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Lichen community diversity on a remnant forest in south of Chaco region (Cordoba, Argentina)

Diversidad de la comunidad líquénica en un bosque remanente del sur de la región chaqueña
(Córdoba, Argentina)

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SUMMARY

The lichen community diversity in patches of Chaco forest -NE of Cordoba Province, Argentina was analyzed. Fifteen forest patches embedded in farmland areas were sampled. Size of the patch and exposure to the crops were registered. In each patch, ten trees (sample units) with epiphytic lichens were sampled. The cover for epiphytic lichen species and the number of species present were recorded. Shannon-Wiener diversity index was calculated for each patch and multivariate analyses (DCA and Indicator Species Analyses) were applied in order to study the composition of the community. The sample patches in the DCA were associated with patch exposition. Four quantitative variables (patch size, relative cover of Physciaceae, Parmeliaceae and Collembataceae; the most representative families) were related with the first two axes of DCA using correlations coefficients. Twenty one species in patches were identified. A multivariate analysis of sample units showed preferences of some species to exposure of patches to the crops. The data indicated that there would be a degradation marked by the impact of the edges on the remaining forests. There is a trend towards more homogeneous communities, formed by species resistant to these boundary conditions and possessing high coverage.

Key words: agriculture, Chaco, epiphytes, patches, community structure.

RESUMEN

Se analizó la diversidad de la comunidad líquénica del bosque chaqueño en el NE de la provincia de Córdoba, Argentina. Se registraron quince parches de bosque inmersos en áreas de cultivo, su exposición a los cultivos y el tamaño de los parches. En cada parche se muestrearon los líquenes epífitos de diez árboles (unidades muestrales). Se registró la cobertura y el número de especies presentes. Se calculó el índice de diversidad de Shannon-Wiener para cada parche y se aplicaron análisis multivariados (análisis de correspondencia detendenciado –DCA– e índice de indicador de especies) para estudiar la composición de la comunidad. En el DCA se asoció la muestra de parche con su exposición. Se relacionaron cuatro variables cuantitativas (tamaño del parche, cobertura relativa de familias, Physciaceae, Parmeliaceae y Collembataceae, que fueron las más representativas) con los primeros dos ejes del DCA, usando coeficiente de correlación. Se identificaron 21 especies en los parches. El análisis multivariado de las unidades muestrales evidenció preferencia de algunas especies a la exposición de los parches al cultivo. Los datos muestran una degradación debida al impacto del borde en el bosque remanente. Existe una tendencia hacia las comunidades más homogéneas, formadas por especies resistentes a estas condiciones de borde y que presentan altos valores de cobertura.

Palabras clave: agricultura, Chaco, epifitas, estructura de la comunidad.

INTRODUCTION

The conservation of native forests is an essential component for the maintenance of the biodiversity that they sustain. In the Chaco region, large forest areas are affected by different factors, especially the deforestation for lumber use or the advance of the agricultural border that, lately, has led to the fragmentation of formerly contiguous forests (Hoyos *et al.* 2012). Forest fragmentation represents one of the major threats to global biodiversity conservation (Hedenäs and Ericson 2000).

When continuous cover of forests becomes disperse patches with different sizes and isolation, the ecological process

changes (Rheault *et al.* 2003). Fragmentation produced changes in climate homeostasis and in biotic–abiotic conditions. As a general rule, in the edge of patches, climate conditions (humidity, temperature and light) became extreme and not adequate for living organisms adapted to living in the center of the forest (Renhorn *et al.* 1997, Rehault *et al.* 2003). These conditions generate changes in the responses of forest lichen communities.

Lichen communities play an important role in the forest ecosystem, although they are not the major part of the biomass. Included in these roles are: nitrogen fixation, the cycle of nutrients and the provision of materials for feeding or nests construction (Will-Wolf *et al.* 2002).

Epiphytic lichens are dependent on the substrate they grow up (Snäll *et al.* 2003, 2005). They are especially sensitive to environmental variations because they have no regulation mechanisms to acquire or lose water and take their nutrient from atmospheric sources. By the above, epiphytic lichens are sensitive to fragmentation and forest management (Kivistö and Kuusinen 2000, Aragón *et al.* 2010). Such alterations reduce substrate availability (such as tree bark) and produce changes in micro climate conditions (Hilmo and Sæstad 2001), generating lichens variations in composition and diversity (Johansson 2008). Lichens are also an important component of biodiversity and habitat for numerous living organisms such as insects, mollusks, mites and amphibians (Esseen and Renhorn 1998).

