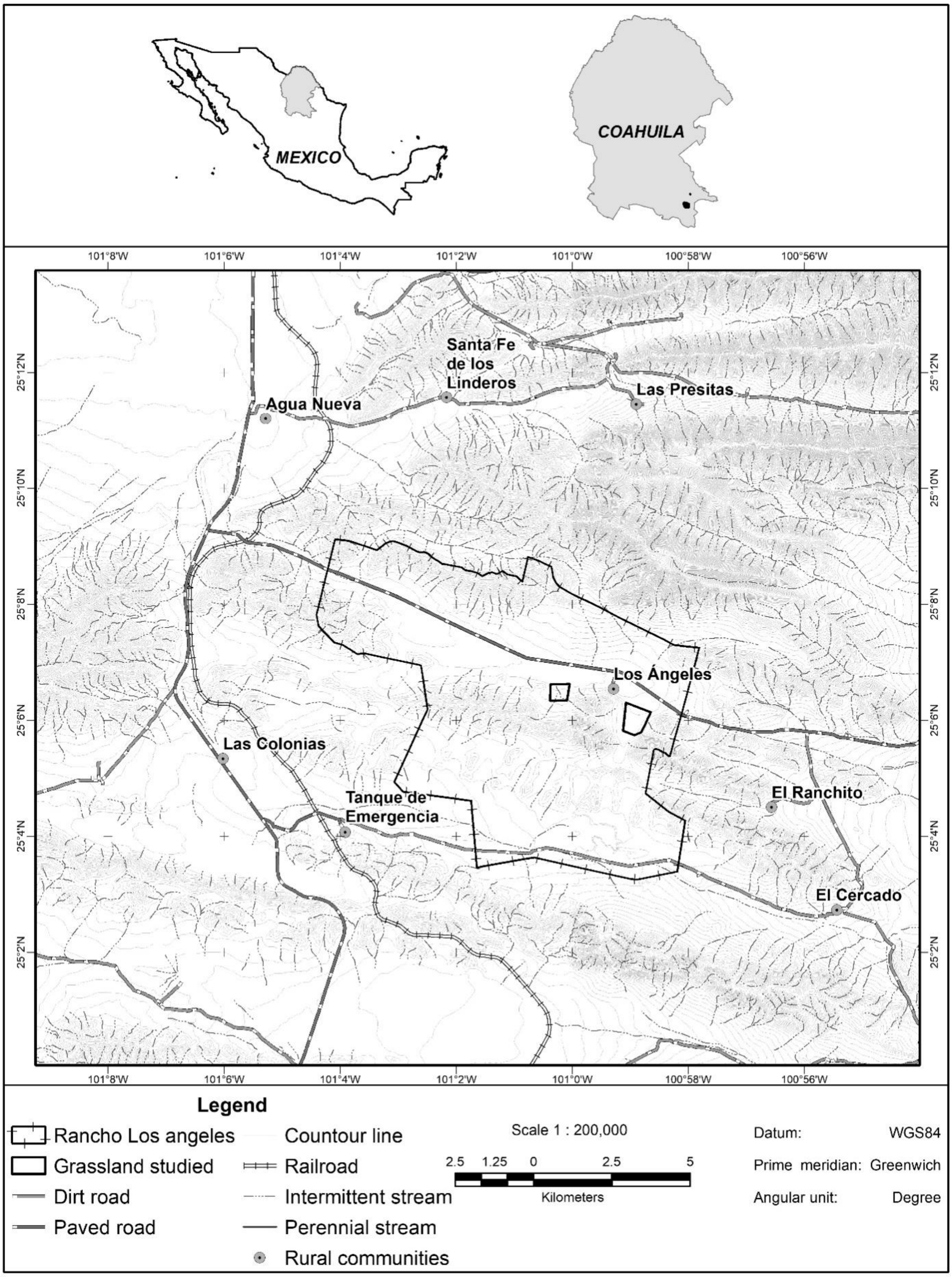

Figure 1. Location of the study area Rancho Los Angeles (enclosed by the thin black line polygon) in northern Mexico (25° N). The two blocks of this study inside Rancho Los Angeles are enclosed in the two polygons in thick black lines.

Experimental plots were established in two agricultural areas abandoned in 2009—one with a surface area of 40 and the other 60 ha. After the suppression of the agricultural activity (mainly cereal with some short periods of opening for cattle grazing), spiny grass (*Amelichloa clandestina*) colonized the area, and gradually, a dense grassland was formed, where the herbaceous stratum has become dominant. The long use of these rangelands had an impact on the potential vegetation of the area, and restoration should be based on the native species composition of this particular area and reduction of shrubs, with the promotion of annual species highly affected by these longs' periods of use.

