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Changes of Vegetation and Diversity in Grasslands along 28 Years of Continuous Grazing in the Semi-Arid Durango Region, North Mexico

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Abstract: Researchers analyzed the effects in floristic composition and vegetation structure in grassland of the Semi-arid region of Durango, Mexico under continuous grazing for 28 years. Researchers carried out quantitative sampling of the vegetation in two cycles, Autumn, 1979 and repeated in Autumn, 2007. Data set obtained for relative density, dominance and frequency of species were analyzed in terms of cycles and sampling sites. Researchers analyzed changes in diversity through Shannon-Wiener's index while for spatial distribution Ward's algorithm and principal component analysis were used. An increase in soil vegetation cover (25.46%) resulted as well as an increase in biomass (161%) mainly due to the greater precipitation that occurred in 2007 (550 mm) compared to that of 1979 (293.4 mm). However, a decrease of native grass diversity occurred while the African introduced species (*Melinis repens)* Zizka rose Natal grass increased in dominance from 4-30%. That gave us a major change in the vegetation structure going from *Bouteloua bothriochloa* association to *Melinis heteropogon*.

Key words: Changes in vegetation, diversity, continuous grazing, Durango, Mexico

INTRODUCTION

Grasslands which started to evolve approximately 200 million years ago and encompass a little more than a fourth of earth's landmass (Newman, 2000), facilitate the life of 1.3 billion people worldwide because for many farmers in developing countries livestock is an important source of food and energy when used as work animal force and as a source of organic fertilizers in agriculture. Grasses are adapted for life at a variety of climatic regimens from sea level to the highest parts of mountains providing environmental services such as the capture and storage of water in aquifers, lakes and rivers.

Grasslands in Durango are part of North America's dessert grassland which extends from its Northern limit in Arizona, New Mexico and Texas to Central Mexico, crossing 13 states from Sonora to Puebla with elevations ranging from 1,100-1,800 m in the United States of America up to 2.500 m in Mexico. There are 368 grass species in 97 genera distributed in Durango.

The great grassland biome in Mexico represents close to 23% of the territory of the main ecosystems in Mexico. Gentry research is one of the most important regarding the characterization of grasslands in the state of Durango from ecological, physiographical and floristic points of views having noted its great potential. Recent studies have provided data that 2.15 million ha or 17.5% of the state's surface are covered by various types of grassland. The ecological land use of the State of Durango describes the types of vegetation that are capable of being used by extensive livestock farming which represents a total of 2´843,171 ha or 23% of the state's surface. In this study, natural and induced grasslands represented 45.9 and 25.4%, respectively. After >460 years, since the introduction of domestic livestock to the state, there are areas with severe degradation processes due to diverse causes among them overloading the animal load capacity, prolonged droughts insufficient livestock infrastructure mainly in the social sector, wildfires and inappropriate land use changes that cause severe deterioration of the vegetation cover, loss of soil, erosion, reduction in water infiltration and magnification of drought effects and in general, the loss of ecosystem sustainability.

Continuous grazing in terms of a herd in a paddock for 12 months year^{-1} is adequate in paddocks that have excellent or good grassland conditions but it is not recommended when the condition is regular or poor as this can cause overgrazing in detriment of the ecosystem. This is the most common extensive farming system in

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Mexico. An inventory of the grass species within the grassland represents the first step in assessing the appropriate management of the grazing system while its permanent monitoring is the key to its modification, improvement or maintenance.

Extensive livestock farming is the main cause of vegetation degradation in the state, affecting biodiversity conservation and ecosystem integrity. Sustainable use of grasslands requires the establishment of a system of indicators for the follow up and short, mid and long term control of its status (Rebollo and Gomez-Sal, 2003).

The hypothesis that species diversity influences productivity and stability of the grassland ecosystem has been tested by two independent research groups; Hector *et al*. (1999) in European grasslands and Tilman *et al*. (1997) in North American grasslands. Both groups similarly conclude that biodiversity reduction directly affects grassland productivity.

Considering the aforementioned, the importance of assessing the changes in vegetation and diversity that have occurred in natural semi-arid grassland at North Mexico under continuous grazing for 28 years was established.