In central Argentina and particularly in Chaco region, studies have been carried out to know lichen diversity in different environments (Estrabou *et al.* 2005, Estrabou *et al.* 2006) and to evaluate modifications against disturbances (Estrabou *et al.* 2004, 2011, Quiroga *et al.* 2008, Rodríguez *et al.* 2009). No study has been carried out to know changes in lichens community in fragmented forests. We assume that lichen diversity diminishes in patches and increases the cover of species that tolerate or resist the new conditions.

The present work aims at knowing and evaluating changes in the structure of epiphytic lichen communities (cover, richness, diversity and composition) in remnant forest in Chaco region.

METHODS

Study area. The study area is located in the phytogeographic Province of Chaco (Cabrera 1976) belongs to the ecoregion of the Gran Chaco (Morello 1983). This area is characterized by a strong seasonality and a large daily temperature range. It presents a heterogeneous matrix with forest patches with different sizes and different degrees of disturbance. The vegetation of the Chaco forest zones with little disturbance is characterized by the presence of trees as *Aspidosperma quebracho-blanco* Schltdl., *Prosopis alba* Griseb., *Prosopis nigra* Griseb. and *Zizyphus mistol* Griseb. Some patches are in contact with crops in only one of its edges, while others are totally enclosed within them becoming true “islands” (isolated patches) of native forest. Due to this management, on these patches of forest, some tree species are lost and replaced by other species such as *Acacia caven* (Molina) Molina, *Acacia praecox* Griseb., among others, thus bushes receive more sunlight. In addition, they are more exposed to particulate products of land-work and spraying, among other factors affecting them (Viglizzo *et al.* 2010). In addition, the isolated patches are exposed to products used in the agriculture.

Sampling. Inside the “Chaco Oriental” (Luti *et al.* 1979), 15 patches of native forest bordering farmland were sampled for this study, which was carried out between 2010

and 2011. These patches are irregularly distributed in a homogeneous area of 50 km² (30° 31' S and 30° 53' S 63° 69' W and 64° 09' W, 450 m a.s.l.) (figure 1). Each patch was geopositioned and data on its size and exposure to the crop were recorded. The patches were mostly rectangular and the exposure was specified according to number of sides of the patch bordering the crops. The patches were classified into three types: isolated patches (forest in the middle of crops), two borders (patches with two borders to the crops), one border (patches with one border to the crops) (table 1). Roads, shrublands or grasslands limited the patches with borders without crops. In each patch 10 phorophytes belonging to the native flora of the place, with diameter at breast height over 10 cm, were randomly selected. A total of 150 phorophytes were sampled. The coverage for each species of lichen present on the southwest side of trees - the side of the trunk which has higher coverage of lichens in this region- and at 1.50 m in height was determined for each phorophyte using a transparent plastic grid of 20 x 20 cm. This method was standardized in Estrabou and García (1995), Estrabou (2007) and Estrabou *et al.* (2011).

All species were identified using routine methods (Estrabou *et al.* 2006); with the exception of crustose lichens which were identified at genus level or not classified. For each species, the family and percentage of coverage were determined.

Data analysis. A Kruskal Wallis test was applied for the total lichen cover in order to know if there are significant differences among the patches. Moreover, Spearman correlation index was applied for the total lichen cover and richness.

For each patch studied, the species richness was registered and diversity index of Shannon-Wiener (H') was calculated according to the formula [1].

$$H' = -\sum p_i \cdot \log(p_i) \quad [1]$$

where

p_i = relative proportion (coverage) of the i species.

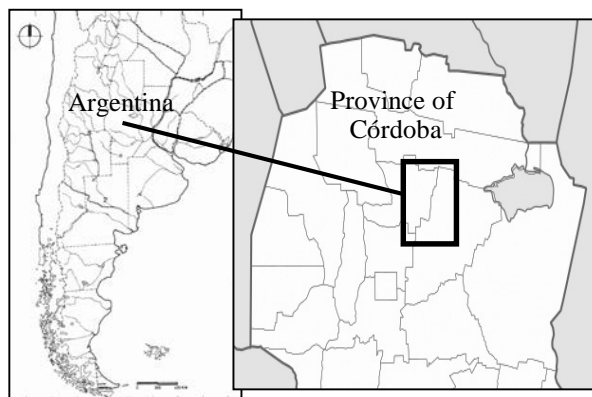


Figure 1. Location of the study area.

Ubicación del sitio de estudio.