2.2. The Species

Amelichloa clandestina (Hack.) Arriaga & Backworth (Poaceae) is a native perennial grass (Figure 2). The leaves are basal, erect, 10–50 cm long with a sharp brown tip when dry. It has tufted culms 40 to 100 cm high, erect, thin, internodes glabrous, 1–2 noded, with a rhizomatous base; sheaths are glabrous except on the neck, where they are hispid. The lower sheaths frequently hide cleistogamous inflorescences [20]; ligule, a small scale 0.1 to 0.2 mm long. Blades are 10 to 30 cm long, bent or generally involute, glabrous to scabrous with muchronous apex. The inflorescence is a narrow panicle 8 to 35 cm long. Spikelets have only one fertile floret. The floret has a densely bearded callus, and a twice geniculate awn, glabrous, and 12 to 20 mm long [21].

Figure 2. Inflorescence *Amelichloa clandestina* in the study site.

The species is distributed in Coahuila and Nuevo León, Mexico, and has been introduced to western Texas. Its presence was first recorded in the early 1950s [22]. Misidentification prevented it from being recorded until 1987. Since then, it has spread throughout the Edwards Plain and parts of central Texas [15]. It occurs in disturbed places, on calcareous soils, in impacted areas, grasslands, and pinyon pine forests between 800 and 2100 m altitude.

2.3. Sampling

Two blocks in two different pastures (1 km apart approximately) of 12 plots of 10 × 10 m were established, with 5 m separation between plots, and four different treatments randomly assigned to the plots (2 blocks × 4 treatments × 3 replicates; Figure 3). In all these plots, the dominant grass is *Amelichloa clandestine* with over 95% cover of the plot. Treatments were applied in March 2020 before the rainy season and included the following: Treatment 1 (burn): Around the plots, 2 m wide fire breaks were made to isolate the vegetation where controlled burning was applied. The concentric burning technique was applied, which consists of making an ignition line at the end opposite to the wind direction, then ignition is started at the other end so that both lines meet and extinguish each other; Treatment 2 (herbicide): A minimum dose of glyphosate herbicide (2.3 L ha^{-1}) was homogenously applied on the plot, supplemented with 15 mL of liquid soap as an adherent; Treatment 3 (clipping): *A. clandestina* individuals were cut at a height of 5 cm from the ground, in spring. All cut foliage (leaves and culms) were removed from the plots; Treatment 4 (control): The case was considered as a control, in which the surface and species of the plots were not treated.