MATERIALS AND METHODS

Study area: The study area is located in the pasture of the San Jose de Tuitan community owned land (ejido) (Fig. 1) in the municipality of Nombre de Dios, State of Durango, approximately 68 km East of the city of Durango along the Durango-Mexico highway at 24°01´52´´N and 104°15´11´´W in the region known as La Brena and El Malpais. This livestock production society has a total surface of 3.932 ha divided into 6 grazing units under collective exploitation since, 1960 in which there is commercial extensive production of Hereford animals for breeding and export of veal-calves as well as the sale of calves for the domestic market. It has a BS1k y BS0k temperate dry climate with a warm summer and BS1h semi-warm dry climate with an average annual temperature ranging from 14-20°C, annual rainfall between 450 and 550 mm, rainy season in Summer, dry season of 7-8 months long and an average of 210 days free of below freezing temperatures. The soil is of *in situ* origin derived from igneous rock with diverse depths as there are deep soil pockets (>50 cm), other areas with medium depth (25-50 cm) and parts with superficial soil (0-25 cm) with abundant rock outcroppings (about 30%) with areas surpassing 50%, reddish brown to dark brown in color with a sandy to granular texture with little gravel, granular structure, slightly hard consistency, drains internally at medium to fast velocity with superficial moderately slow drain and a 6.5-7.5 pH. Land topography is flat or rolling with low hills with 0-10% slopes. Vegetation is composed mainly of native grasses of which the most common and important are those species of the Bouteloua genus such as blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*) and buffalograss (*Bouteloua dactyloides*) among others together with tanglehead (*Heteropogon contortus*), threeawn (*Aristida* sp.), muhlys (*Muhlenbergia* sp.), spiked crinkleawn (*Trachypogon secundus*), nineawn pappusgrass (*Enneapogon desvauxii*), common wolfstail (*Lycurus phleoides*) and others with lower frequency. The Zizka rose Natal grass (*Melinis repens*) is a species recently (<50 years) introduced from Africa which is currently abundant in this grassland region in all paddocks and can be seen at the forefront. The Shrubbery stratus is formed by *Opuntia* sp. which can constitute an important forage resource during the dry season (Fig. 2).

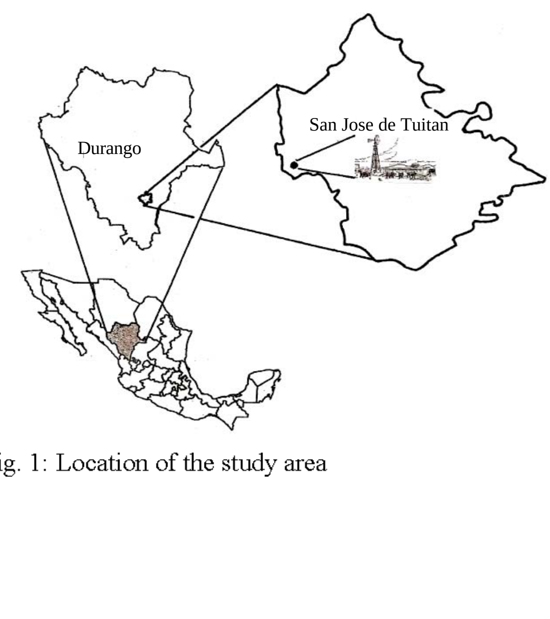

Fig. 1: Location of the study area

Vegetation sampling: In 1979, a total of 12 sites from the study area were selected and established approximately every 2 km avoiding closeness to water sources for cattle. Vegetation sampling was carried out in each site applying the minimum sampling area techniques

Fig. 2: Medium semi-arid grassland with shrubs at Durango, North Mexico

(Mueller-Dombois and Ellenberg, 1974), Linear transect (Canfield, 1941) and Forage production square method in order to obtain density, dominance and frequency of the species as well as forage production. For this, researchers had themed cartography from INEGI. Sampling carried out in 1979 was repeated in October, 2007.

Together with the field study, records of temperature and pluvial precipitation in the region (1979-2007) were obtained to determine the climatic behavior during the analysis period and its influence on vegetation.