Table 1. Size and exposition to culture of the 15 sampled patches.
Tamaño y exposición a cultivo de quince muestras de parches de bosque.

Patches	Size (ha)	Patch exposition to culture
1	0.90	isolated patches
2	0.30	2 borders
3	0.51	1 border
4	0.66	isolated patches
5	3.40	isolated patches
6	1.04	2 borders
7	0.82	2 borders
8	0.57	isolated patches
9	0.22	isolated patches
10	0.10	1 border
11	0.10	1 border
12	1.35	1 border
13	0.15	2 borders
14	50.00	2 borders
15	52.00	2 borders

The composition of the community was studied calculating the relative cover of lichen families. Also a detrended correspondence analysis ordination (DCA) was conducted on a matrix of sample units by species cover to detect groups. We calculated coefficients of determination between original sample unit's distances and distances in the final ordination solution to assess how much variability in lichen community composition was represented by the DCA axes (McCune and Grace 2002). The sample points in the DCA were associated with the qualitative variable patch exposition using different symbols for each group. Also, four quantitative variables were related with the first two axes of DCA using correlations coefficients (McCune and Grace 2002). The variables used were: patch size, relative cover of Physciaceae, Parmeliaceae and Collembataceae families.

In addition, Indicator Species Analysis (Dufrene and Legendre 1997) was applied using a Monte-Carlo simulation to detect species that have significant preferences for exposure to culture (McCune and Grace 2002). In order to filter noise that could underlie the structure of the data and to reduce the stochastic effects of rare species, we applied the multivariate analysis to a partial dataset including only the lichen species found in more than 15 trees (more than 10 % frequency). The data analysis was performed using Infostat v. 2011 and PCORD v. 5.1.

RESULTS

Figure 2 shows the diversity index and the average of total lichen cover for each patch. Only four species were identified in patch 8, 9 and 11. On the other hand, 14 spe-

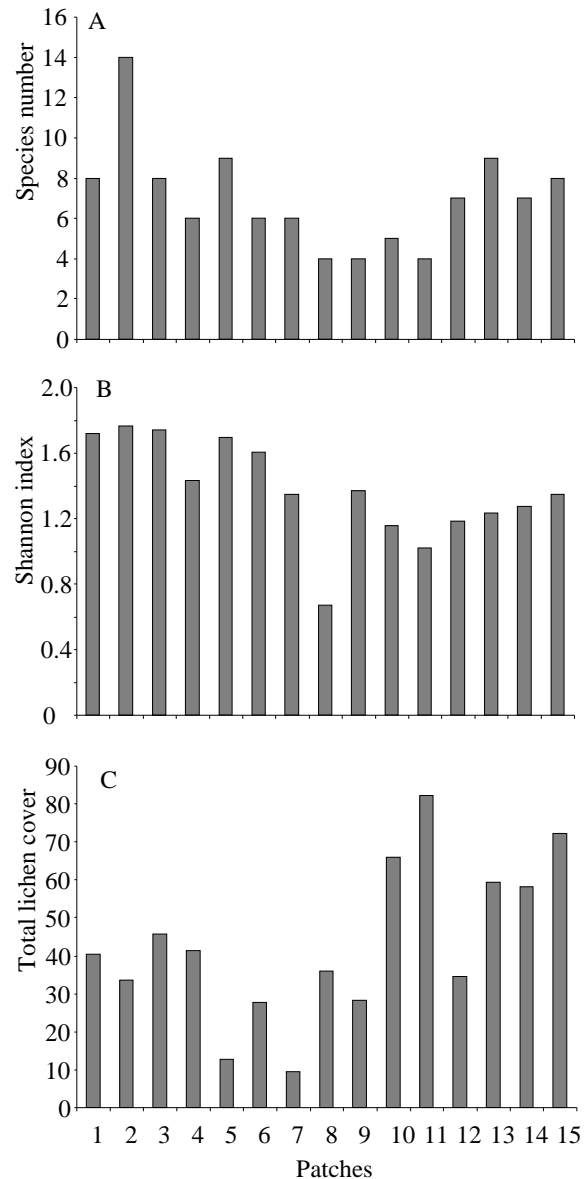


Figure 2. A: Richness, B: Shannon-Wiener index and C: average cover or total cover in patches.

