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Elaeagnus Angustifolia Colonization and Understory Floristic Successional Patterns at Mid Valley, North Patagonia, Argentina

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Abstract: From circa 1970, *Elaeagnus angustifolia* (olivillo, Russian olive) has been a notorious invader in the valley livestock fields at Mid Valley of Rio Negro, in North Patagonia, Argentina. The species colonized riparian and plain areas forming different stands. Once introduced in this semiarid region, the seasonal and yearly climatic variations, as well as the flow regimen of the river, influenced the colonization speed. Depending on the landscape, *E. angustifolia* stands may develop as monospecific groups or in associations with other trees, leaving some uninvaded areas in-between. The different shapes and the main species forming the canopy of the stands, affect the floristic composition, and the cattle forage quality, of the US (Understory) community, if compared with the uninvaded zones. Other herbaceous community can be distinguished at the stands' border. The description of the different stages on *E. angustifolia* colonization in Mid Valley for 25 years, shows that the colonization was hastened by rainy years and wet soils. Once established, and while the new specimens reached the reproductive age, the enhancement of the population was the result of vegetative sprouting and diminished US diversity. This period was immediately followed by drought years, but the amelioration of soil quality of the already nitrogen fixating roots and the attenuation of incident sunlight, benefited herbaceous strata under the canopy of all the stand with Russian olive. Posterior changes in trees composition and management of the cattle fields, influenced US diversity. Today, the herbaceous composition studies show that, under dense monospecific population of *E. angustifolia*, the pasture reduces forage quality because of the dominance of non-palatable species. Stands' border areas combine an enhanced nitrogen content in soils, and enough light to develop a herbaceous community of annual and perennial grasses and forbs. An increment on biodiversity and spontaneous forage biomass is noticed after the Russian olive plants are removed.

Key words: *Elaeagnus angustifolia*, invaders, US vegetation, forage resources, successions.

1. Introduction

Explores as Darwin in 1839 [1] and Villegas in 1881 [2] described the Río Negro, in North Patagonia, Argentina as a wide river surrounded by plains with rich grasses and willow-trees. Riparian ecosystems are prone to invasion of non-native species because of their permanent landscape exposition to disturbance factors. From circa 1970 a notorious invader of the river Negro' coastal land has been *Elaeagnus angustifolia* (olivillo, silverberry, Russian olive, Boheme olive) [3].

Plants invade and colonize a place when they find the adequate ecological conditions, avoiding predators or usual competitors. A tree invasion implies changes in the floristic composition and influences the US (Understory) microclimate, soil, and plant community. The interactions between plants are particularly important and they decisively determine the composition and structure of plant communities which, in turn, set the primary productivity of the ecosystem and are imperative to manage cattle fields.

The areas located outside the canopy are exposed to extremer environmental conditions than those located under the influence of the trees [4]. This determines the number and abundance of species established in and out of the US [5], and the differences due to environmental heterogeneity caused by the presence of a tree layer [6, 7].

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E. angustifolia displayed multiple growth strategies to invade the Rio Negro valleys [8], as seed production, dispersal and germination, vegetative reproduction, allometric adaptation to space and ubication, root distribution related to soil and humidity. Stakeholders can view an introduced population as harmful or useful depending on their own perspectives. During the diverse stages from invasion to colonization of the area, the species received contrasting evaluation from the rural coastal cattlemen. Livestock producers first ignored *E. angustifolia* due to unawareness; then they considered it a weed because of the inconvenience it caused in the management of cattle in extensively used fields. When weather conditions turned adverse for cattle breeding due to a long and severe drought in the region cattle owners realized that the Russian olive trees' foliage and fruits were forage [9]. Other uses added further value to the species. It may be used for fence posts, or in carpentry for furniture and wall coatings, or simply be considered a firewood resource [10].

E. angustifolia has changed the appearance of the valleys by altering the predominant color of the tree/shrub layer from the vivid green of the willows to the silver-gray of its leaves, but also turned the plant interspecific relationship.