Comparative statistical analysis between cycles and sites was carried out by estimating Shannon-Wiener's index for local diversity or alpha diversity (Magurran, 1988) while in order to estimate beta diversity an analysis of similitudes with Ward's algorithm (Ward Jr., 1963) and Euclidean distance were used.

RESULTS AND DISCUSSION

Sampling of the 1979 cycle: A total of 26 species in 15 genera were recorded: *Bouteloua gracilis*, *B. curtipendula*, *B. repens* and in a lesser proportion *Bouteloua hirsuta* and *B. radicosa*; buffalograss (*B. dactyloides)*, marsh bristlegrass (*Setaria parviflora*), green sprangletop (*Leptochloa dubia*), needlegrass, threeawn (*Aristida divaricata*, *A. ternipes*, *A. orcuttiana*, *A. pansa* and *A. adscensionis*), muhlys (*Muhlenbergia rigida*, *M. emersleyi* and *M. minutissima*), cane bluestem (*Bothriochloa barbinodis*), crimson bluestem (*Schizachyrium sanguineum*), tanglehead (*Heteropogon contortus*), spiked crinkleawn (*Trachypogon secundus*), nineawn pappusgrass (*Enneapogon desvauxii*), common wolfstail (*Lycurus phleoides*), woolyspike balsamscale (*Elionurus barbiculmis*), Zizka rose Natal grass (*Melinis repens*) and otthers (*Microchloa kunthii*, *Zuloagaea bulbosa*). While in the shrubbery stratus the characteristic species were: Duraznillo pricklypear (*Opuntia leucotricha*), nopal cardona pricklypear (*O. streptacantha*) and pricklypear cactus (*O. megacantha*). The species that were common to all the sites were: *Bouteloua curtipendula*, *Bouteloua gracilis*, *Heteropogon contortus* and *Muhlenbergia minutissima* which define the association *Bouteloua heteropogon* referenced by Gentry.

Sampling of the 2007 cycle: A total of 22 species in 12 genera were recorded. The four grass species not found when compared to 1979 were *Bouteloua dactyloides*, *Leptochloa dubia*, *Enneapogon desvauxii* and *Zuloagaea bulbosa*. The most abundant grasses in the 12 sampling sites were *Bouteloua gracilis*, *Heteropogon contortus* and *Melinis repens* followed by *Bothriochloa barbinodis* and *Elionurus barbiculmis* in 10 sites.

The most relevant datum between both periods is the increase of the *Melinis repens* grass which in 2007 was present in all samplings while *Bouteloua gracilis*, *B. curtipendula* and *B. repens* decreased in frequency. An increase in general of the area covered with vegetation (21.48% in 1979 vs. 46.9% in 2007) with a consequent decrease in naked ground (78.51% in 1979 vs. 53.05% in 2007).

In general, species composition showed that the Bouteloua genus as well as *Trachypogon secundus*, *Aristida* (*orcuttiana* and *pansa*) and the scarce species, decreased in density, dominance and frequency while there was a notorious increase of the species *Melinis repens*, *Heteropogon contortus* and *Muhlenbergia minutissima* whose presence was determinant in increasing cover on naked ground and production of forage.

Comparing the relative dominance of grasses (Table 1), it can be observed that floristic composition decreased between 1979 and 2007, particularly in the *Bouteloua* genus species, particularly of *B. curtipendula*

Table 1: Average values of relative density, dominance and frequency of some species (1979-2007)