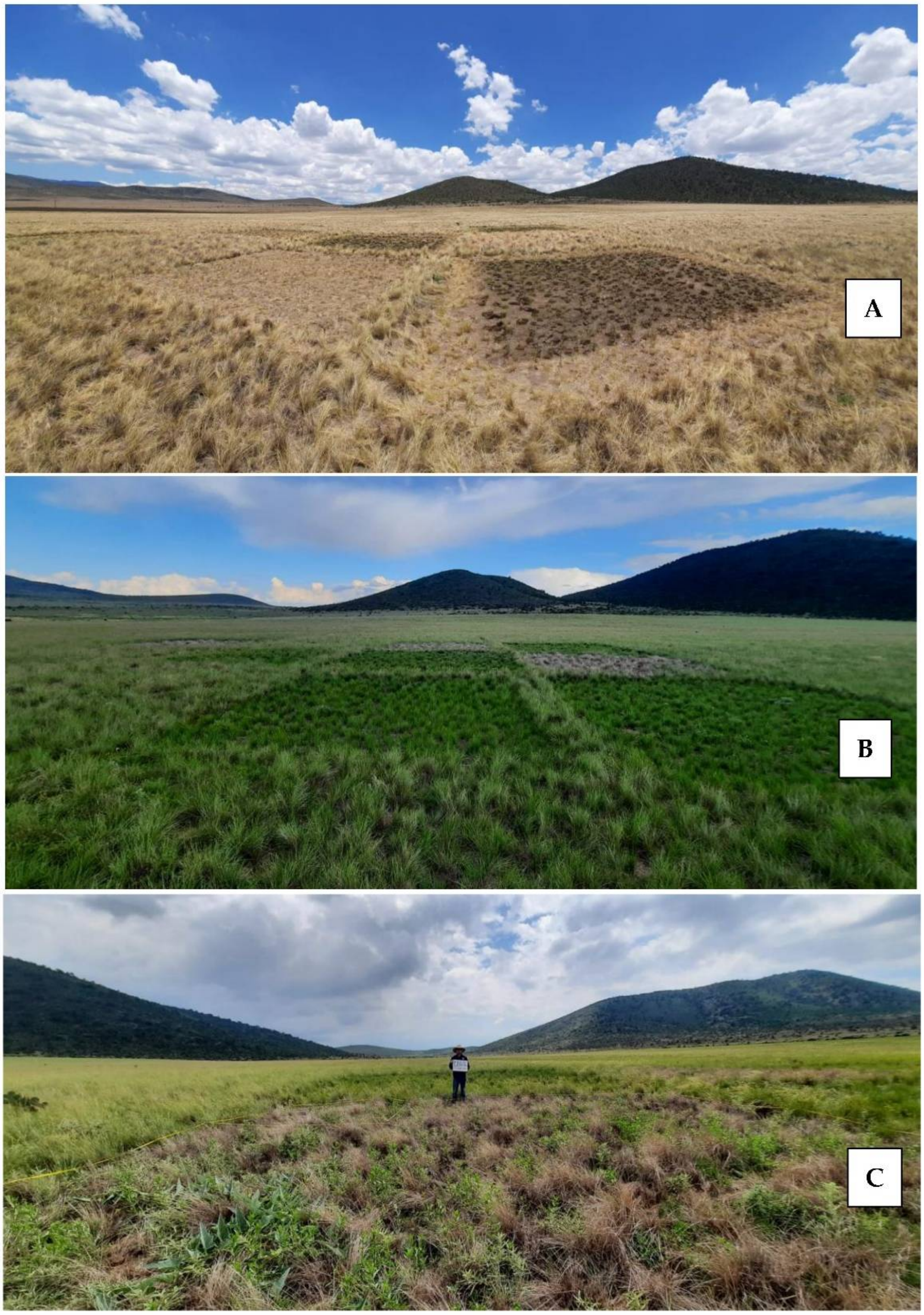

Figure 3. Grassland of Mexican needlegrass (*Amelichloa clandestina*): (**A**) application of burning and clipping treatments in foreground of the photo; (**B**) response of the grass after application of treatments and during the rainy season in the following summer; (**C**) plot where the herbicide glyphosate was applied, in which a greater richness of species can be observed.

In each plot, we measured altitude, slope, and aspect. We also visually estimated rock, bare soil, and litter cover, as well as grass and forb cover (no woody species were present in the plots) within each plot on a scale of 1–10 (corresponding to percentage cover classes):

1, traces; 2, 0–1%; 3, 1–2%; 4, 2–5%; 5, 5–10%; 6, 10–25%; 7, 25–50%; 8, 50–75%; 9, 75%; 10, 100%). Additionally, the height of the grasses and forbs were measured (to identify the tallest ones in the plot).

In each plot, we recorded all plant species. Sampling was conducted from the end of August to the beginning of October 2020 (3 different sampling periods). This period encompassed the peak appearance of annual plants. Thus, most annual species present in the plots were recorded, including the alien species. Cover of species at ground level was estimated on a scale of 1–10 (previously defined).

2.4. Statistical Analyses

Ordination techniques help to explain community variation [23], and they can be used to evaluate trends over time and space [24]. We used detrended correspondence analysis (DCA) [25] of Software for Canonical Community Ordination (CANOCO) [24] to examine how species composition changed and whether the change could be attributed to the different treatments: control, clipping, herbicide, and burning.

To confirm differences in species composition based on treatment, we used the multiple-response permutation procedure (MRPP) in the PC-Ord statistical package [26]. MRPP, a non-parametric procedure, was used for testing the hypothesis that no difference existed in species composition between different plots. Relative Sørensen (Bray–Curtis) was used as a distance measure as it considers both composition (presence–absence of species) and abundance (cover values).

We conducted an analysis of similarity (ANOSIM) with 999 permutations to determine significant differences in species composition by treatment. This analysis provides pair tests among groups, thus helping to determine any differences. In order to identify species indicators for each group, the indicator species analyses (ISA) were implemented to determine the abundance and frequency of dominant species across the different treatments, and tests for statistical significance using a randomization technique (Monte Carlo) [27] were conducted. Both analyses (ANOSIM and ISA) were carried out with a PC-Ord statistical package [26].

Rock, soil, litter, grass, and forb cover (based on percentages), in addition to the evenness index of Smith and Wilson [28] and richness, were compared individually using a 2-way distance-based, permutational, repeated-measure ANOVA, with treatments used as factors (4 treatments and 6 plots in each one). Analysis was based on Bray–Curtis distances of raw data, with p-values obtained by using 9999 permutations of the appropriate exchangeable units [29]. Pairwise posteriori comparisons using t-statistics were applied when PERMANOVA revealed significant differences among groups (for a $p < 0.05$). We used the same analysis to compare the cover of *Amelichloa clandestina* in the different treatments.

