

Fragmented areas due to agricultural activity: native vegetation dynamics at crop interface (Montecaseros, Mendoza, Argentina)

Áreas fragmentadas por la actividad agrícola: dinámica de la vegetación nativa en su interfase con cultivos (Montecaseros, Mendoza, Argentina)

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ABSTRACT

Plant communities fragmented by agricultural activities were analyzed in a 250-ha area in eastern plains of Montecaseros, Gral. San Martín Department, Mendoza, Argentina. A phytosociological method assessed different sites along a gradient of human intervention, from natural environments with no evidence of altered native vegetation to maximum farming modification, also including cleared and abandoned fields. Soil analyses supplemented the characterization of six plant communities. A scrubland physiognomy dominates the area, with species of the genera *Larrea*, *Atriplex* and *Lycium*. Tillage and crop abandonment can alter natural factors involved in soil formation, causing deterioration and exerting selective pressure on species colonizing these degraded environments. Evaluating natural vegetation before land clearing for agriculture is essential to assess, through species that indicate environmental conditions, edaphic limitations hindering crop establishment and affecting productivity. The conservation of natural communities on private lands destined for agriculture is valued.

Keywords

plant communities • abandoned crops • dynamism • habitat fragmentation • soil degradation

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RESUMEN

Se analizaron comunidades vegetales fragmentadas por actividades agrícolas en un área de 250 ha en las llanuras orientales de Montecaseros, Departamento de Gral. San Martín, Mendoza, Argentina. Se aplicó el método fitosociológico en sitios a lo largo de un gradiente de intervención humana, desde ambientes naturales sin evidencia de vegetación nativa alterada hasta la máxima modificación debido a la agricultura, incluyendo también parcelas desmontadas y abandonadas. La caracterización de seis comunidades vegetales se complementó con análisis de suelo. La fisonomía dominante en la zona es el matorral, con especies de los géneros *Larrea*, *Atriplex* y *Lycium*. La labranza y el abandono de cultivos pueden alterar los factores naturales involucrados en la formación del suelo. Estas actividades causan deterioro y ejercen una presión selectiva sobre las especies que colonizan estos ambientes degradados. La evaluación de la vegetación natural antes del desmonte para la agricultura es fundamental para valorar, a través de especies indicadoras de las condiciones ambientales, las limitaciones edáficas que dificultan el establecimiento de cultivos y afectan su productividad. Se pone en valor la conservación de comunidades naturales en terrenos privados destinados a la agricultura.

Palabras clave

comunidades vegetales • cultivos abandonados • dinamismo • fragmentación de hábitat • degradación de suelos

INTRODUCTION

Plant biodiversity plays a strategic role in ecosystemic provision of goods and services for human health and well-being (21). Agriculture causes changes in these ecosystems involving both productive activities and consequent effects on the socioeconomic and biophysical environment. Agriculture requires ecosystem services (water, soil and genetic diversity) while generating food, fiber and fuel, soil fertility, habitats for wildlife, landscape and culture, among others (29). However, the dominant models of agricultural intensification affect natural resources by generating pollution, fragmentation and degradation, associated with loss of ecosystem services (33).

Fragmentation of natural environments consists of disintegrating a continuous landscape into smaller fractions, separated from one another by a cover matrix resulting from human activity (9). Replacement of natural ecosystems for agroecosystems, urbanization, and other infrastructures increases land vulnerability. Landscape fragmentation levels could be considered an indicator of soil degradation (28) generally related to inappropriate agricultural practices, overgrazing, unplanned urbanization and expansion of agriculture frontier.

In Argentina, 66% of the territory corresponds to arid, semiarid and dry sub-humid areas, where water and wind erosion affect two million hectares a year (16). In turn, about 47% of agricultural production comes from drylands under desertification processes (2). These ecosystems have low capacity for natural regeneration. Degradation associated with reduced biological and economic productivity is hard to reverse. Consequently, water and food supplies are affected, threatening investment and technical development, and causing poverty and rural desertion, feeding back the originating processes (27).

Mendoza plains, where the most important agricultural activities take place, belongs to the Monte Phytogeographic Province, an extensive vegetation unit that occupies great part of Argentina's drylands (7). Given water deficit is the major factor limiting productivity, agriculture is intensive and irrigated. Productive activities follow an agro-industrial model in the large irrigated oases of Mendoza, already expanded over non-irrigated areas. In San Martín (east Mendoza), more than 2200 farms comprise 94000 ha of private producers, most of them landowners (14). In Montecaseros, a district of San Martín, viticulture occupies most agricultural land, where clearing has resulted in a mosaic of landscapes. Productive crops merge with abandoned crops (with virtually bare soils, evidence of degradation and low floristic diversity) and fragments of natural fields

(with appropriate native flora coverage preventing erosion processes). Vegetation is an important component of landscape affected by geomorphology, soil, climate, and even land use history (35). Physiognomically, the area reflects environmental heterogeneity. *Prosopis flexuosa* DC. woods and other areas representative of the Monte biodiversity in Montecaseros provide fundamental ecosystem services, where native plants might constitute reservoirs for pest predators and crop pollinators.

At local level, no publications addressing fragmentation in agricultural environments or floristic-ecological studies are available. Related references in the region involve ecology, management and conservation of *Prosopis* woodland (36), flora and vegetation in protected areas (25), vegetation assessment of peripheral oasis lands (11), and vegetation coverage classification in San Martín (19).

Considering background information scarcity in San Martín and the importance of viticulture for economic and social development, this study aimed to characterize plant communities in natural and intervened environments, in a representative area of the fragmentation processes caused by agriculture in Montecaseros district.

MATERIALS AND METHODS

Study area

The area comprises 250 ha in Montecaseros district, General San Martín Department, Mendoza, Argentina (figure 1), located on the eastern fluvial-eolian plain of Mendoza (1), concentrating the greatest agricultural activity of the province. Altitude ranges between 598 and 644 m a. s. l. Climate is desertic (17), with mean annual temperature of 15°C, mean annual rainfall reaching 200 mm under a spring-summer regime, and prevalence of SE winds, frequently warm and dry (föhn type or “Zonda” winds).