A: Riqueza, B: Índice de Shannon-Wiener y C: Porcentaje de cobertura total en los parches.

cies were identified in patch 2. The highest diversity was found in patch number 2 and the smallest one was found in patch number 8. Average of the total lichen coverage and diversity did not show relation (Spearman correlation index was 0.35). The highest cover was registered for patch 11 with only four species (*Physcia undulata*, *Candelaria concolor*, *Canoparmelia crozalsiana* and *Punctelia microsticta*). On the other hand, patches seven and five contain six and nine species respectively with poor lichen cover. In general, the total lichen cover showed significant differences among patches (Kruskal-Wallis test with $P < 0.0001$).

The composition of the lichen community in forest patches was represented by twenty one species (table 2). The 38.10 % of the species belongs to the family Physciaceae, the 38.10 % to the Parmeliaceae and 9.52 % to the Collemataceae; they represent almost the 90 % of the lichen cover. Families Telochistaceae, Candelariaceae and Ramalinaceae were represented by 4.76 %.

The first three ordination axis of DCA analysis captured 47.1 % of the variability in the dataset (figure 3). The ordination analysis showed three groups of samples partially related with the exposition of patches to crops. Group A is partially composed by samples from patches with two borders to crops and associated with *Parmotrema pilosum*, *P. reticulatum*, *Punctelia microsticta* and *Hyperphyscia endochrysea*. Group B is composed by samples from patches with one border to crops and associated with *Ramalina celastri*, *Leptogium cyanescens*, *Collema* sp. and *Physcia erumpens*. Group C is not clearly defined but it is composed mainly by samples from patches in isolated patches and associated with *Physcia undulata* and *Heterodermia albicans*.

The size of patches did not show correlation with the axis (Axis 1 $r = -0.086$, Axis 2 $r = 0.028$). The cover of Physciaceae family correlated weakly with axis 1 ($r = 0.261$). The cover of Parmeliaceae family correlated negatively with axis 1 ($r = -0.361$). The cover of Collemataceae family correlated positively with axis 1 ($r = 0.644$).

The species indicator analysis for the patch exposition showed (table 3) that *Candelaria concolor* had preference for the patches in isolated patches. The species *Physcia aipolia*, *P. erumpens*, *Ramalina celastri*, *Collema* sp. and *Leptogium cyanescens* were indicator of patches with one border to crops. Finally, *Hyperphyscia endochrysea*, *Parmotrema pilosum* and *P. reticulatum* were indicators of patches with two borders to crops.

DISCUSSION AND CONCLUSIONS

The total lichen coverage in patches was 34.09 % in average. This value is relatively high when compared to studies carried out in the region (Estrabou *et al.* 2005, Estrabou 2007). However, when the patches species were

Table 2. Lichen species found in all sampled patches, family and average cover of each one.
Especies líquénicas encontradas en los parches, familias y porcentaje de cobertura de cada una.

Species	Average cover	Family
<i>Candelaria concolor</i> (Dickson) Arnold.	0.57	Candelariaceae
<i>Collema</i> sp.	7.17	Collemataceae
<i>Leptogium cyanescens</i> (Ach.) Körb	3.22	Collemataceae
<i>Canoparmelia crozalsiana</i> (de Lesd.) Elix <i>et</i> Hale*	0.49	Parmeliaceae
<i>Canoparmelia texana</i> (Tuck.) Elix <i>et</i> Hale*	0.03	Parmeliaceae
<i>Parmotrema austrosinense</i> (Zahlbr.) Hale*	1.00	Parmeliaceae
<i>Parmotrema cetratum</i> (Ach.) Blanco <i>et al.</i> *	0.20	Parmeliaceae
<i>Parmotrema conferendum</i> (Hale) Kurok.*	0.03	Parmeliaceae
<i>Parmotrema pilosum</i> (Stizenb.) Elix <i>et</i> Hale	9.46	Parmeliaceae
<i>Parmotrema reticulatum</i> (Taylor) Hale <i>et</i> A. Fletcher	1.79	Parmeliaceae
<i>Punctelia microsticta</i> (Müll. Arg.) Krog	1.65	Parmeliaceae
<i>Heterodermia albicans</i> (Pers.) Swinscow <i>et</i> Krog	1.57	Physciaceae
<i>Hyperphyscia endochrysea</i> (Kremp.) Moberg	1.42	Physciaceae
<i>Physcia aipolia</i> (Humb.) Fűrnröhr.	1.59	Physciaceae
<i>Physcia alba</i> (Fee) Müll. Arg.*	0.04	Physciaceae
<i>Physcia erumpens</i> Moberg	2.80	Physciaceae
<i>Physcia poncisi</i> Hue.*	1.81	Physciaceae
<i>Physcia tribacia</i> (Ach.) Nyl.*	0.28	Physciaceae
<i>Physcia undulata</i> Moberg	6.30	Physciaceae
<i>Ramalina celastri</i> (Spreng.) Krog <i>et</i> Swinscow	1.31	Ramalinaceae
<i>Teloschistes cymbalifer</i> (Meyer) Müll. Arg.*	0.01	Telochistaceae
Crustose	0.43	

* Species excluded from multivariate analysis (less than 10 % frequency).