3. Results

The two blocks, which had been under similar management for the last 50 years, presented similar environmental conditions in terms of altitude, aspect, and slope (Table 1) and were separated by around 1 km. In the case of grass and forb cover, the differences were statistically significant among treatments (Pseudo $F_{3,20} = 27.17$ and Pseudo $F_{3,20} = 9.35$, respectively, for a $p < 0.01$). The lowest values of grass cover were in herbicide plots (20%), while the highest were in the control plots (76%). However, forb cover was higher in the herbicide plots (37%) and lower in the control and clipped plots (5%), as indicated by the pairwise posteriori comparisons ($p < 0.01$).

Table 1. General abiotic and plant community information of the plots (* Spc: Species richness; #: number). Average values and standard deviation (Std) for the information of the different variables are also included.

	Altitud	**Aspect**	**Slope**	**Grasses**	**Forbs**	**Rock**	**Soil**	**Litter**	**Grasses**	**Forbs**	**Spc ***	**Evenness**
Plot **	**(m)**		**(Sex)**			**%Cover**			**Height (cm)**		**#**	
CL21	2137	65	15	55	3	0	5	85	30	25	26	0.87
CL22	2117	85	25	40	5	15	10	50	40	50	22	0.78
CL41	2133	65	15	40	3	0	5	60	40	35	23	0.85
CL42	2125	85	25	45	2	10	20	45	50	20	24	0.86
CL61	2133	65	15	50	15	0	10	40	50	30	20	0.84
CL62	2119	85	25	45	2	12	10	40	40	8	30	0.83
Average	*2127.3*		*20.0*	*45.8*	*5.0*	*6.2*	*10.0*	*53.3*	*41.7*	*28.0*	*24.2*	*0.8*
Std	*8.2*		*5.5*	*5.8*	*5.0*	*6.9*	*5.5*	*17.2*	*7.5*	*14.2*	*3.5*	*0.0*
H101	2135	65	15	25	45	0	10	80	20	50	17	0.88
H102	2122	85	25	15	25	10	20	45	70	15	33	0.84
H121	2141	65	15	10	45	0	20	70	30	40	24	0.85
H122	2124	85	25	25	40	10	25	75	70	25	26	0.81
H81	2133	65	15	25	25	0	30	65	30	25	27	0.87
H82	2118	85	25	20	40	15	20	35	65	30	31	0.83
Average	*2128.8*		*20.0*	*20.0*	*36.7*	*5.8*	*20.8*	*61.7*	*47.5*	*30.8*	*26.3*	*0.8*
Std	*8.8*		*5.5*	*6.3*	*9.3*	*6.6*	*6.6*	*17.8*	*23.2*	*12.4*	*5.6*	*0.0*
B11	2139	65	15	60	5	0	10	5	28	30	32	0.83
B12	2116	85	25	40	5	10	30	5	30	25	27	0.82
B71	2133	65	15	30	15	0	20	5	30	35	29	0.87
B72	2125	85	25	40	5	30	35	3	35	20	31	0.81
B91	2133	65	15	30	15	0	30	5	35	30	32	0.81
B92	2122	85	25	35	30	5	45	5	35	20	35	0.85
Average	*2128.0*		*20.0*	*39.2*	*12.5*	*7.5*	*28.3*	*4.7*	*32.2*	*26.7*	*31.0*	*0.8*
Std	*8.5*		*5.5*	*11.1*	*9.9*	*11.7*	*12.1*	*0.8*	*3.2*	*6.1*	*2.8*	*0.0*
C111	2139	65	15	80	15	0	5	20	55	50	24	0.84
C112	2123	85	25	65	5	25	20	10	60	25	25	0.82
C31	2135	65	15	85	2	0	5	15	60	40	24	0.83
C32	2119	85	25	70	3	25	30	15	60	25	20	0.83
C51	2133	65	15	85	3	0	20	10	70	45	11	0.75
C52	2125	85	25	70	2	5	20	20	75	25	21	0.83
Average	*2129.0*		*20.0*	*75.8*	*5.0*	*9.2*	*16.7*	*15.0*	*63.3*	*35.0*	*20.8*	*0.8*
Std	*7.8*		*5.5*	*8.6*	*5.0*	*12.4*	*9.8*	*4.5*	*7.5*	*11.4*	*5.2*	*0.0*

(**) The letters indicated the treatment as CL: clipping; H: herbicide; B: burning; C: control.

A total of 70 species were found in the study (Appendix A), with a low number of introduced species (10). Richness varied significantly among treatments (Pseudo $F_{3,20} = 4.01$, $p < 0.01$), revealing higher values of species richness for burned plots ($p < 0.01$; Figure 4a). For evenness, differences were not significant ($F_{3,20} = 1.13$, p = n.s.; Figure 4b).