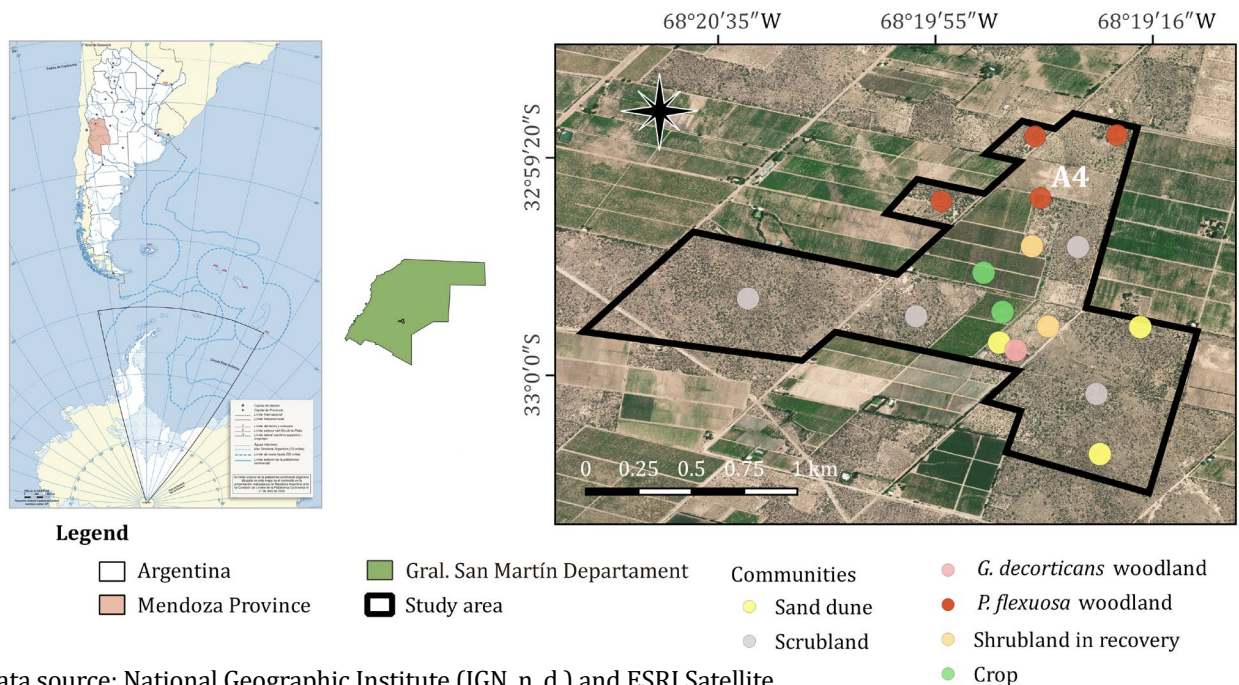


Figure 1. Study area and distribution of communities surveyed.
Figura 1. Área de estudio y distribución de las comunidades relevadas.

The vegetation corresponds to the Monte Phytogeographic Province (7), typical of the Northern District and Central Sub-district of the Monte Desert (26), recently considered within the Septentrional District according to the latest classification (3). In natural environments, evergreen shrub-steppe and scrubland are dominant, represented by species of the genera *Larrea*, *Atriplex* and *Lycium*, and small relics of *Prosopis flexuosa* and *Geoffroea decorticans* woodland (Gillies ex Hook. & Arn.) Burkart. Grasses develop on open sites with low tree and shrub coverage. Fixed and semi-fixed sand dunes are frequent, with bare-root growth and psammophilous plants. Crops have fragmented these natural vegetation areas, creating ideal conditions for the development of native and exotic weed species.

Montecaseros soils are poorly developed Entisols (23, 32) with strong moisture deficit most of the year. Sandy textures prevail, with surface or subsurface sites with finer soil layers, suitable for cropping given groundwater availability. The entire area is affected by land degradation processes, accelerated by natural water and wind erosion events.

METHODOLOGY

Analysis of plant communities

Areas were selected by satellite imagery (Google Earth, 2012) and available maps, representing regions affected by fragmentation processes (figure 1, page 48). Research activities were conducted between December 2011 and June 2012. Maps were made using free access QGIS software, version 3.22.6 (2022).

Plant communities were studied by the phytosociological method (5), based on criteria of floristically, physiognomically and ecologically homogeneous sites. Each species was assigned abundance-dominance and sociability values in every location (24). In total, 87 surveys were conducted, and the study area was delimited in the field according to community composition and physiognomy. All plots were 49 m² except at crop sites (30 m²) and in *P. flexuosa* woodland, where surveys were done over a larger area (225 m²). Additionally, each survey included vegetation stratification, geographic and altitude coordinates (GPS) and visual assessment of slope decline, water of dynamic and wind processes, solar exposure and evidence of human activity. Data were first ordered and analyzed on a comparative table of surveys, and summarized in a synthetic comparative table (table 1, page 50 and 51), grouping those species best adjusted to each environment. Categories describing each group of species (24) were 1- Exclusive characteristic species (strongly linked to a community, practically not observed outside) or Preferential characteristic species (with a wider ecological range but finding an optimum in one community), 2- Accompanying species (wide ecological range, not related to a particular community, indifferent) and 3- Accidental species (intruders in a community). Floristic compositions of non-cleared sites (scrubland) were interpreted as reference to the original natural vegetation. Table 2 (page 52) synthesizes total mean coverage of each community, floristic richness and dominant processes.

Life form was analyzed for each species according to perpetuation organ position (22) as succulent phanerophytes or cacti (SP, plants with thick juicy stems), geophytes (G, plants with underground survival organs), hemicryptophytes (H, herbs and perennial grasses with renewal buds at ground level), microphanerophytes (M, trees with renewal shoots from 2 to 8 m), nanophanerophytes (N, shrubs with renewal buds at less than 2 m height), and therophytes (T, annual plants). In each community, relative contributions of every biological form were estimated according to coverage and frequency, and expressed in histograms or biological spectra (figure 2, page 52). Coverage spectrums were determined after mean coverage values per abundance-dominance interval of each species (24). A frequency spectrum considered the number of species of each biological form over total species in the community.

Table 1. Survey synthetic comparative table (24).
Tabla 1. Cuadro comparativo sintético de relevamientos (24).