	Relative density		Relative dominance		Relative frequency	
Species	1979	2007	1979	2007	1979	2007
Bothriochloa barbinodis	4.12	0.86	3.31	1.01	4.30	2.52
Bouteloua cutipendula	14.92	1.39	14.15	1.25	10.15	3.08
Bouteloua gracilis	17.57	10.64	15.92	10.46	10.12	13.24
Bouteloua hirsuta	0.78	0.93	0.62	0.87	1.64	1.73
Bouteloua radicosa	1.07	0.47	0.95	0.44	1.98	1.21
Bouteloua repens	21.00	3.44	11.60	2.81	10.35	5.16
Elionurus barbiculmis	2.53	2.31	3.91	2.51	3.61	5.22
Heteropogon contortus	4.36	21.97	5.41	21.66	6.66	13.73
Melinis repens	3.60	30.30	4.16	29.65	5.29	17.17
Muhlenbergia minutissima	0.28	13.53	0.23	14.11	0.74	6.94
Trachypogon secundus	6.73	1.56	10.07	1.99	7.81	1.97
Especies escasas **	2.97	1.93	2.52	0.97	6.09	4.94
Aristida orcut. y A. pansa	10.11	1.92	8.35	1.56	11.34	2.90
Muhlenbergia emersleyi y M. rigida	1.75	2.40	3.92	4.32	5.31	5.03
Otros (herb-arbustivas)	8.21	6.35	13.78	6.39	14.62	15.16
Total	100.00	100.00	100.00	100.00	100.00	100.00

***Aristida adscensionis*; *A. divaricata*; *A. ternipes*; *Lycurus phleoides*; *Microchloa kuntii*; *Setaria parviflora*; *Schyzachyrium sanguineum*

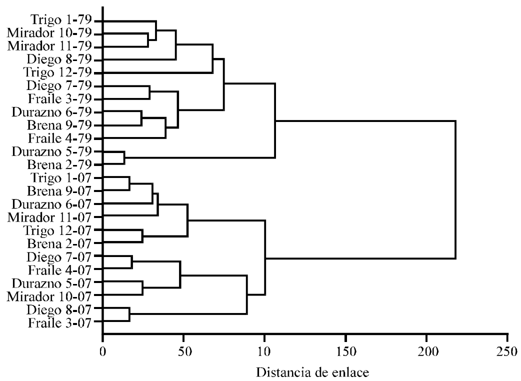

Fig. 3: Diagram of Ward's algorithm (Euclidian distances); relative dominance

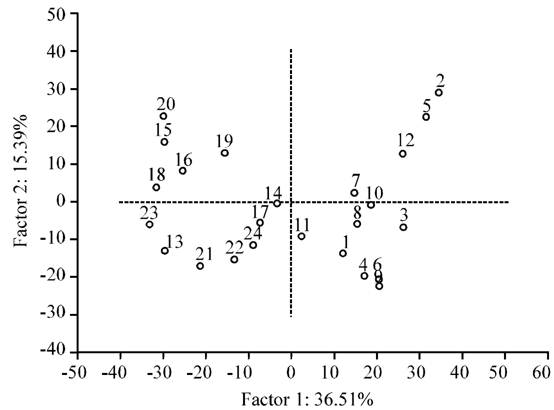

Fig. 4: Principal component analysis of relative dominance of sampling sites and cycles; 1: Trigo 1-79; 2: Brena 2-79; 3: Fraile 3-79; 4: Fraile 4-79; 5: Durazno 5-79; 6: Durazno 6-79; 7: Diego 7-79; 8: Diego 8-79; 9: Brena 9-79; 10: Mirador 10-79; 11: Mirador 11-79; 12: Trigo 12-79; 13: Trigo 1-07; 14: Brena 2-07; 15: Fraile 3-07; 16: Fraile 4-07; 17: Durazno 5-07; 18: Durazno 6-07; 19 Diego 7-07; 20: Diego 8-07; 21: Brena 9-07; 22: Mirador 10-07; 23: Mirador 11-07; 24: Trigo 12-0

(91.2%), *B. gracilis* (34.3) and *B. repens* (75.8%). The species *Bothriochloa barbinodis* decreased its cover (69.5%) as well as *Trachypogon secundus* (80.2%) and *Elionurus barbiculmis* (35.8%) while *Muhlenbergia* (*emersleyi* and *rigida)* scarcely increased its dominance (10.2%) while *Melinis repens* (612.74%), *Heteropogon contortus* (300.36%) and *Muhlenbergia minutissima* (5326.9%) markedly increased their presence. In general, the cover of other species with lesser presence (*A. adscensionis*, *A. divaricata*, *A. ternipes*, *Lycurus phleoides*, *Setaria parviflora*, *Microchloa kunthii* and *Schizachyrium sanguineum*) decreased (61.5%) as well as other vegetal strata (53.5%).