The DCA analysis discriminated among the different treatments along axis II. We represented the bidimensional space with the species and the plot coordinates, and polygons containing the plots of each treatment (minimum area polygons containing the plots). This species composition analysis revealed that control and clipping are poorly discriminated, and we also found low discrimination for control and herbicide plots. *Amelichloa clandestina* is more representative in terms of the species composition in the first two treatments than for burned or herbicide treatments. More exotic species are representative of the burned and herbicide treatments, such as *Erodium cicutarium*, *Parthenium hysterophorus*, *Eruca sativa*, *Taraxacum officinale*, or *Sonchus oleraceus*. For control and clipping, the most representative species, based on species composition, are *Solidago velutina*, *Hesperostipa comata*, *Muhlenbergia rigida*, *Townsendia mexicana*, *Cylindropuntia imbricata*, or *Nassella tenuissima* (Figure 5).

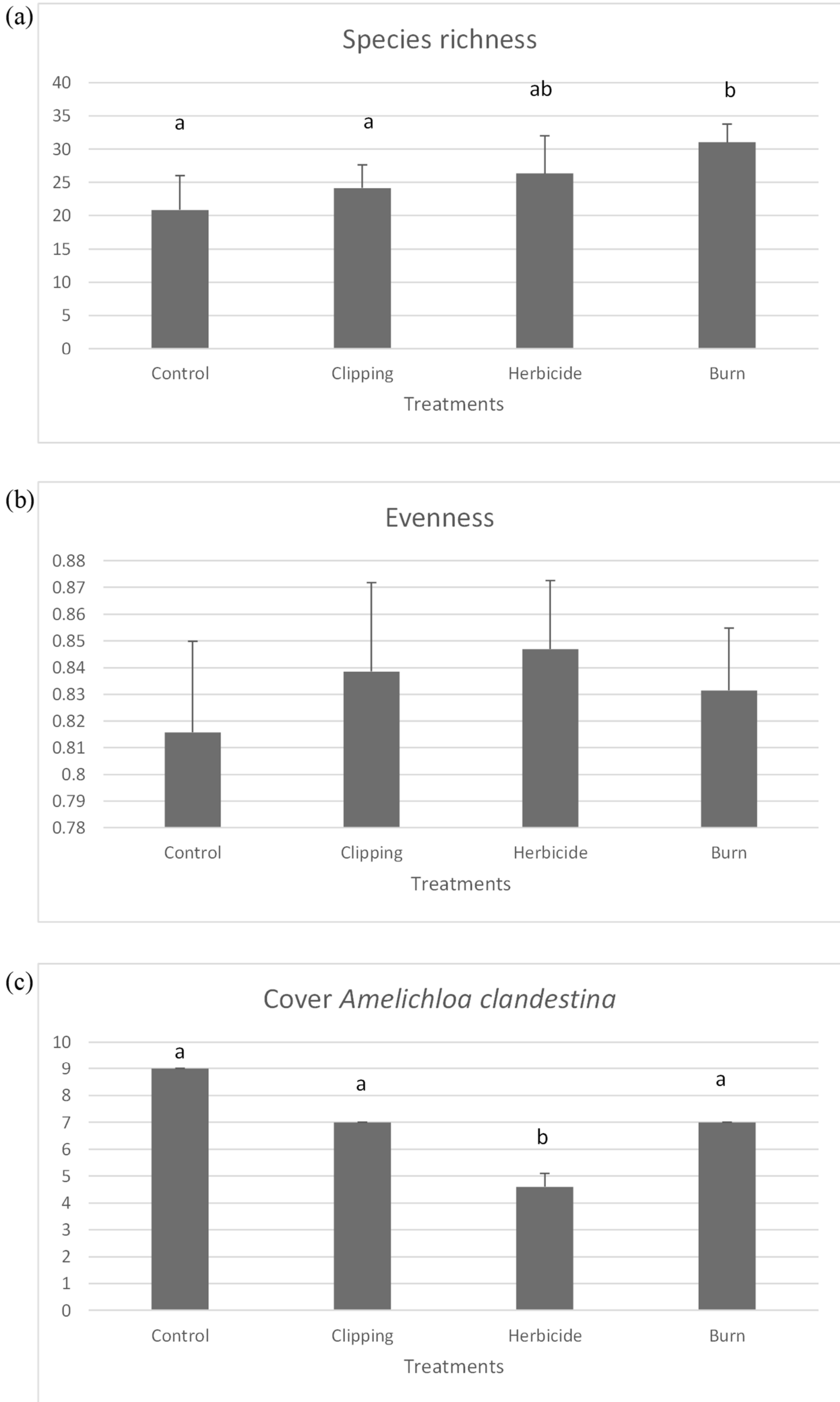

Figure 4. Mean values and standard deviations for (**a**) species richness, (**b**) evenness, and (**c**) cover of *Amelichloa clandestina* for the different treatments. Identical letters on top of bars indicate non-significant differences ($p < 0.05$ for d.f. = 23 for the error term).