BF	SPECIES	Sand dune		Scrubland		G. decorticans woodland		P. flexuosa woodland		Shrubland in recovery		Crop	
		P	Cov.	P	Cov.	P	Cov.	P	Cov.	P	Cov.	P	Cov.
Native species with wider ecological range													
H	<i>Leptochloa crinita</i> (Lag.) P.M. Peterson & N.W. Snow	V	488.9	V	895.0	V	106.0	IV	355.8	V	1544.7	V	597.5
T	<i>Tribulus terrestris</i> L.	V	752.2	IV	291.2	IV	8.0	III	64.2	IV	281.8	V	315.0
M	<i>Prosopis flexuosa</i> DC.	III	792.2	IV	1347.7	IV	1600.0	V	4229.2	V	1367.7	I	1.3
M	<i>Geoffroea decorticans</i> (Gillies ex Hook. & Arn.) Burkart	IV	667.2	III	288.5	V	4300.0	V	1208.3	II	338.8	I	1.3
N	<i>Atriplex lampa</i> (Moq.) D. Dietr.	IV	514.4	III	231.2	II	52.0	III	333.3	IV	221.8	II	32.5
H	<i>Pappophorum philippianum</i> Parodi	IV	238.3	IV	52.7	II	52.0	IV	191.7	V	414.7	I	31.3
Native species common in cleared and non-cleared areas													
N	<i>Lycium tenuispinosum</i> Miers	V	944.4	V	1654.2	V	4800.0	IV	688.3	III	295.9	.	.
N	<i>Lycium chilense</i> Miers ex Bertero	IV	405.6	IV	118.5	III	352.0	III	145.8	III	134.1	.	.
N	<i>Larrea cuneifolia</i> Cav.	II	125.0	IV	481.5	III	352.0	I	145.8	III	677.1	.	.
M	<i>Bulnesia retama</i> (Gillies ex Hook. & Arn.) Griseb.	II	333.9	II	163.5	I	50.0	III	458.3	III	544.7	.	.
N	<i>Grahamia bracteata</i> Gillies ex Hook. & Arn.	III	848.3	IV	128.5	II	52.0	I	21.7	I	0.6	.	.
N	<i>Mulguraea aspera</i> (Gillies & Hook. ex Hook.) N. O'Leary & P. Peralta var. <i>aspera</i>	IV	278.9	I	29.6	I	50.0	III	25.8	I	0.6	.	.
Native species in non-cleared areas													
N	<i>Atamisquea emarginata</i> Miers ex Hook. & Arn.	II	195.0	III	308.1	V	1200.0	III	250.0	.	.	.	.
N	<i>Suaeda divaricata</i> Moq.	IV	486.7	IV	194.2	III	102.0	I	125.0	.	.	.	.
N	<i>Bougainvillea spinosa</i> (Cav.) Heimerl	IV	153.3	II	77.7	III	102.0	III	64.2	.	.	.	.
H	<i>Setaria leucopila</i> (Scribn. & Merr.) K. Schum.	IV	169.4	II	3.1	IV	8.0	I	1.7	.	.	.	.
SP	<i>Cereus aethiops</i> Haw.	III	17.8	III	5.4	III	6.0	V	8.3	.	.	.	.
SP	<i>Echinopsis leucantha</i> (Gillies ex Salm-Dyck) Walp.	III	31.1	III	5.8	I	2.0	II	2.5	.	.	.	.
SP	<i>Opuntia sulphurea</i> Gillies ex Salm-Dyck	II	30.6	II	3.1	IV	56.0	II	2.5	.	.	.	.
Native species common to sand dunes and scrubland													
T	<i>Bouteloua barbata</i> Lag.	III	210.0	II	68.1	.	.	.	.	I	0.6	.	.
H	<i>Sporobolus phleoides</i> Hack.	II	28.9	II	30.4	.	.	I	0.8	.	.	.	.
T	<i>Sclerophylax arnottii</i> Miers	I	83.9	I	1.9	I	2.0	.	.	.	.	.	.
N	<i>Ximenesia americana</i> L.	I	13.9	I	10.0	.	.	.	.	.	.	.	.
N	<i>Lycium ciliatum</i> Schltld.	I	13.9	I	9.6	.	.	.	.	.	.	.	.
SP	<i>Gymnocalycium schickendantzii</i> (F.A.C. Weber) Britton & Rose	I	1.7	I	1.5	.	.	.	.	.	.	.	.
H	<i>Commelina erecta</i> L.	I	1.7	I	0.8	.	.	.	.	.	.	.	.
SP	<i>Setiechinopsis mirabilis</i> (Speg.) de Haas	I	1.1	I	1.9	.	.	I	0.8	.	.	.	.
Scrubland of <i>T. usillo</i> and <i>L. divaricata</i> with <i>M. ephedroides</i> and <i>P. urvilleanum</i>													
N	<i>Tricomaria usillo</i> Hook. & Arn.	IV	695.0	I	230.8	.	.	I	145.8	.	.	.	.
N	<i>Larrea divaricata</i> Cav.	III	625.6	.	.	.	.	.	.	I	88.2	.	.
N	<i>Mimosa ephedroides</i> (Gillies ex Hook. & Arn.) Benth.	II	105.6	I	77.3	.	.	.	.	.	.	.	.
G	<i>Panicum urvilleanum</i> Kunth	II	306.7	.	.	I	50.0	.	.	.	.	.	.
T	<i>Portulaca grandiflora</i> Hook.	III	31.1	I	19.6	.	.	I	20.8	I	0.6	.	.
T	<i>Gomphrena mendocina</i> (Phil.) R.E. Fr.	II	43.3	I	10.0	.	.	II	23.3	I	0.6	.	.
N	<i>Prosopidastrum globosum</i> (Gillies ex Hook. & Arn.) Burkart	I	83.3	.	.	.	.	.	.	.	.	.	.
N	<i>Senecio goldsackii</i> Phil.	I	0.6	.	.	.	.	.	.	.	.	.	.
T	<i>Ibicella parodii</i> Abbiatti	I	0.6	.	.	.	.	.	.	.	.	.	.
H	<i>Chloris castilloniana</i> Lillo & Parodi	I	0.6	.	.	.	.	.	.	.	.	.	.
Dense scrubland of <i>L. tenuispinosum</i> and <i>A. argentina</i> with <i>P. flexuosa</i>													
N	<i>Atriplex argentina</i> Speg.	.	.	II	471.2	.	.	.	.	I	14.7	.	.
N	<i>Cyclolepis genistoides</i> Gillies ex D. Don	I	0.6	III	201.9	.	.	I	21.7	.	.	.	.
N	<i>Plectrocarpa tetraacantha</i> Gillies ex Hook. & Arn.	.	.	II	163.9	.	.	.	.	.	.	.	.