Analysis of similarities: Comparing the floristic composition between cycles and sampling sites, relative dominance results in the similitude tree (Fig. 3) shows two large branches that correspond to the 1979 and 2007 cycles. In the first cycle, the species *Bouteloua gracilis*, *Bouteloua repens* and *Bouteloua curtipendula* mark the difference as they are represented in greater percentages than the rest of the grasses. Three groups can be distinguished in this branch of which the group that is formed by sites 2 and 5 (La Brena and El Durazno) are associated due to having greater dominance of the 3 aforementioned species while in the remaining two groups, the dominance becomes more heterogeneous.

For the 2007 cycle, the formation of two branches in the dendrogram is established by the dominance of *Melinis repens* in association with *B. gracilis* and *H. contortus* at various percentages. The topmost group in the graph formed by sites 1, 9, 6, 11, 12 and 2 is basically defined by the dominance of *M. repens* with values between 40 and 60% while the bottommost group in the tree composed by sites 7, 4, 5, 10, 8 and 3 shows a lower dominance of *M. repens* that fluctuates between 7 and 17% in co-dominance with *B. gracilis*, *H. contortus* and *Muhlenbergia minutissima*. In general, the groups are highly homogeneous in which the same species converge at different percentages. Similitudes among sites in 1979 are due in general to the uniform distribution of the Bouteloua genus while in 2007 *Melinis repens* occupies almost 50% of the site dominance in co-dominance with *Heteropogon contortus* and *Muhlenbergia minutissima* (at lower percentages).

Principal component analysis: Figure 4 clearly shows what is recorded in the dendrogram in that two groups are clearly demarcated (1979 and 2007) along the first axis, one in the positive quadrant and the other on the negative quadrant. A more homogeneous dispersion can be seen along the second canonic axis toward both sides of the 1979 sites in comparison with those of 2007, mainly due to the co-dominance shown by species of the Bouteloua genus in contrast with that of 2007 in which the sites are dispersed due to the heterogeneous dominance of *Melinis repens*. The relative density and relative frequency results in the similitudes tree mirror the pattern described for relative dominance in which two large groups are formed by the independent cycles. In the 1979 cycle, it is the presence of *Bouteloua gracilis*, *Bouteloua repens* and *Bouteloua curtipendula* vs. The 2007 cycle where *Melinis repens*, *Heteropogon contortus* and *Muhlenbergia minutissima* are the ones with higher density and frequency creating a trend toward homogenizing the link distances providing no additional data for their discussion. The principal component analysis shows similar results.

Floristic diversity: Floristic diversity analyzed through Shannon-Wiener's index showed that only 2 of the 12 sites had an increase in diversity when the number of grasses present was reduced by 2007. The graphical representations of Ward's algorithm (Euclidian distances) regarding relative density, dominance and frequency reveal that two main groups are established as well as subgroups that correspond to cycles and sampling sites with greater species heterogeneity in 1979. As can be seen in the results of the Shannon-Wiener analysis (Table 2), the sites that showed an increase in diversity were La Brena and El Fraile while the remaining sites had a decrease in diversity. Therefore, a decrease in diversity towards 2007 can be appreciated.

Table 2: Results of Shannon-Wiener's diversity index

Sites	Paddock	1979	2007	2007-1979	Result
1	El Trigo	2.409	2.029	-0.380	Decrease in diversity
2	La Breña	1.914	2.391	0.477	Increase in diversity
3	El Fraile	1.990	2.118	0.128	Increase in diversity
4	El Fraile	2.306	1.767	-0.539	Decrease in diversity
5	El Durazno	2.531	1.947	-0.584	Decrease in diversity
6	El Durazno	2.083	1.841	-0.242	Decrease in diversity
7	San Diego	2.510	2.251	-0.259	Decrease in diversity
8	San Diego	2.224	2.106	-0.118	Decrease in diversity
9	La Breña	2.290	2.267	-0.023	Decrease in diversity
10	El Mirador	2.490	2.073	-0.416	Decrease in diversity
11	El Mirador	2.326	1.979	-0.347	Decrease in diversity
12	El Trigo	2.150	1.812	-0.338	Decrease in diversity
	Average	2.268	2.48	-0.220	Decrease in diversity
	SD	0.203	0.193	-	-

SD: Standard Deviation

Forage production: Cycle and animal load capacity-1979 cycle average production per hectare was 1,067 kg/dm/ha with which the calculated grazing coefficient resulted in 7.69 ha/aau and a load capacity of 517.13 aau (annual-animal-unit) (Table 3). According to the livestock inventory, the real animal load capacity in this cycle reached 815.8 aau representing a 57% overload.