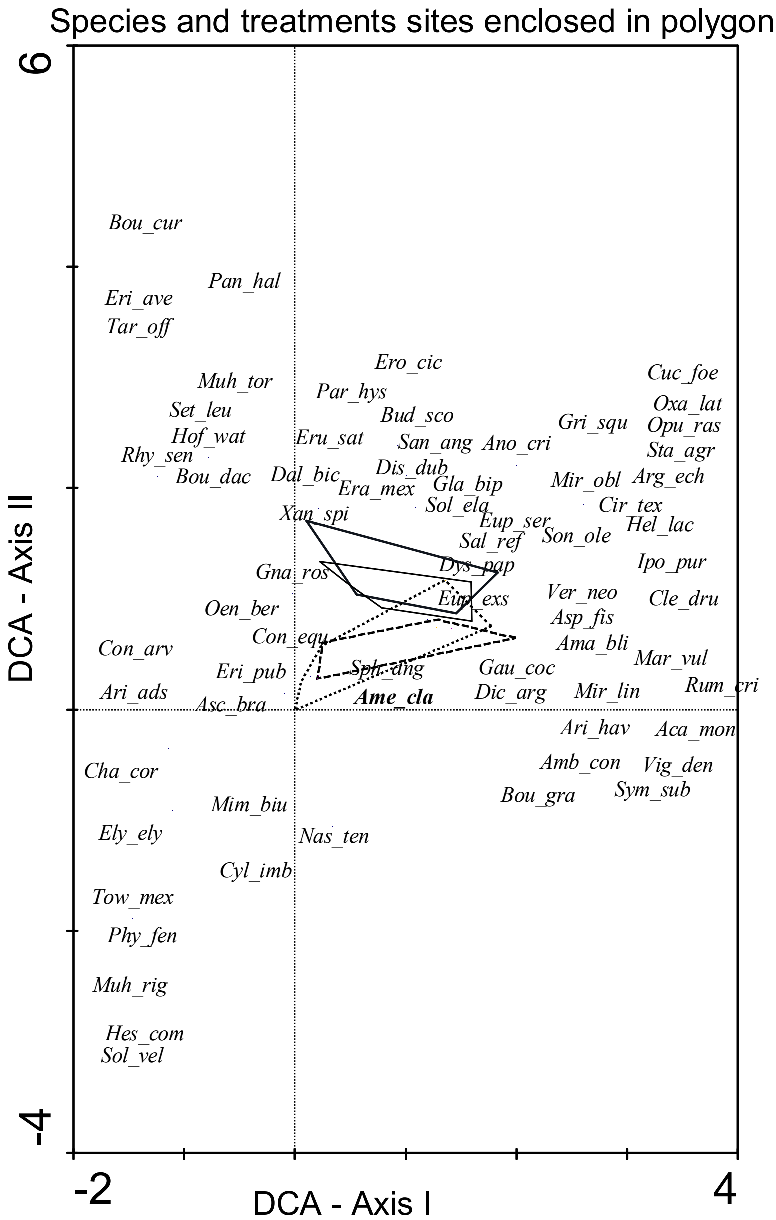

Figure 5. Detrended correspondence analysis axes I and II. Species coordinates and treatment plots' coordinates (each treatment with a different symbol). Eigenvalues for axis I: 0.30, eigenvalue for axis II: 0.14, cumulative percentage of total inertia for axes I and II: 26.4%. Polygons enclosed plots under same treatment: Polygon with a slashed line for control plots, dotted line for clipped plots, solid thick line for burned plots, and solid thin line for herbicide plots (species names use the three first letters of the genus, followed by the three first letters of the specific epithet from Appendix A).

Differences between treatments based on species cover were significant (MRPP), with a T = −3.551 and group probability correction of A = 0.058 for a $p < 0.01$. ANOSIM was used to reveal the differences in paired treatments. We found evidence of significant variations among species groups for the different treatments (R = 0.2026, $p < 0.001$ for 1000 iterations). Indeed, pair comparisons revealed that control plot species compositions were significantly different from the burned and herbicide plots (both with a $p < 0.01$).

Finally, the ISA base in 1000 permutations revealed that the species *Anoda cristata*, *Erodium cicutarium*, *Euphorbia serrula*, *Parthenium hysterophorus*, *Sanvitalia angustifolia* were indicators of burned plots, while *Eruca sativa* and *Townsedia mexicana* were indicators of herbicide and control plots, respectively. In all these cases, the indicator value (IV) was significant, with a $p < 0.05$.