BF	SPECIES	Sand dune		Scrubland		G. decorticans woodland		P. flexuosa woodland		Shrubland in recovery		Crop	
		P	Cov.	P	Cov.	P	Cov.	P	Cov.	P	Cov.	P	Cov.
Woodland of G. decorticans with L. tenuispinosum and A. emarginata													
H	<i>Allionia incarnata</i> L.	I	14.4	II	11.5	IV	152.0	.	.	II	132.4	.	.
H	<i>Tweedia brunonis</i> Hook. & Arn.	.	.	I	1.2	III	6.0	I	0.8	.	.	.	.
H	<i>Cucurbitella asperata</i> (Gillies ex Hook. & Arn.) Walp.	I	0.6	I	0.8	II	52.0	.	.	.	.	.	.
T	<i>Solanum triflorum</i> Nutt.	.	.	.	.	I	50.0	.	.	.	.	.	.
Woodland of P. flexuosa with A. emarginata and A. patens													
N	<i>Austrobrickellia patens</i> (D. Don ex Hook. & Arn.) R.M. King & H. Rob.	.	.	.	.	.	.	III	190.0	.	.	.	.
M	<i>Prosopis sp.*</i>	I	729.2	.	.	.	.
N	<i>Araujia odorata</i> (Hook. & Arn.) Fontella & Goyder	.	.	.	.	.	.	II	22.5	.	.	.	.
N	<i>Prosopis strombulifera</i> (Lam.) Benth.	.	.	.	.	.	.	II	2.5	.	.	.	.
M	<i>Vachellia aroma</i> (Gillies ex Hook. & Arn.) Seigler & Ebinger	.	.	.	.	.	.	I	0.8	.	.	.	.
Steppe of L. crinita and P. flexuosa with L. cuneifolia and B. retama in abandoned crops													
N	<i>Senecio subulatus</i> D. Don ex Hook. & Arn.	.	.	I	0.4	.	.	I	1.7	III	74.7	I	1.3
H	<i>Digitaria californica</i> (Benth.) Henrard	I	0.6	.	.	.	.	.	.	I	15.3	.	.
G	<i>Pitreaa cuneato-ovata</i> (Cav.) Caro	.	.	.	.	.	.	.	.	I	14.7	.	.
T	<i>Flaveria haumanii</i> Dimitri & Orfila	.	.	.	.	.	.	.	.	I	14.7	.	.
Ruderal species indicating effect of crops													
G	<i>Pascalía glauca</i> Ortega	I	13.9	.	.	.	.	.	.	II	30.6	II	656.3
T	<i>Flaveria bidentis</i> (L.) Kuntze	.	.	I	0.4	.	.	.	.	I	0.6	V	567.5
T	<i>Setaria verticillata</i> (L.) P. Beauv.	I	13.9	.	.	.	.	.	.	I	14.7	III	563.8
T	<i>Amaranthus hybridus</i> L. <i>quitensis</i> Ssp. (Kunth) Costea & Carretero	.	.	I	10.8	.	.	.	.	I	0.6	IV	127.5
G	<i>Cynodon dactylon</i> (L.) Pers.	.	.	.	.	.	.	.	.	I	29.4	II	32.5
G	<i>Asparagus officinalis</i> L.	.	.	.	.	.	.	.	.	I	0.6	V	98.8
G	<i>Hoffmannseggia glauca</i> (Ortega) Eifert	.	.	.	.	.	.	I	0.8	I	1.8	I	31.3
T	<i>Solanum euacanthum</i> Phil.	.	.	.	.	.	.	.	.	I	0.6	I	1.3
Vitis vinifera crop with M. albus and F. bidentis													
N	<i>Vitis vinifera</i> L.	.	.	.	.	.	.	.	.	.	.	V	4562.5
T	<i>Melilotus albus</i> Desr.	.	.	.	.	.	.	.	.	.	.	IV	1062.5
T	<i>Conyza bonariensis</i> (L.) Cronquist	.	.	.	.	.	.	.	.	.	.	V	128.8
T	<i>Chenopodium album</i> L.	.	.	.	.	.	.	.	.	.	.	IV	156.3
T	<i>Sonchus asper</i> (L.) Hill	.	.	.	.	.	.	.	.	.	.	V	98.8
H	<i>Taraxacum officinale</i> F.H. Wigg.	.	.	.	.	.	.	.	.	.	.	V	68.8
T	<i>Bromus catharticus</i> Vahl	.	.	.	.	.	.	.	.	.	.	III	563.8
T	<i>Chenopodium papulosum</i> Moq.	.	.	.	.	.	.	.	.	.	.	II	93.8
T	<i>Cenchrus spinifex</i> Cav.	.	.	.	.	.	.	.	.	.	.	II	32.5
G	<i>Physalis viscosa</i> L.	.	.	.	.	.	.	.	.	.	.	I	31.3
H	<i>Phyla nodiflora</i> (L.) Greene var. <i>minor</i> (Gillies & Hook. ex Hook.) N. O'Leary & P. Peralta	.	.	.	.	.	.	.	.	.	.	I	31.3
T	<i>Eruca vesicaria</i> (L.) Cav.	.	.	.	.	.	.	.	.	.	.	II	3.8
T	<i>Bidens pilosa</i> L.	.	.	.	.	.	.	.	.	.	.	I	1.3
T	<i>Silene gallica</i> L.	.	.	.	.	.	.	.	.	.	.	I	1.3
G	<i>Euploca mendocina</i> (Phil.) Diane & Hilger	.	.	.	.	.	.	.	.	.	.	I	1.3
T	<i>Bassia scoparia</i> (L.) A. J. Scott	.	.	.	.	.	.	.	.	.	.	I	1.3
T	<i>Raphanus sativus</i> L.	.	.	.	.	.	.	.	.	.	.	I	1.3
T	<i>Salsola kali</i> L.	.	.	.	.	.	.	.	.	.	.	I	1.3

BF: biological forms (SP: succulent phanerophytes, G: geophytes, H: hemicryptophytes, M: microphanerophytes, N: nanophanerophytes and T: therophytes). P: species degree of presence (V: presence>80% of surveys; IV: 60.1-80%; III: 40.1-60%; II: 20.1-40%; I: <20%).

Cov.: global coverage value (sum of mean species covers divided by total surveys per community, multiplied by 100). Annex 2 details species with low values of presence and/or coverage in each community. * Possible hybrid between *P. flexuosa* and *P. chilensis*.

BF: formas biológicas (SP: fanerófitas suculentas, G: geófitas, H: hemicriptófitas, M: microfanerófitas, N: nanofanerófitas y T: terófitas).

P: grados de presencia de cada especie (V: presencia >80% de los relevamientos; IV: 60.1-80%; III: 40.1-60%; II: 20.1-40%; I: <20%).