Cycle and animal load capacity-2007 cycle: The average forage production reached 1,780 kg/dm/ha which represents an increase of 161% when compared to the initial year 1979. This resulted in an average grazing coefficient of 2.96 ha/aau which increased the load capacity by 29% when compared to 1979 (Table 4).

The 1979 cycle with an animal load reaching 816 aau and a grazing coefficient of 7.69 ha/aau showed an overload of 299 aau equivalent to >30% its load capacity. In contrast, the 2007 cycle with an animal load reaching 997 aau and a load capacity estimated at 1,306 aau showed an excess forage production equivalent to 908 ha.

Climate

Rainfall: The information relative to rainfall recorded in the historical time, graphically shown in Fig. 5 allowed the determination of its influence both in cover and forage production as well as the change in species composition. Climatic information in the study period allowed the recognition that 1979 was the cycle with the least rainfall

Table 3: Estimates of the grazing coefficient and load capacity for 1979

Quadrants/1	Paddock	Forage production (kg/dm/ha)	F.U.A/2 Percent	F.U.A/2 kg ha^{-1}	Pasture coefficient (3 /ha/u.a.y)	Area (ha)	Animal load capacity (aau)
1 and 12	El Trigo	1.067	60.0	640.2	7.69	420-00-00	54.61
7 and 8	San Diego	800.000	60.0	480	10.26	576-90-00	56.22
5 and 6	El Durazno	1,015	60.0	609	8.09	561-22-00	69.37
2 and 9	La Breña	1,260	60.0	756	6.51	728-02-00	111.83
3 and 4	El Fraile	1,195	60.0	717	6.87	710-34-00	103.39
10 and 11	El Mirador	1,067	60.0	640.2	7.69	936-02-00	121.71
	Total	6,404	-	3,842.4	-	3,932-50-00	517.13
	Average	1,067	640.4	7.69 4/	-	7.60 5/	-

Table 4: Estimates of the grazing coefficient and load capacity for 2007

Quadrants	Paddock	Forage production (kg/dm/ha)	F.U.A./2 Percent	F.U.A./2 kg ha^{-1}	Pasture coefficient (3/ha/u.a.y)	Area (ha)	Animal load capacity (aau)
1 and 12	El Trigo	3,150	60	1,890	2.60	420-00-00	161.53
7 and 8	San Diego	1,290	60	774	6.30	576-90-00	91.57
5 and 6	El Durazno	4,245	60	2,547	1.93	561-22-00	290.78
2 and 9	La Breña	2,840	60	1,704	2.89	728-02-00	251.91
3 and 4	El Fraile	3,020	60	1,812	2.71	710-34-00	262.11
10 and 11	El Mirador	2,175	60	1,305	3.77	936-02-00	248.28
	Total	16,720	-	10,032	-	3,932-50-00	1,306.18
	Average	2,786.6	60	1,672	2.94 4/	3.01 5/	-

1/From the quadrant average; 2/Appropriate grassland use factor; 3/From the consumption of 4,927.5 kg/dm/year for each aau; 4/From the annual DM consumption and the FUA average; 5/Weighted pasture coefficient

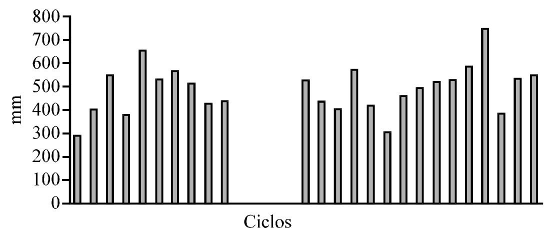

Fig. 5: Historical rainfall 1979-2007; * the period between 1989 and 1992 CNA does not have any records