4. Discussion

The study was carried out in an area after 12 years of agriculture abandonment. This area was colonized by *Amelichloa clandestina*, a plant that completely dominated the site and significantly reduced species richness. Farmland abandonment constitutes a major land use change, with its importance acknowledged today due to the implications it has for biodiversity and cultural values [1,30]. We suggested the use of three different management techniques in the area in order to increase native plant community and species composition. Mechanical treatments, such as clipping, reduce biomass and give species present in the seed bank the chance to occupy the open area, but these seeds will need to grow faster than the target species *Amelichloa clandestina*. In the case of herbicide treatment, glyphosate is a very potent one [31], whose usefulness in weed control has been recognized for over 25 years [32]. However, having no specific effect on the target species (it affects all the species treated), it is necessary to analyze its impact on the plant community before generalizing its use. Finally, burning is a useful management tool for preventing large wildfires [33], though it can have significant effects on diversity [34] and species composition [35], depending on how and where it is applied.

With regard to the plots, all of them presented similar environmental conditions (altitude, aspect, slope, and rock cover). However, plot characteristics related to the treatments revealed significant differences, as in the case of grass cover, with lower values in the herbicide plots and the highest values in the control plots. By contrast, forbs presented the largest cover in the herbicide-treated plots and lower cover in the control and clipped plots. Herbicide affected the dominant grass, favoring the cover of forbs (Table 1).

In the case of species richness, the burned plots presented the highest values (greater than 10 species more, on average, than control plots). This is an expected value, as most sources suggest an overall trend of increasing species richness after fire [36–38]. In most cases, this increase in richness occurs during the first-to-second year after fire and is related to herbaceous pioneer species [39], which are linked to canopy opening and higher light availability at the soil surface after fire [40]. In addition, herbicide plots presented a significantly high value of species richness due to the impact of the herbicide on the dominant grass, *Amelichloa clandestina*, as the open space allowed the occupancy of forbs, which have a faster response to this management (Figure 3A).

Non-significant differences were found for evenness among treatments, and although on average, control plots presented lower values (related to the dominance of *Amelichloa clandestina*), high variability did not allow for significant differences (Figure 3B). In the case of cover, *A. clandestina* showed some differences between treatments, with significantly lower values in the herbicide plots ($F_{3,20} = 129.63$, $p < 0.01$.; Figure 3C).

In the case of species composition, the treatment that most differed from the control plots was burning, revealed by axis II of the DCA analysis. Some were more abundant in the control plots with respect to the treated plots, such as *Solanum elaeagnifolium*, *Solidago velutina*, *Hesperostipa comata*, *Muhlenbergia rigida,* or *Townsendia mexicana*, indicating they were favored after the abandonment of these fields, while in the case of the burned plots, *Bouteloua curtipendula*, *Panicum hallii*, *Erioneuron avenaceum*, or *Muhlenbergia torreyi* dominated, all of them grasses, alongside the forb *Taraxacum officinale* or *Erodium cicutarium*, both exotic forb species. *Amelichloa clandestina* was more abundant in the control and clipped plots, but its presence was reduced by the other treatments. The lowest cover of *A. clandestina* was present in the herbicide-treated plots.

The RPPP significantly differed between the groups, and the ANOSIM pair tests analyses revealed that species composition was different between control plots and burned and herbicide plots. The clipping did not produce any important difference with respect to the control plots, very likely due to the regrowth of perennial forbs, although mechanical removal has been effective in other experiments in different areas [41].

Indicator species of the burned plots that were identified in the analyses were all annuals (in some cases introduced ones, such as *Erodium cicutarium* or *Parthenium hysterophorus*). Other authors have found that competition from perennial grasses limits shrub production [42,43]. *Eruca sativa*, an introduced annual, characterized the herbicide plots and the native perennial forb, *Townsendia mexicana,* dominated the control plots.

Based on the results, two treatments appear to be more suitable approaches: burning, as a treatment to favor the increase in species richness, and herbicide to keep the dominance of *Amelichloa clandestina* under control. Regardless, we can discard the clipping methods, as the impact is very limited. Burning and herbicide treatments have the highest impact on species richness and composition in these highly disturbed rangelands.

5. Conclusions

Although the treatments revealed significant effects on species richness and composition, the presence of the target species was still substantial while being quite reduced relative to control plots. Burning appears to be effective, favoring an increase in species richness and revealing a less significant presence of *Amelichloa clandestina*, but with a dominance of annuals, a short-term common result after burning or wildfire [44]. The most significant reduction of *A. clandestina* cover was shown in the herbicide treatment.

In order to keep species under control, the use of periodical burning seems to be necessary, but exotic species can also be favored by this treatment; therefore, we can consider this an effective management technique to increase diversity. The herbicide, although important in reducing the cover of *Amelichloa clandestina* at the first application, when dominance is over 90% of cover, needs to be used with caution in reapplications to avoid an effect on native species. Other more complex biological treatments, such as the introduction of natural enemies of the target species [45], are riskier from an ecological point of view and require long experimental periods, though they can be highly recommended whenever they are possible and affordable.