The herbaceous layer that originally developed under the willows had a different composition than that growing now under the Russian olive trees. These changes are quite difficult to analyze. Valleys in semiarid regions present special climatic conditions influenced by the balance between soil and air humidity. Depending on the distance to the river, the presence of old river channels and the shape of the plains in the meadow valley, *E. angustifolia* may form stands alone or monospecific or in multispecific trees asociations. Some areas of the valleys are not invaded [3]. It must be also mentioned that *E. angustifolia* establishes a symbiosis with *Frankia*. Actinorhizal species have a pronounced effect on ecosystem processes, contributing to increased organic matter and soil structure and to creating a favorable habitat for the establishment of other plant species [11]. It has been found that *E. angustifolia* contributes significantly to the enrichment of the soil with nitrogen [12, 13].

Author has studied the growth forms of *E. angustifolia* since 1994 [8] and surveyed, until nowadays, the vegetation changes under the canopy in invaded areas, while observing the plant community responses to droughts, floods and cattle feeding. The aim is to find the clue to evaluate and eventually anticipate the effect of the different *E. angustifolia* stands on herbaceous forage resources on livestock fields. Different sampling environments were defined during these 25 years of observations. As explained by Tuttle [14], to understand the overall effect of an exotic plant species, the assessment of its impact across the range of environmental conditions characteristic of the invaded ecosystem is required.

2. Material and Methods

2.1 Study Site

The Mid Valley of Río Negro province, Argentina, is a temperate semiarid region with annual precipitation of 303 mm. Long droughts are common. The river is characterized by meandering and branching. The natural flow regime depends on snowmelt in the Andes Mountains and hydroelectric dam regulation. The study was conducted in an area at the northern margin of the river Negro, Argentina (39º30′ S, 65º30′ W) where the expansion of *E. angustifolia* has been notable in the last 40 years. During previous studies [7, 8] the ecological strategies of *E. angustifolia* were identified and the introduction, colonization, and establishment of the species in the Mid Valley were related to climatic events and anthropogenic resolutions (for example dam construction) that influence the water status of the soils. Regional climatic data were consulted in INTA [15] and site data of rain were recorded.

2.2 Methodology

To compare the condition under and out of the canopy of *E. angustifolia*, the solar radiation and rain were monitored with an automatic data recorder KADEC-U. The determinations of fertility and soil salinity were made with an Atomic Emission Spectrometer for Inductively Coupled Plasma (ICP-AES), Shimadzu ICPE-9000. Detailed distribution of *E. angustifolia* stands in the study site, and contribution of the species as forage for cattle and livestock yearly management have been already published [9].

Between 1994 and 2009, the US vegetation was observed and described but not quantified. From 2010 to 2011 (severe drought) and 2012 to 2014, plant species, biomass and cover were monitored in the US of the invader stands and on NIAs (Non-Invaded Areas). From 2015 to 2018, rain was near or superior to average values and the studied area was used for cattle breeding with high animal pressure (3 to 5 cow equivalent/ha).

In spring 2018, five environments were defined to monitor herbaceous vegetation: UE.a.S (Under *E. angustifolia* Monospecific Stands), UMixS (Under Mixed *E. angustifolia*-Other Trees Stands), the BE.a.S (Border of *E. angustifolia* Stands), BMixS (Border of Mixed Stands) and *E. angustifolia* NIA between them. During all the years reported, periodical field excursions were made to identify plants.

In the growth period 2015-2016, the revegetation success after mechanical tree suppression at silverberry sites was studied in a 3-hectare area.

Plant taxonomic classification was made with the help of taxonomist working at National University of the South and National University of Rio Negro. Each species was assigned to one functional group: annual grass, annual forb, perennial grass, perennial forb, and woody. Floristic compositions in the different environments were compared using the Sorensen similarity index [16]. The forage aptitude of the different plants of the community considered in this paper, follows the results obtained by the research group working on rangeland functional groups in Mid Valley [17, 18].

3. Results and Discussion

Cattlemen reports remarked some forage plants that are mentioned in the first three files of Table 1, and are light grey colored, to distinguish these estimated data from the quantified values.

The identified main species under the different stages of *E. angustifolia* colonization from 1994 onwards, are shown in Table 1 and related to environmental conditions. Annual rainfalls registered at the site for 25 years are shown in Fig. 1.

Table 1 Herbaceous strata under *Elaeagnus angustifolia* (E.a.) stands during different periods of the species colonization and under diverse climatic conditions: Families, dominant species, % cover, DM (Dry Matter) production in ton by hectare (t/he), and the most grassed US herbaceous.