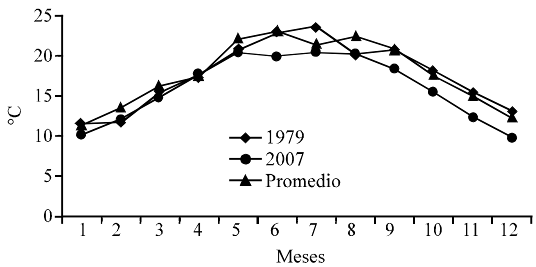

Fig. 6: Monthly temperatures 1979, 2007 and average

recorded in history with 293 mm while 2007 had the highest amount at 550 mm, surpassing by 11% the historical mean.

Temperature: The mean historical temperature and its graphical shown in Fig. 6 also give support to the analysis of the behavior of the variables.

The information obtained in the years, 1979 and 2007 allowed the analysis of the trend of the vegetation, supported by statistical methods as well as similitude indexes and species diversity between sites and cycles with an emphasis on grasses that constitute the basis of livestock feeding, considering the influence of the animal load and climate on the grassland.

The results obtained from both cycles allowed the recognition that species diversity in 2007 decreased in four species (*Bouteloua dactyloides*, *Leptochloa dubia*, *Enneapogon desvauxii* and *Zuloagaea bulbosa*) that are no longer present in the grassland. Furthermore, the decrease in density, dominance and frequency of species of the Bouteloua genus whose species are considered indicators of good management of the grassland could be due to the grazing index more than the grazing system as the animal load during the study period exceeded the recommendations by Cotecoca stated as 6.7-8.5 ha/aau for the area. It is expected that a high animal load causes overuse of species and thus produces changes in plant composition, process which is strengthened with adverse climatic conditions. Taking into consideration the aforementioned it is important to carry out continuous monitoring of the grassland conditions in order to adjust its management since, the grassland does not respond in a single direction, fact that is stated by Gillen and Sims (2006).

The most relevant datum between both sampling periods was the increase in the *Melinis repens* grass. By 2007, this invasive species was present in all samples and its dominance increased from 4.16-29.65% which represents a 612.74% increase while the *Bouteloua* species substantially reduced their co-dominance. The Zizka rose Natal grass or *Melinis repens* is a very aggressive species introduced from Africa that has been occupying open spaces in pastures displacing native species. This effect is not only due to the inherent aggressiveness of the species but also to the grazing rate that plays an important role in the increase of relative abundance of the introduced species since it is less liked by livestock similar to what has been reported by McClaran and Anable (1992) in studies carried out with *Lehmann love grass* as an invasive species. The progressive advance of *Melinis repens* together with *Heteropogon contortus* and *Muhlenbergia minutissima*, although providing better soil protection conditions as a whole have displaced other grasses that represent the climax formation of this type of vegetation such as the species of the *Bouteloua*, *Lycurus*, *Trachypogon*, *Elionurus* and *Muhlenbergia* genus among others. Their reduction has been strengthened by the preference that livestock has for their consumption motivated by the need to satisfy their nutritional requirements. The displacement of native species and occupation of spaces by introduced and annual species (less preferred) have promoted selective consumption affecting a uniform distribution, particularly when the areas where they are located are close to water sources, salt licks, rest areas, etc. Selectivity and consumption of more palatable species by livestock, climatic conditions with more extreme temperatures and prolonged drought periods have strengthened the proliferation of aggressive species.

In general, these species are introduced and when favored increase their productivity by seedling forming grassland with important monospecific portions. Other results found include the decrease in naked ground and rock area equivalent to the increase in vegetation during rainy years. This noticeable increase in vegetation, 25.4% on average and a decrease in 19% of naked area could be interpreted as a better condition probably due to the following factors.