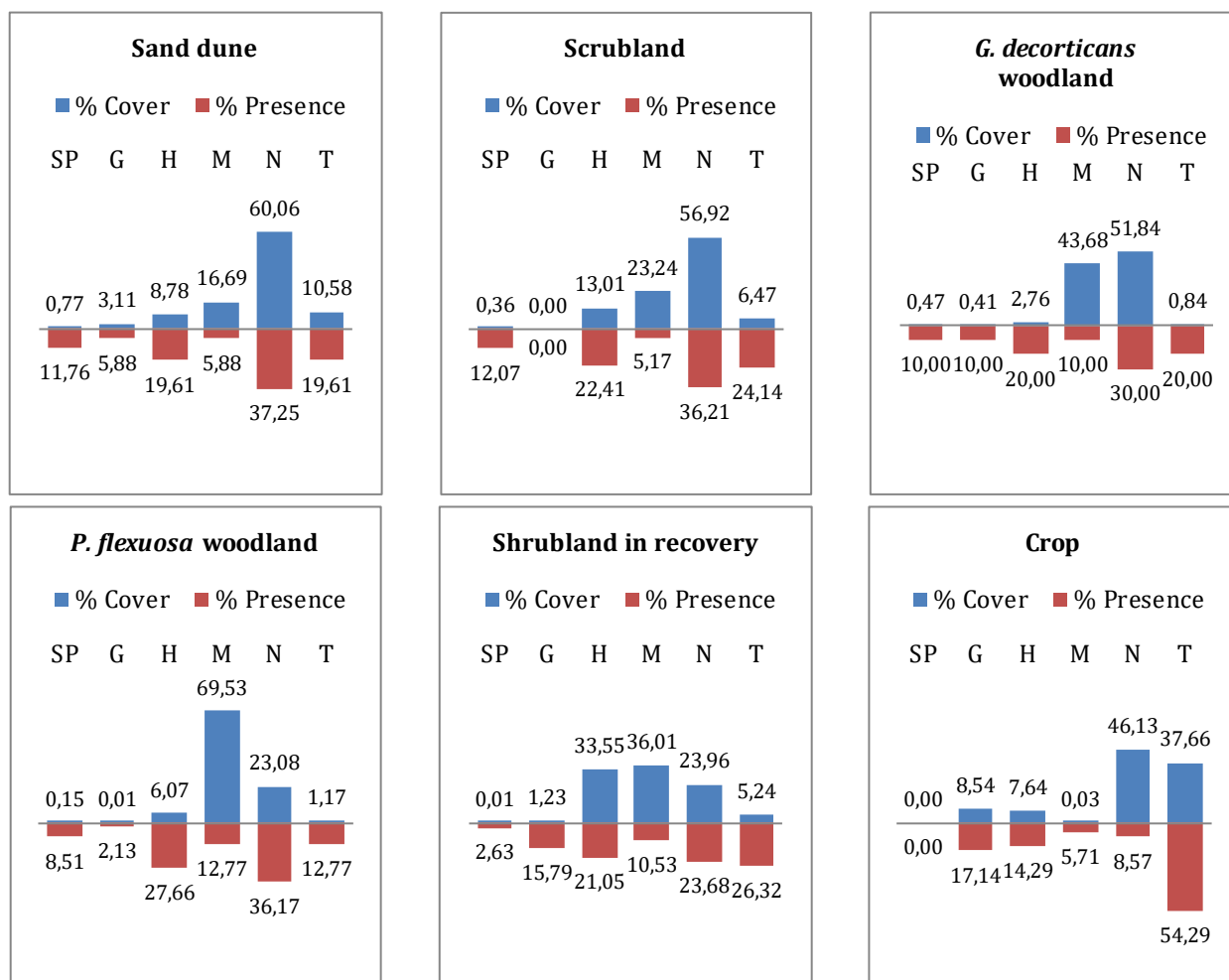
Cov.: valor global de cobertura (suma de las coberturas medias de cada especie dividido el número total de los relevamientos de cada comunidad por 100). El Anexo 2 detalla las especies con valores escasos de presencia y/o cobertura en cada comunidad.

* Posible híbrido entre *P. flexuosa* y *P. chilensis*.

Total mean coverage (M.C.) expresses mean percentage of soil covered with vegetation. Richness (R) represents mean number of species per survey. Super-indices and sub-indices show maximum and minimum observed values, respectively. La cobertura total media (M.C.) expresa el porcentaje promedio de suelo cubierto por vegetación. La riqueza (R) representa el número medio de especies por relevamiento. Superíndices y subíndices muestran los valores máximos y mínimos observados, respectivamente.

Table 2. Dominant processes and characteristics of identified communities.
Tabla 2. Procesos dominantes y características de las comunidades identificadas.

Community	Vegetation		Dominant processes/characteristics
	M.C. (%)	R	
Sand dune	63 ⁸⁵ ₄₀	16 ²³ ₉	Wind erosion (localized deflation and accumulation).
Scrubland	58 ⁹⁵ ₃₀	16 ²⁷ ₃	Localized water and wind erosion.
<i>G. decorticans</i> woodland	78 ⁹⁵ ₅₅	16 ²¹ ₁₂	Longitudinal development, on a sand dune base.
<i>P. flexuosa</i> woodland	73 ¹⁰⁰ ₂₅	14 ²³ ₄	Humus accumulation, some plants are bare-rooted from water erosion.
Shrubland in recovery	52 ⁹⁰ ₃₀	9 ¹⁵ ₆	Water (laminar and linear runoff) and wind erosion, plow pan compaction and soil sealing (surface hardening), crusting, etc.
Crop	78 ⁹⁵ ₃₅	14 ¹⁸ ₉	Drip irrigation and no tillage.



SP: succulent phanerophytes, G: geophytes, H: hemicryptophytes, M: microphanerophytes, N: nanophanerophytes and T: therophytes.
 SP: fanerófitas suculentas, G: geófitas, H: hemicriptófitas, M: microfanerófitas, N: nanofanerófitas y T: terófitas.

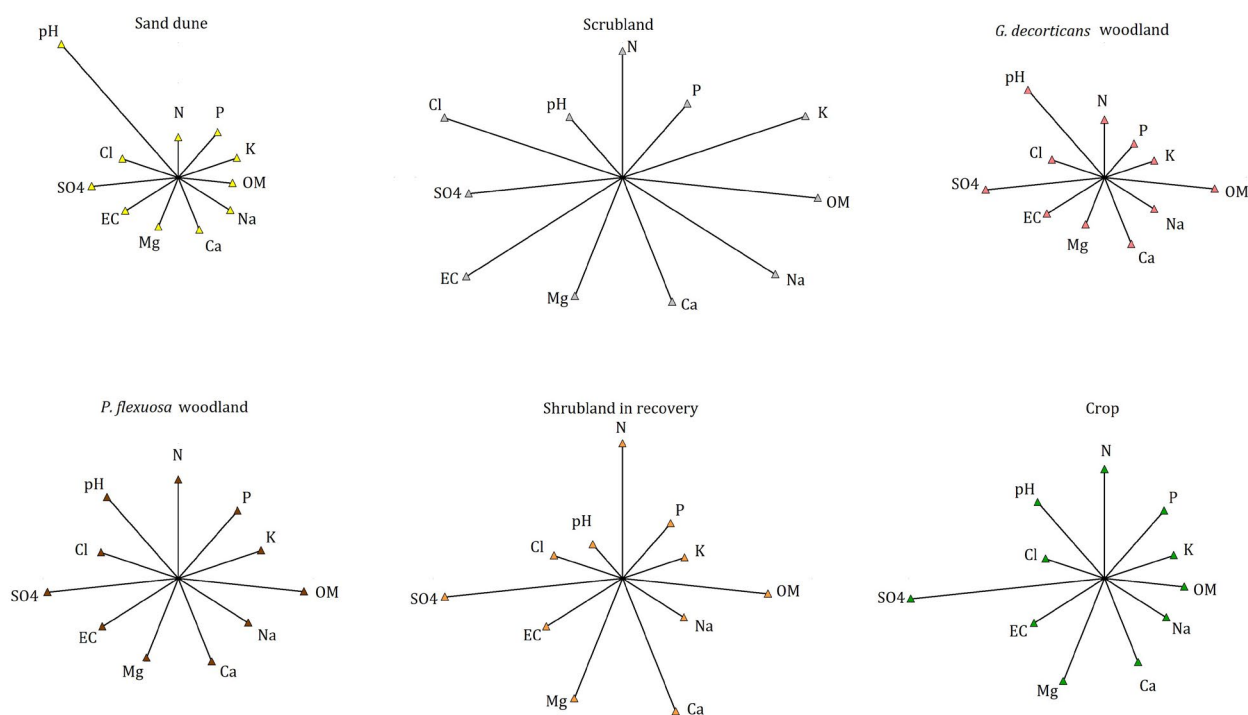
Figure 2. Biological cover and frequency spectra for each community.
Figura 2. Espectros biológicos de cobertura y frecuencia para cada comunidad.