The eradication methods, although useful, will require monitoring of the changes of the plant community, as long as we have seen that they can promote some exotic species that may need specific attention. To control their spreading, after burning, we suggest applying herbicide on individual plants of these species.

It is worth mentioning that the use of burning allows for the removal of part of the dominant species, which increases the time for invasive species to occupy the new area and therefore favors the recovery of natural vegetation, increasing species richness. However, we still recommend herbicide application to support the treatment of repeated burning to keep *A. clandestina* and other exotic species under control.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Species characteristics with the life cycle, origin, and growth form indicated. Bold use for introduced species.

Species Name	Life Cycle	Origin	Growth Form
Acalypha monostachya	Perennial	Native	Forb
Amaranthus blitoides	Annual	Native	Forb
Ambrosia confertiflora	Perennial	Native	Forb
Amelichloa clandestina	Perennial	Native	Grass
Anoda cristata	Annual	Native	Forb
Argemone echinata	Annual	Native	Forb
Aristida adscensionis	Perennial	Native	Grass
Aristida havardii	Perennial	Native	Grass
Asclepias brachystephana	Perennial	Native	Forb
Asphodelus fistulosus	**Perennial**	**Introduced**	Forb
Bouteloua curtipendula	Perennial	Native	Grass
Bouteloua dactyloides	Perennial	Native	Grass
Bouteloua gracilis	Perennial	Native	Grass
Buddleja scordioides	Perennial	Native	Shrub
Chamaesaracha coronopus	Perennial	Native	Forb
Cirsium texanum	Perennial	Native	Forb
Clematis drummondii	Perennial	Native	Shrub
Convolvulus arvensis	**Perennial**	**Introduced**	Forb
Convolvulus equitans	Perennial	Native	Forb
Cucurbita foetidissima	Perennial	Native	Forb
Cylindropuntia imbricata	Perennial	Native	Shrub
Dalea bicolor	Perennial	Native	Shrub
Dichondra argentea	Perennial	Native	Forb
Disakisperma dubium	Perennial	Native	Grass
Dyssodia papposa	Annual	Native	Forb
Elymus elymoides	Perennial	Native	Grass
Eragrostis mexicana	Annual	Native	Grass
Erigeron pubescens	Perennial	Native	Forb
Erioneuron avenaceum	Perennial	Native	Grass
Erodium cicutarium	**Annual**	**Introduced**	Forb
Eruca sativa	**Annual**	**Introduced**	Forb
Euphorbia exstipulata	Annual	Native	Forb
Euphorbia serrula	Annual	Native	Forb
Gaura coccinea	Perennial	Native	Forb
Glandularia bipinnatifida	Annual	Native	Forb
Gnaphalium roseum	Perennial	Native	Forb
Grindelia squarrosa	Perennial	Native	Forb
Helianthus laciniatuus	Perennial	Native	Forb
Hesperostipa comata	Perennial	Native	Grass
Hoffmannseggia watsonii	Perennial	Native	Forb
Ipomoea purpurea	**Annual**	**Introduced**	Forb
Marrubium vulgare	**Perennial**	**Introduced**	Forb
Mimosa biuncifera	Perennial	Native	Shrub
Mirabilis linearis	Perennial	Native	Forb
Mirabilis oblongifolia	Perennial	Native	Forb
Muhelenbergia rigida	Perennial	Native	Grass
Muhlenbergia torreyi	Perennial	Native	Grass
Nassella tenuissima	Perennial	Native	Grass

Table A1. *Cont.*

Species Name	Life Cycle	Origin	Growth Form
Oenothera berlandieri	Perennial	Native	Forb
Opuntia rastrera	Perennial	Native	Shrub
Oxalis latifolia	Perennial	Native	Forb
Panicum hallii	Perennial	Native	Grass
Parthenium hysterophorus	**Annual**	**Introduced**	Forb
Physaria fendleri	Perennial	Native	Forb
Rhynchosia senna	Perennial	Native	Forb
Rumex crispus	**Perennial**	**Introduced**	Forb
Salvia reflexa	Annual	Native	Forb
Sanvitalia angustifolia	Annual	Native	Forb
Setaria leucopila	Perennial	Native	Grass
Solanum elaeagnifolium	Perennial	Native	Forb
Solidago velutina	Perennial	Native	Forb
Sonchus oleraceus	**Annual**	**Introduced**	Forb
Sphaeralcea angustifolia	Perennial	Native	Forb
Stachys agraria	Annual	Native	Forb
Symphyotrichum subulatum	Annual	Native	Forb
Taraxacum officinale	**Perennial**	**Introduced**	Forb
Townsedia mexicana	Perennial	Native	Forb
Verbena neomexicana	Perennial	Native	Forb
Viguiera dentata	Perennial	Native	Forb
Xanthisma spinulosum	Perennial	Native	Forb

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