Period	Stage/climate /condition	Main US families	Dominant spring-summer herbaceous, grasses and forbs	Total % herbaceous cover	DM t/ha	Most grazed US spp.
Before 1970 Cattlemen reports	Before introduction of *E. angustifolia*	Poaceae Fabaceae Asteraceae Geranaceae	*Lolium* sp. *Hordeum* sp. *Bromus* sp. *Melilotus* sp. *Erodium cicutarium*	> 90%	¿?	*Lolium* sp. *Hordeum* sp. *Bromus* sp. *Melilotus* sp., *Erodium cicutarium*,
Since 1970 Cattlemen reports	Introduction of *E. angustifolia* seeds	Poaceae Fabaceae Asteraceae Geranaceae	*Lolium* sp. *Hordeum* sp. *Bromus* sp. *Melilotus* sp. *Medicago* sp. *Erodium cicutarium*	> 90%	¿?	*Melilotus* sp., *Lolium* sp. *Hordeum* sp. *Bromus* sp. *Erodium cicutarium*
Up to 1994	Colonization	Poaceae Fabaceae Asteraceae		Decreasing to 20%	¿?	
1994-1998	Low reproduction *E. angustifolia*. Local drought, low river level.	Poaceae Fabaceae Asteraceae	*Hordeum* sp. *Cynodon dactylon*, *Melilotus* sp., *Hirschfeldia incana*	20-40%	¿?	*Hordeum* sp. *Cynodon dactylon*, *Melilotus* sp., *shrubs*
1999-2006	Enhanced Colonization Rain/flood	Poaceae Fabaceae Asteraceae	*Cynodon dactylon*, *Melilotus albus*, *Xanthium* sp. plus *E.angustifolia* plantlets	< 20%	¿?	*Cynodon dactylon*

Table 1 to be continued

2007-2011	Drought	Poaceae Fabaceae Asteraceae Brassicaceae	*Bromus* sp., *Lolium* sp., *Hordeum* sp., *Xanthium* sp., *Melilotus albus, Medicago lupulina.*	20-40%	1.2	*Bromus catharticus, Bromus brevis, Melilotus albus, Hordeum murinum*
2012-2016	Annual rain superior to or on average values	Poaceae Asteraceae Brassicaceae	*Carduus* sp., *Taraxacum officinalis, Sonchus oleraceus, Hirschfeldia incana, Boopis anthemoides, Geranium* sp., *Mentha* sp., *Rumex crispus, Urtica* sp., *Cynodon dactylon*	20-30%	0.7	*Cynodon dactylon* *Sonchus oleraceus*
2017-2018	Rainy. High summer bovine browse pressure on E.a.	Poaceae Asteraceae Brassicaceae	*Hordeum murinum, Sonchus oleraceus, Hirschfeldia incana* *Cynodon dactylon, Urtica* sp *Stellaria media, Galium richardianum, Xanthium* sp.	60%	0.9	*Hordeum murinum* *Cynodon dactylon*

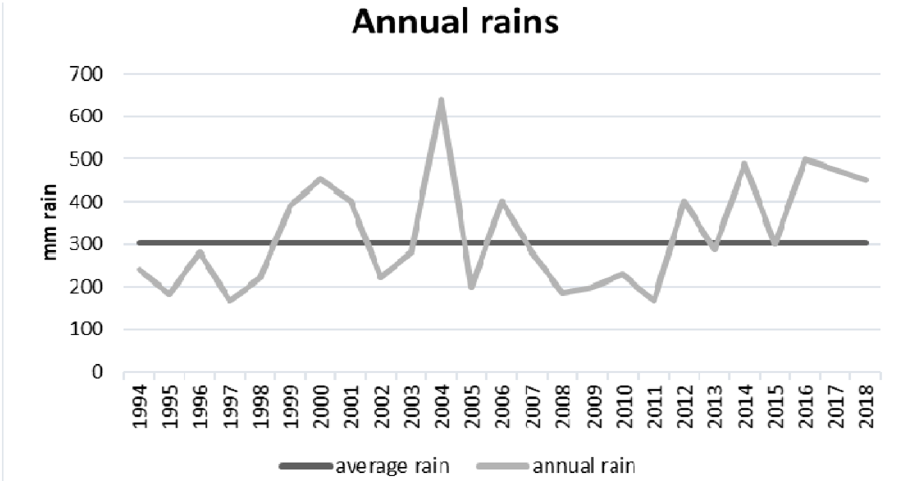

Fig. 1 Annual rains registered at the study site in the period 1994-2018.