Taxonomic determinations

Representative samples of species found in the area were herborized and taxonomically identified based on reference specimens from the Mendoza Ruiz Leal Herbarium (MERL, Argentine Institute for Dryland Research), and monographic works and publications on Argentina's regional floras. Regarding nomenclature, we consulted the Catalog of Vascular Plants of Argentina (38) and the database of Argentine Flora (n. d.), the International Plant Names Index (n. d.), Tropics organization (n. d.), and the International Code of Nomenclature for algae, fungi, and plants (2018). Recently, a disintegration of the genus *Prosopis* L. based on molecular phylogeny has been proposed, followed by a new nomenclatural combination for American species of the genera *Neltuma* and *Strombocarpa* (12). Nevertheless, we keep Burkart's traditional classification of *Prosopis* (6) for nomenclatural stability, prevailing current use and disadvantageous changes (31, articles 14, 34 and 56), until acceptance of nomenclatural changes by the International Committee of Nomenclature.

Soil analysis

Soil samples supplemented environmental descriptions of different communities. After establishing 16 sites, three samples were removed from a pit dug in each site, achieving a maximum depth of 1.10 m, totalling 48 samples and including data from the intermediate layer (0.20 to 0.50 m), where most root activity is concentrated (table 3, Annex 1). Texture, fertility (nitrogen, phosphorus, potassium and organic matter), salinity (electric conductivity and sodium adsorption ratio), acidity (pH), ion complex (sodium, calcium, magnesium, carbonate, bicarbonate, sulfate and chloride) and humidity were determined for each sample (4). Results were analyzed with descriptive statistics by InfoStat software version 2020 (8), graphed on star charts for every community, where each variable is represented by a radius whose length is the mean value of samples taken from each community (figure 3).



Each graph shows mean values of N: nitrogen, P: phosphorus, K: potassium, OM: organic matter, Na: sodium, Ca: calcium, Mg: magnesium, EC: electric conductivity, SO4: sulfates, Cl: chlorides and pH: hydrogen potential.

En cada uno de los gráficos valores medios de N: nitrógeno, P: fósforo, K: potasio, OM: materia orgánica, Na: sodio, Ca: calcio, Mg: magnesio, EC: conductividad eléctrica, SO4: sulfatos, Cl: cloruros y pH: potencial hidrógeno.

Figure 3. Star graphs for main edaphic variables analyzed in each community.

Figura 3. Gráficos de estrellas para las principales variables edáficas analizadas en cada comunidad.

RESULTS AND DISCUSSION

Six plant communities were identified as sand dunes, scrubland, *G. decorticans* woodland, *P. flexuosa* woodland, shrubland in recovery after crop abandonment, and crop (photo 1; table 1, page 50 and 51; figure 1, page 48). Species with wider ecological range (accompanying species) were *L. crinita*, *T. terrestris*, *P. flexuosa*, *G. decorticans*, *A. lampa* and *P. philippianum*.

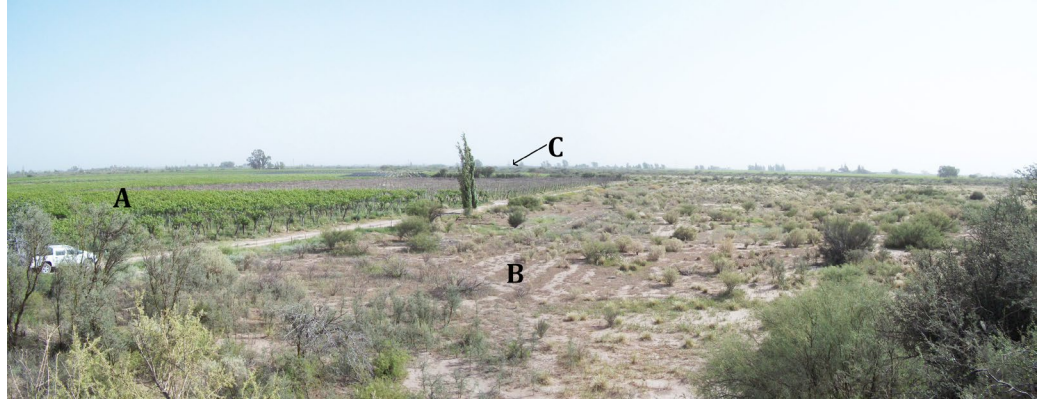


Photo 1. Study area: A, crop, B, shrubland in recovery and C, non-cleared scrubland.

Foto 1. Área de estudio: A, cultivo, B, arbustal en recuperación y C, matorral sin desmontar.

Poor soils in organic matter and nitrogen had good contents of phosphorus and potassium, and different levels of salinity. Most of the samples showed mildly alkaline and non-sodic characteristics (table 3, Annex 1).

Scrubland of *T. usillo* and *L. divaricata* with *M. ephedroides* and *P. urvilleanum* on sand dunes

Sand dunes had predominant scrub vegetation and small isolated trees, distributed in three vegetation-height layers as trees dominated by *P. flexuosa* and *G. decorticans* (average height of 3 m), shrubs dominated by *T. usillo* and *L. divaricata* (1.5 m), and an herbaceous layer dominated by *L. crinita* and *P. urvilleanum* (0.5 m). Heterogeneous sun exposure of this natural topography (from 5 to 10 m in height) was evidenced in vegetation growth. Thus, *P. urvilleanum* forms compact colonies and is occasionally dominant in dry sunny areas (fixing and stabilizing more exposed dune sectors), whereas *Z. jamesonii* grows mostly in shady places, reflecting the micro-environmental diversity of dunes and being one of the greatest floristic resources of the study area (table 2, page 52).

Exclusive characteristic species of this community resulted *P. urvilleanum*, *S. goldsackii*, *P. globosum*, *I. parodii* and *C. castilloniana*, preferential characteristic species are *T. usillo*, *M. ephedroides*, *L. divaricata*, *P. grandiflora*, *G. mendocina*, *X. americana* and *T. terrestris*, and accompanying species are represented by *A. lampa*, *L. chilense*, *M. aspera*, *B. spinosa*, *S. divaricata*, *G. bracteata*, *S. leucopila*, *B. barbata*, *S. arnottii* and *E. leucantha*.

Species coverage and presence spectra reflected a community dominated by nanophanerophytes (distinctive plants in a sand dune physiognomy), therophytes and hemicryptophytes. Microphanerophytes, although not frequent, seemed to contribute considerable coverage in contrast to the numerous succulent phanerophytes, of insignificant relative coverage (figure 2, page 52).