- In general, a favorable climatic influence in the past 9 years except in 2005 which received 400 mm in rainfall (Fig. 5)

Table 5: Historical inventory of livestock 1979-2007

Cycle	Bulls	Cows	Heifers	Bull calves	Heifer calves	Equines	Total Cab	Total aau
	Cab							
1979	26	455	166	150	170	35	1002	815.8
1980	26	450	160	180	177	35	1028	834.8
1981	25	421	179	116	170	35	946	783.2
1982	24	431	105	128	127	35	854	717.7
1995	31	460	198	113	123	34	959	817.8
1997	31	680	175	155	120	35	1119	1041.5
1999	31	485	150	141	156	36	999	840.3
2002	23	429	101	86	91	55	785	705.6
2005	28	485	140	144	116	36	949	810.4
2006	28	450	100	180	165	35	958	786.4
2007	37	616	140	179	168	36	1176	996.6

- The animal load which was maintained at capacity limits even with forage surplus except in 1979, 1997 and 2005 (Table 5)
- The increase in *Melinis repens* (Table 1), an invasive species which was introduced to Southwestern United States as forage and whose aggressiveness allows it to occupy spaces with little topsoil
- The grazing in some paddocks after grass maturity such as in the El Mirador paddock where the greatest increase occurred (Table 3 and 4)

The analysis of similitudes reflects the changes in vegetation recorded during the study period, establishing in different groups each of the predominant vegetation associations of their period; the *Bouteloua gracilis*, *B. curtipendula* and *B. repens* association in 1979, 28 years later in 2007 changed to a *Melinis repens*, *Heteropogon contortus* and *Muhlenbergia minutissima* association.

Regarding the forage production in the 2007 cycle, the increase in relation to the initial cycle in 1979 was notable in that rainfall was the least of the historical series at 293.4 mm. This positive correlation between the increase in vegetation cover and accumulated rainfall is similar to that which was found by Laundre in a study of the impact of rainfall on primary and secondary production of a grassland community in the Biosphere Reserve of Mapimi, Durango, Mexico in which there is also a similar effect on biomass production of herbaceous vegetation and grasses.

Animal load appears to be the most important factor that drives forage availability. Nevertheless, climatic conditions, mainly the frequency and occurrence of rainfall, dominate the fluctuation in forage production. Milchunas and Lauenroth (1993) found a trend to decrease forage production with grazing, suggesting that any community is influenced by the combination of availability and historical grazing evolution. They also point out that changes in forage production are related mainly to rainfall periods regarding prolonged drought periods or when these are low and erratic highly affecting desirable plants. Cyclical changes in plant densities along several years have also been documented. Nevertheless, the direct effect of grazing and the influence of climate are often confused making a distinction between them more difficult.

In this study, the increase in forage quantity produced in 2007 was favored by rainfall above the historical mean which results in that the pasture index decreased from 7.69 ha aau^{-1} in 1979 to almost 3 ha aau^{-1} in 2007. These average estimates need to be modified within paddocks to account for areas that due to their proximity to points with higher livestock concentration (water sources, salt licks, resting areas, etc.) have higher deterioration. When the aforementioned is recognized, calculated estimates can be adjusted and thus guarantee dry matter consumption.

Nevertheless, the importance of biodiversity conservation must not be undervalued, especially if the findings by Hector *et al.* (1999) are to be considered since, they carried out a mega study to estimate the effect of species diversity on European grassland productivity. These researchers found in experiments in which they controlled the diversity of the grassland that when comparing productivity squares within natural areas to productivity squares in mono-cultivars of the most productive species, the decrease in biodiversity entails a significant decrease in productivity. In parallel, Tilman *et al.* (1997) reached similar conclusions with experiments carried out in North America. These researchers using modeling systems in the same context but also observing the competition for nutrients between plants in the productivity squares conclude that nutrient retention and productivity of the grassland ecosystem increases with biodiversity.

Therefore, taking into consideration that productivity decreases with species loss, researchers can infer that productivity in the grasslands of the Semi-arid Durango region has decreased through the 28 years of this study.

CONCLUSION

Continuous grazing apparently does not produce unfavorable changes in terms of ground cover and forage production which in turn are highly likely to be affected by climate. Nevertheless, it is assumed that the change in species composition and their replacement with others that are less desirable translates into a decrease in biodiversity which in turn will have an effect on productivity and nutrient retention on the long term. Evidence points towards animal load having a greater influence on pasture diversity than the actual grazing system used in the region.

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