Photographic records show that *E. angustifolia* was not present in Mid Valley cattle fields before 1970. It was introduced to the Mid Valley riparian zone circa 1970 and in two decades the species reproduced and colonized the area. The herbaceous forage production of the valleys decreased. The monitoring of *E. angustifolia* population development started in 1994. From 1994 to 1998, the effect of the local drought and the lack of snow in the mountains implied soils dry in the surface and underneath and no proliferation of many new *E. angustifolia* plants. Poaceae, Fabaceae and Asteraceae were Families commonly found in the herbaceous stories with some increase of herbaceous cover.

During the rainy years of 2000 to 2006, the vegetation underneath the silverberry trees included their own seedlings, plus patches of *Cynodon dactylon* and caltrops (*Xanthium* sp.). Light attenuation under *E. angustifolia* trees reached 90%. These dense populations originate habitats characterized by vertical environmental gradients and trees developed plasticity to adapt to the wide range of site conditions [7], but the herbaceous vegetation underneath suffered the lack of light.

In 2002 and 2006, water released from dams caused coastal floods and temporary reactivation of old channels leading to *E. angustifolia* colonization of temporally wet lands, so the species enhanced the occupied area, specially by root vegetative reproduction.

In 2007, a long drought period started with diminished *E. angustifolia* seed germination and vegetative reproduction. The floristic inventory for the growing cycle of the last year of a long and severe drought (2010-2011) showed 47 species in the US belonging to 20 families. Poaceae and Asteraceae were the most represented families. The Sorensen index was 0.28, showing differences in floristic composition underneath and outside the canopy. The extreme drought induced edge plants to lose their leaves. Leaf abscission decreased by 10 to 30% the rate of light attenuation previously quantified and the presence of *E. angustifolia* facilitated an increase in plant diversity.

Since 2010, the cattle field from where these data were obtained has been divided in small plots and a rotational grazing system has been planned to use efficiently the different forage resources. The Russian olive sites had been used to feed breeding cows during spring and summer, using a schedule of high-density grazing (3 to 5 cow equivalent/ha) during one month in each plot. The grazing, trampling and cattle dung under trees may have affected the US communities.

Since 2012, there are few species growing under the dense *E. angustifolia* areas (Table 1). With some exceptions (e.g. *Cynodon dactylon* and *Sonchus oleraceus*) the herbs are not grazed. An enhanced nitrogen level in the soil and the decreased light incidence in the US favors the development of not cattle edible plants such as *Carduus* sp., *Boopis anthemoides*, *Geranium* sp., *Mentha* sp., *Rumex crispus* or *Urtica* sp..

Russian olive now occurs patchily distributed in open meadow habitats and in the narrow old river channels common in the riparian area or in the US of the willow gallery forest, sharing the strata with *Tamarix* sp. In the valley plains *E. angustifolia* patches may include a single tree or few of them or may cover several hectares in size interspersed with areas of open meadow (Fig. 2). Table 2 shows the vegetation found in the growing cycle 2017-2018, UE.a.S, UMixS, the BE.a.S, BMixS and *E. angustifolia* NIA, classified as annual grass, annual forb, perennial grass, perennial forb, and woody, and classified as edible and not eaten plant by bovine. Sorensen Index is presented in Table 3. Soil characteristics are exposed in Table 4.

Fig. 2 View of the *E. angustifolia* stands, monospecific (grey patches) and mixed with *Salix* sp. and *Tamarix* sp. (green and grey patches).

Table 2 Vegetation UE.a.S, UMixS, the BE.a.S, and BMixS and *E. angustifolia* NIA, functional group and classification of the plants as edible or not eaten. (2017-2018).