Sand dunes are generally not saline due to soil permeability. The low water content of soil surface layers hinders organic matter decomposition and nutrient fixing, resulting in low fertility. Nevertheless, higher nitrogen values were found on shady sides of the dune, closest to crops and coinciding with a higher density of *P. flexuosa* trees, harbouring atmospheric nitrogen-fixing bacteria in their roots (34). Dunes pH was moderately to strongly alkaline, consistent with higher carbonate and bicarbonate values.

Dense scrubland of *L. tenuispinosum* and *A. argentina* with *P. flexuosa*

This community, on sites with no evidence of clearing, is mainly composed of tall shrubs and trees, isolated or in small groups (photo 2). It presented three height layers, trees dominated by *P. flexuosa* (average height of 3 m), shrubs dominated by *L. tenuispinosum*, *L. cuneifolia* and *A. argentina* (1.8 m), and an herbaceous layer dominated by *L. crinita* (0.5 m). These scrublands on saline soils occupy the greatest land expanse in the study area, fragmented by vineyards. Tall and dense scrubland is physiognomically predominant in the landscape, alternating with sparse shrubland, sandy deposit sites, ground surface water accumulation, or evidence of laminar runoff in natural drainage areas. This scrubland would be considered a reference of typical natural vegetation in the area, helping understand plant plot recovery after crop abandonment, since both communities show similar edaphic and floristic features.



Photo 2. Overall scrubland physiognomy.

Foto 2. Fisonomía general del matorral.

Exclusive characteristic species are *P. tetraantha*, *G. boliviana* and *M. ovata* in sandy soils, and *A. spagazzinii* in saline, finer-textured soils. All preferential characteristic species like *A. argentina*, *C. genistoides*, *S. mirabilis* and *S. phleoides* are typical of saline soils. Accompanying species are *P. flexuosa*, *A. emarginata* and *T. usillo* in sandy areas, and *L. tenuispinosum*, *L. crinita*, *L. cuneifolia* and *S. divaricata* in saline or floodable lands. *A. hybridus* and *F. bidentis* appear as accidental species after nearby crop influence.

Scrubland physiognomy was evidenced by dominance of nanophanerophytes, followed by microphanerophytes. Therophytes and hemicryptophytes species were abundant. All succulent phanerophyte species surveyed in this study are represented in this community.

Scrubland soil varied depending on the area surveyed, with sandy to loamy textures, low fertility, on slightly to excessively saline sites. In the latter case, the highest soluble sodium salt content (chlorides and sulfates) indicated strongly sodic soils.

Closed dune-base woodland of *G. decorticans* with *L. tenuispinosum* and *A. emarginata*

Closed *G. decorticans* woodland with three height layers included trees dominated by *G. decorticans* with some *P. flexuosa* trees (heights from 1.5 to 5 m), shrubs dominated by *L. tenuispinosum* and *A. emarginata* (average height of 1 m), and an herbaceous layer

with low coverage values, dominated by *L. crinita* (0.80 m) and *A. incarnata* (0.1 m). *Geoffroea decorticans* woodland, longwise developed, was found at the base of a sand dune, spreading by gemmiferous roots, facilitating colonization of the abandoned crop area in recovery process.

Solanum triflorum was found exclusive to this community, beneath *P. flexuosa* canopies. Preferential characteristic species are *G. decorticans*, *L. tenuispinosum* and *O. sulphurea* (tolerant to floodable, clay or saline soils); *A. emarginata* and *T. brunonis* (representative of *P. flexuosa* woodland), and *A. incarnata* and *C. asperata* (linked to sandy soils by proximity to the sand dune of *G. decorticans* woodland). Accompanying species observed included *P. flexuosa*, *L. cuneifolia* and *L. chilense*, notoriously affecting total coverage and presence, where 95% of the relative cover is contributed by nanophanerophytes and microphanerophytes, and 4% by hemicryptophytes and therophytes. This is the only community comprising all life forms, showing a more equitable distribution of presence values.

Soil is sandy-loam up to 0.70 m deep, and sandy at greater depths. Fertility is low and the sand dune base determines good water drainage, reflected in the low-salinity soil profile.

Woodland of *P. flexuosa* with *A. emarginata* and *A. patens*

Relics of *P. flexuosa* woodland, fragmented by crops or cleared areas, were surveyed on 12 plots of 225 m² each showing open *P. flexuosa* groves (trees between 2.5 and 5 m tall, whose canopies rarely touch), or closed and semi-closed groves (trees up to 6.5 m tall, whose canopies frequently touch). Three height layers were distinguished with trees dominated by *P. flexuosa*, sometimes accompanied by *G. decorticans* and *B. retama* (average height of 3 m), shrubs dominated by *L. tenuispinosum* and/or *A. emarginata* (1 m), and an herbaceous layer dominated by *L. crinita* (0.80 m). We observed *P. flexuosa* trees with a single trunk and multiple stems and mean tree coverage ranging between 22.5% and 62.5% (value explained by the great number of saplings with main shoot diameter under 5 cm: 130/survey, on average).

A. patens, *P. strombulifera*, *A. odorata*, *V. astringens* and *V. aroma* are exclusive characteristic species in this community. *P. flexuosa* reaches the highest relative coverage in the area, as well as *A. mendocina* and *S. aphylla*, identified as preferential characteristic species. *P. flexuosa* canopies prevent light from reaching the ground, limiting development of succulent phanerophytes, geophytes and therophytes with low relative coverage values.

Soil samples were collected from the grove adjoining the crop (A4, figure 1), finding non-saline soils of sandy loam texture up to 0.20 m deep and sandy at greater depths. Nitrogen and organic matter contents were among the highest recorded at all sites in the study area and, just as phosphorus and potassium contents, reached higher values in surface layers, probably induced by humus beneath tree canopies (34).

Low and open steppe of *L. crinita* and *P. flexuosa* with *L. cuneifolia* and *B. retama* in abandoned crops

Open steppe (52% of mean total coverage) showed shrubs and grasses with young, isolated, small, multi-stemmed trees (photo 3, page 57). Three height layers were distinguished by trees dominated by *P. flexuosa* and *B. retama* (average height of 2 m), shrubs dominated by *L. cuneifolia* (1 m), and an herbaceous layer of *L. crinita* and *P. philippianum* (0.80 m). This community corresponds to cleared areas levelled in 1972 for crop establishment (grapes, apricots, alfalfa and vegetables), labored for as long as 15 years and abandoned in 1987 due to poor performance and yield. Agricultural tillage altered soil characteristics in this area during 25 years between abandonment and present surveys. The surrounding natural vegetation has recolonized this site with numerous species, typical of fine-textured, saline or floodable soils. Adjoining crops contribute to species surviving the edaphic limitations of these abandoned plots.

Flaveria haumanii and *P. cuneato-ovata* behave as exclusive characteristic species; *L. crinita*, *P. philippianum*, *L. cuneifolia*, *B. retama*, *S. subulatus* and *D. californica* as preferential characteristic species, depending on site propensity for salt and water accumulation, or surface runoff after rainfall (25). *P. flexuosa*, as an accompanying species, contributes important coverage and presence, and *C. dactylon* and *P. glauca*, as accidental species, denote close crop-area influence.