Place	Families (sp/family)	Species	Functional group	Edible	Not eaten
UE.a.S	Asteraceae (3)	*Sonchus oleraceus*,	Annual forb	x	
		Xanthium strumarium	Annual forb		x
		Xanthium spinosum	Annual forb		x
	Brassicaceae (1)	*Hirschfeldia incana*	Annual forb	x	
	Caryophyllaceae (1)	*Stellaria media*	Annual forb		x
	Poaceae (2)	*Cynodon dactylon*,	Perennial grass	x	
		Hordeum murinum,	Annual grass	x	
	Rubiaceae (1)	*Galium richardianum*	Annual forb		x
	Urticaceae (2)	*Urtica urens*	Annual forb		x
		Urtica dioica	Annual forb		x
UMixS	Asteraceae (4)	*Sonchus oleraceus*,	Annual forb	x	
		Taraxacum officinalis	perennial forb		x
		Xanthium strumarium	annual forb		x
		Xanthium spinosum	annual forb		x
	Brassicaceae (3)	*Hirschfeldia incana*	Annual forb	x	

Table 2 to be continued

		Capsella bursa pastoris	Annual forb	x	
		Sisymbrium irio	Annual forb	x	
	Caryophyllaceae (1)	*Stellaria media*	Annual forb		x
	Lamiaceae (2)	*Lamium amplexicaule*	Annual forb	x	
		Mentha sp.	Perennial forb		x
	Poaceae (3)	*Cynodon dactylon*,	Perennial grass	x	
UMixS		*Bromus catharticus*	Annual grass	x	
		Hordeum murinum,	Annual grass	x	
	Plantaginacae (1)	*Plantago lanceolata*	Perennial forb		x
	Poligoneaceae (1)	*Rumex crispus*	Perennial forb		x
	Rubiaceae (1)	*Galium richardianum*	Annual forb		x
	Urticaceae (2)	*Urtica urens*	Annual forb		x
		Urtica dioica	Annual forb		x
		Conium maculatum	Annual biannual forb	x	
		Sonchus oleraceus,	Annual forb	x	
		Taraxacum officinalis	Annual forb		
		Hirschfeldia incana	Annual forb	x	
		Capsella bursa pastoris	Annual forb	x	x
	Apiaceae (1)	*Sisymbrium irio*	Annual forb	x	
	Asteraceae (2)	*Stellaria media*	Annual forb		
		Medicago lupulina	Annual forb	x	
	Brassicaceae (3)	*Medicago sativa*	Perennial forb	x	x
		Melilotus albus	Annual-bi annual forb	x	
		Melilotus officinalis	Annual-bi annual forb	x	
	Caryophyllaceae (1)	*Vicia sativa*	Annual forb	x	
	Fabaceae (5)	*Erodium cicutarium*	Annual-bi annual forb	x	
BE.a.S		*Geranium core-core*	Perennial forb		
		Lamium amplexicaule	Annual forb	x	
		Marrubium vulgare	Perennial forb		x
		Polypogon monspeliensis	Annual grass	x	
	Geraniaceae (2)	*Cynodon dactylon*	Perennial grass	x	x
		Bromus hordeaceus	Annual grass	x	
	Lamiaceae (2)	*Poa lanuginosa*	Perennial grass	x	
		Poa ligularis	Perennial grass	x	
	Poacea (12)	*Glyceria multiflora*	Perennial grass	x	
		Panicum urvilleanum	Perennial grass	x	
		Hordeum murinum	Annual grass	x	
		Hordeum procerum	Perennial grass	x	
		Lolium multiflorum	Annual grass	x	
		Loliun perenne	Perennial grass	x	
		Elytrigia elongatum	Perennial grass	x	
	Apiaceae (1)	*Conium maculatum*	Annual biannual forb	x	
	Asteraceae (2)	*Sonchus oleraceus*,	Annual forb	x	
		Taraxacum officinalis	Annual forb		x
	Brassicaceae (3)	*Hirschfeldia incana*	Annual forb	x	
		Capsella bursa pastoris	Annual forb	x	
		Sisymbrium irio	Annual forb	x	
	Caryophyllaceae (1)	*Stellaria media*	Annual forb		x
	Fabaceae (5)	*Medicago lupulina*	Annual forb	x	
		Medicago sativa	Perennial forb	x	
BMixS		*Melilotus albus*	Annual-bi annual forb	x	
		Melilotus officinalis	Annual-bi annual forb	x	
		Vicia sativa	Annual forb	x	
	Geraniaceae (2)	*Erodium cicutarium*	Annual-bi annual forb	x	
		Geranium core-core	Perennial forb		x
	Lamiaceae (2)	*Lamium amplexicaule*	Annual forb	x	x
		Marrubium vulgare	Perennial forb		
	Poacea (10)	*Polypogon monspeliensis*	Annual grass	x	
		Cynodon dactylon	Perennial grass	x	
		Bromus hordeaceus	Annual grass	x	
		Poa lanuginose	Perennial grass	x	

Table 2 to be continued

		Poa ligularis	Perennial grass	x	
		Glyceria multiflora	Perennial grass	x	
		Panicum urvilleanum	Perennial grass	x	
BMixS		*Hordeum murinum*	Annual grass	x	
		Lolium multiflorum	Annual grass	x	
		Elytrigia elongatum	Perennial grass	x	
	Rubiaceae (1)	*Galium richardianum*	Annul forb		x
	Asclepidacea (1)	*Asclepia mellodora*	Perennial forb		x
	Asteraceae (11)	*Taraxacum officinalis*	Perennial forb		x
		Xanthium strumarium	Annual forb		x
		Carduus thoermeri	Annual forb		x
		Centaurea calcitrapa	Annual forb		x
		Centaurea solstitialis	Annual forb		x
		Cirsium vulgare	Annual forb		x
		Onopordum acanthium	Annual forb		x
		Gaillardia megapotamica	Woody shrub		x
		Senecio subulatus	Woody shrub		x
		Baccharis ulicima	Woody shrub		x
		Baccharis crespa	Perennial forb		x
	Brassicaceae (5)	*Hirschfeldia incana*	Annual forb	x	
		Capsella bursa pastoris	Annual forb	x	
		Sisymbrium irio	Perennial grass	x	
		Diplotaxis tenuifolia	Perennial forb		x
		Eruca vesicaria ssp. *sativa*	Annual forb		x
	Boraginaceae (1)	*Pectocarya linearis*	Annual forb		x
	Calyceraceae (1)	*Boopis anthemoides*	Perennial forb		x
	Euphorbiaceae (1)	*Euphorbia collina*	Perennial forb		x
	Fabaceae (6)	*Hoffmannseggia glauca*	Perennial forb		x
		Prosopis strombulifera	Small woody shrub		x
		Medicago lupulina	Annual forb	x	
		Medicago sativa	Perennial forb	x	
		Melilotus albus	Annual-bi annual forb	x	
		Melilotus officinalis	Annual-bi annual forb	x	
NIA	Geraniaceae (2)	*Erodium cicutarium*	Annual-bi annual forb	x	
		Geranium core-core	Perennial forb		x
	Lamiaceae (2)	*Lamium amplexicaule*	Annual forb	x	
		Marrubium vulgare	Perennial forb		x
	Malvaceae (2)	*Sphaeralcea miniate*	Small woody shrub		x
		Distichlis spicata	Perennial grass	x	
	Plantaginacea (1)	*Plantago patagonica*	Perennial forb		x
	Poacea (12)	*Distichlis scoparia*	Perennial grass	x	
		Polypogon monspeliensis	Annual grass	x	
		Cynodon dactylon	Perennial grass	x	
		Bromus hordeaceus	Annual grass	x	
		Poa lanuginosa	Perennial grass	x	
		Poa ligularis	Perennial grass	x	
		Glyceria multiflora	Perennial grass	x	
		Panicum urvilleanum	Perennial grass	x	
		Nassella tenuis	Perennial grass	x	
		Hordeum euclaston	Annual grass	x	
		Hordeum murinum	Annual grass	x	
		Lolium multiflorum	Annual grass	x	
		Rosa rubiginosa	Woody shrub		x
	Rosaceae (1)	*Verbascum thapsus*	Annual-bi annual forb		x
	Scrophulariaceae (2)	*Verbascum virgatum*	Annual-bi annual forb		x
		Lycium tenuispinosum	Woody shrub	x	
	Solanaceae (3)	*Lycium chilensis*	Woody shrub	x	
		Solanum eleagnifolium	Annual forb		x
		Glandularia parodii	Perennial forb		x
	Verbenaceae (1)	*Larrea nitida*	Woody shrub		x
	Zygophyllaceae (2)	*Larrea divaricata*	Woody shrub		x

Table 3 Number of families, number of species and Sorensen Index (QSorensen) comparing each monitored site.

	Families	Species	QSorensen					
UE.a.S	6	10						
UMixS	9	18	0.71		0.26		0.12	
BE.a.S	8	28						
BMixS	9	27		0.94		0.31		0.48
NIA	17	54						

Table 4 Soil characteristic at 0-20 cm depth UE.a.S, UMixS, the BE.a.S, BMixS and *E. angustifolia* NIA.