Photo 3. Physiognomy of shrubland under recovery, colonized by grasses. Old crop furrows with evidence of water erosion are observed.

Foto 3. Fisonomía del arbustal en recuperación, colonizado por gramíneas. Se observan los antiguos surcos de cultivo con evidencias de erosión hídrica.

Hemicryptophytes (primarily *L. crinita*) establishment increases in sunny areas with almost non-competition, defining the vegetation physiognomy together with nanophanerophytes and microphanerophytes. Scarce succulent phanerophytes and geophytes were evidenced by these plant limitation to propagate from seeds or in agamic reproduction.

Soils resulted sandy loam, with nitrogen and organic matter contents similar to non-cleared sites. Salinity increased with depth. A gypsum layer detected in the soil profile was analytically confirmed by higher calcium sulfate concentrations. This pattern may be due to machinery effects during years of tillage, generating a deep compacted layer that favoured salt concentration in the soil profile after periodic irrigation was suspended.

In general terms, these results are consistent with other studies associating site use history, particularly productive plots abandonment with higher soil erodibility and changes in landscape physiognomy of the Monte native vegetation (35, 37).

Vitis vinifera* crop with *M. albus* and *F. bidentis

A 31-ha vineyard with different grapevine cultivars, conducted both vertically and horizontally under drip irrigation, presented two height layers, one shrub layer dominated by *V. vinifera* (average height of 2 m) and a herbaceous layer dominated by *M. albus*, *F. bidentis*, *S. verticillata* and *B. catharticus* (0.5 m). The vineyard was surrounded by cleared areas with spontaneously recovered vegetation, and by other areas with undisturbed natural vegetation, a sand dune, and *P. flexuosa* groves.

Exclusive characteristic species with higher coverage values were *V. vinifera*, *M. albus*, *B. catharticus*, *C. album*, *C. bonariensis*, *S. asper* and *T. officinale*. Overall, they were widely distributed (normally adventitious or introduced). Despite great multiplying capacities, these species require more water than other drought-tolerant ones, such as *H. glauca*, *P. glauca*, *C. dactylon*, *F. bidentis*, *A. hybridus*, *S. verticillata*, *A. officinalis* and *S. euacanthum*, all preferential characteristic vineyard species, although capable of surviving in less favorable conditions. *L. crinita* (more abundant at sunlit crop sites as row ends, borders, plots with young vines, with less coverage or lower height) and *T. terrestris* behave as accompanying species, whereas *P. flexuosa* and *G. decorticans* are accidental, with small presence, coming from adjoining scrublands.

Dominant in biological spectra are nanophanerophytes (primarily grapevines, contributing nearly half the coverage despite low presence) and therophytes (generally small and abundant). Geophytes reach the highest coverage and frequency values, probably because tillage does not remove rhizomes, bulbils or other organs of asexual reproduction. Low microphanerophytes frequency is explained by spontaneous *P. flexuosa* and *G. decorticans* individuals.

Soils are sandy on the surface and intermediate layers and sandy-loam at depths greater than 0.5 m, with low nitrogen and organic matter contents, non to slightly saline.

CONCLUSIONS

Scrubland is the predominant physiognomy in the area, typical for the Monte Province, with species of the genera *Larrea*, *Atriplex* and *Lycium*. According to this study, the prevailing vegetation before crop establishment was halophilic or salt-tolerant. Species like *A. lampa*, *A. spegazzinii*, *A. argentina*, *P. tetraacantha*, *G. bracteata* and *S. divaricata* are frequent and grow in almost all communities identified.

Prosopis flexuosa groves grow where trees can benefit from groundwater, bordering the steppe or in inter-dune areas. As woodland canopy density increases, lower-height vegetation layers tend to diminish and even disappear due to sunlight shortage, except for sciophilous species like *A. emarginata*. *G. decorticans* is abundant on sites with finer-textured soil, at the base of sand dunes or in depressed areas, growing in well-defined groves. Through powerful gemmiferous roots, this species is one main colonizer of abandoned crop fields.

In sand dunes and their surroundings, psammophilous vegetation is well represented by a great diversity of species, given the micro-environmental features of these formations. *P. urvilleanum* is especially frequent in sand dunes destabilized by anthropic action.

Adventitious or introduced species, dependent on adequate water supply (*M. albus*, *C. album*, *S. asper*, *T. officinale*, etc.) coexist in combination with more rustic species able to develop under water and/or saline stress (*F. bidentis*, *P. glauca*, *A. hybridus*, *H. glauca*, *S. verticillata*, *C. dactylon*, etc.). Thus, a crop area is the source of propagules dispersal for these last species being introduced into neighbouring sites.

In shrubland under recovery, clearing, tillage and later crop abandonment emphasized edaphic constraints, analytically determined by signs of soil erosion, compaction or crusting. Spontaneous re-vegetation led to lower floristic richness compared to the adjacent natural areas taken as reference sites, after 25 years of abandonment, with strong presence of tolerant species or species indicating fine-textured soils, floodable areas, or with surface runoff and saline characteristics. Original shrubland has turned into a steppe of bushes (halophilic in part) and grasses with small young trees. Several species present in the surroundings (*O. sulphurea*, *S. divaricata*, *S. mirabilis*, *C. genistoides* and *P. tetraacantha*, among others) had difficult establishments on the plot, despite being halophilic or salt-tolerant. This result supports the hypothesis that the main problem for plot recovery would not be saline content, but soil structure alteration by tillage and subsequent crop abandonment, reinforcing uncertainty about biodiversity restoration levels to be sought in degraded soils, and recovery time span. This study demonstrated that a survey of natural environments with proper assessment methodologies is fundamental before land clearing for agriculture. Determination of plant communities in fragmented areas, and valuation of species indicative of edaphic limitations restricting crop establishment and productivity, are essential in defining land uses.

Flora components and species distribution are adequate indicators for monitoring environmental processes in plant communities. Incorporating the private sector into environmental protection systems towards the establishment of isolated preserved sites is necessary but not sufficient in disjointed landscapes. This first analysis of natural areas fragmented by agriculture in Montecaseros, shows that typical communities of the Monte subsist, demonstrating how diverse flora is preserved in privately owned lands. Changes in floristic composition of plant communities may have occurred in the study area during the time elapsed between this survey and the current situation. The results obtained constitute an important baseline for monitoring sampling sites and vegetation dynamics in fragmented

areas of Montecaseros. Cultivable land is a vulnerable and scarce resource, particularly in drylands. A proper interpretation recognizes limiting territory factors while approaching systemic criteria highlighting complementarity in management between crops and native vegetation areas. Studies of vegetation dynamism in private lands will contribute to plan and implement sustainable land management, tending to recover and conserve biodiversity in degraded soils, considering all associated ecosystem services.

ANNEXES

<https://drive.google.com/file/d/1ST-hgPbnmvltbARGf2o7KkoD0IXoNFGP/view?usp=sharing>

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