Sample place	Depth	pH	Organic Matter (%)	Ntotal (%)	Pdisp (ppm)	Kdisp (ppm)	C.E. (mmhos/cm)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	Na adsorptio n ratio
UE.a.S	0-20	8.3	6.52	0.318	14.3	1,039	2.20	304.3	38.8	115.9	6.25
UMixS	0-20	8.4	3.02	0.155	22.3	717	0.92	66.0	8.0	16.0	6.15
BE.a.S	0-20	8.9	5.34	0.244	14.4	1,212	0.85	136.1	12.3	38.3	4.89
BMixS	0-20	8.6	5.33	0.244	13.4	1,111	0.81	138.2	12.1	38.2	4.88
NIA	0-20	8.2	2.02	0.114	24.3	447	1.80	232.0	34.9	103.0	5.04

Organic matter content of the soils beneath *E. angustifolia* trees is higher than in uncovered valley plains. Measures of soil characteristic comparing 1998 with 2012 showed a significant increase in the amount of organic matter (from 3 to 6.5%) in the upper soil layer (0 to 20 cm depth) under the actinorhizal shrub canopy. Stands border areas also show a higher organic matter content than the NIA.

Vegetation under monospecific stand of *E. angustifolia* is nowadays poor in diversity and composed by many annual forbs that are not eaten by bovines. Many of these species are nitrophilous and are benefited by the increases of organic matter content. Mixed stands do not show such increased OM content in the upper layer of the soil, plant diversity is higher, and the presences of some grasses enhance the forage input. Sorensen index values indicate that both stands understories have many species in common although the mixed one is richer in biodiversity. When comparing the borders' US composition, no significant differences were detected and the Sorensen Index of 0.94 confirmed the similitude. Although the canopies of the stand differ, the distribution on *E. angustifolia* in the mixed stands is uneven and these plants tend to occupy the edges of the stand and in consequence the conditions of the borders of both types of stands offer similar characteristics to the communities of herbaceous. NIA presented higher diversity, product of greater families' presence and represented by a superior number of species. NIA greatly differed from the communities under the monospecific stand (Sorensen Index 0.12) but shared many species with the communities under the mixed stand (Sorensen Index 0.48). Soils analysis indicates that NIA has less OM content and disponible nitrogen. The values of pH indicate slightly alkaline soil in all the sampled places, and no limitations on main mineral content.

After the winter removal of plants near fences, *E. angustifolia* re-sprouted fast. Herbaceous plant germination and growth was notable in the disturbed areas, especially Poaceae and Fabaceae. *Bromus* sp. and *Hordeum* sp. were the most consumed species by cows during summer grazing. By the end of spring (December 2015), the herbaceous biomass production was 7,240 kg DM/ha and exceeded 1.5 m in height at many places. After mechanical removal, the reinvasion of *E. angustifolia* is rapid and difficult to control.

4. Conclusions

After the introduction in the valley, rainy years and wet soils hastened *E. angustifolia* colonization. Once established, the amelioration of soil quality and the attenuation of incident sunlight enhanced herbaceous plant diversity under the shrub canopy during drought years. Under rainy or average climatic condition, some non-palatable species benefited from enhanced soil nitrogen and formed the actual community under monospecific *E. angustifolia* stands. Borders of all invaded zones show higher diversity than the understories, and the most remarkable feature is that they include many edible herbaceous, mostly belonging to two of the important spontaneous forage families identified in this zone, Poaceae and Fabaceae.

When silverberry trees were removed, the herbaceous strata provided important forage biomass, although the reinvasion of *E. angustifolia* was rapid and difficult to control.

Analyzing the data, it can be concluded that herbaceous compositions underneath the *E. angustifolia* stand vary with climate and with accompanying trees. As this invader surely improves organic matter and disponible nitrogen of the soils, the best conditions to use its properties and raise forage input are to avoid the formation of dense stands and to procure the establishment of small stand with higher proportional edges surfaces. As this species is *per se* a forage resource [9], the proportional enhancement of the border areas can increase the grazing and browsing offer for cattle. Mechanical clearance of *E. angustifolia* trees enhances forage production by requiring continuous investments in machinery and fuel since the regrowth of this invasion is fast and aggressive.

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