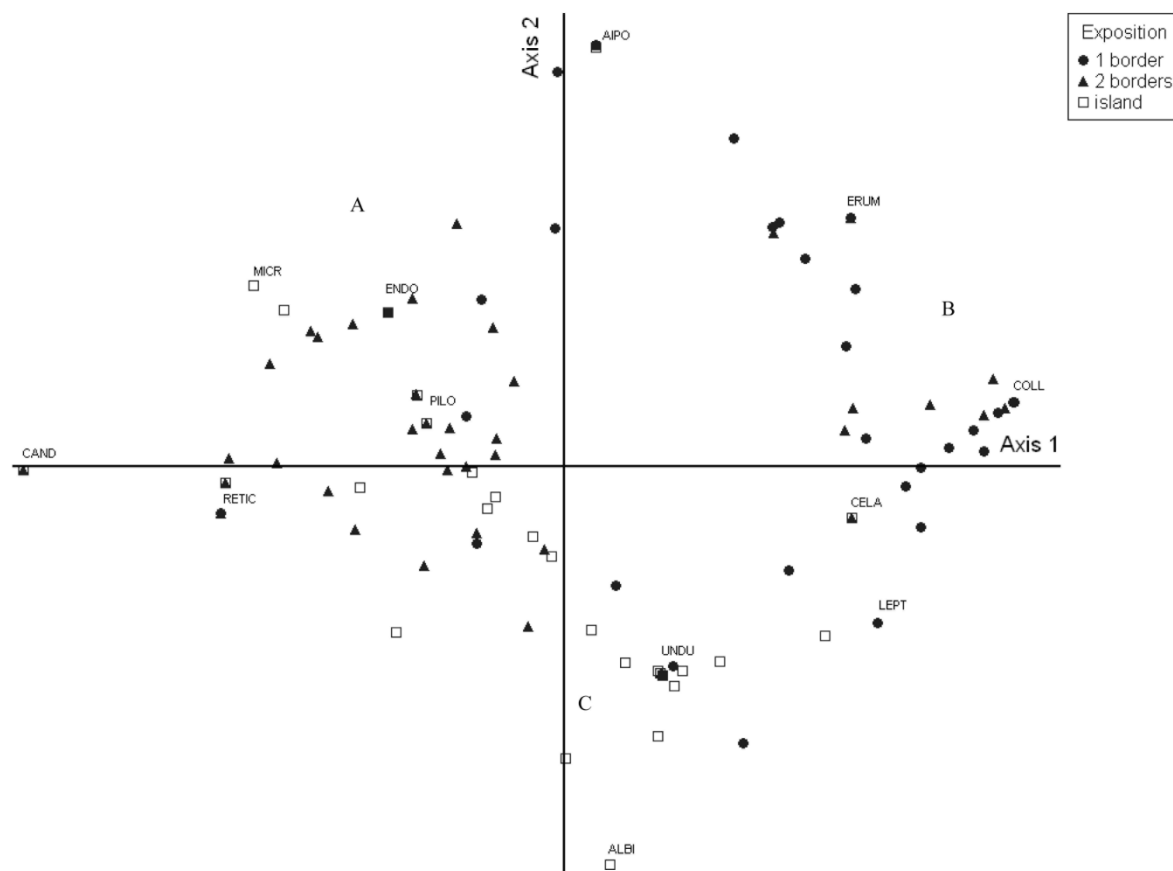


Figure 3. Detrended correspondence analysis (DCA) of samples. Samples are differentiated according to the exposition to crops. Letters A, B and C indicate grouping (see in the text). Species: CAND = *Candelaria concolor*, PILO = *Parmotrema pilosum*, ALBI = *Heterodermia albicans*, ENDO = *Hyperphyscia endochrysea*, LEPT = *Leptogium cyanescens*, RETIC = *Parmotrema reticulatum*, AIPO = *Physcia aipolia*, ERUM = *Physcia erumpens*, UNDU = *Physcia undulata*, MICR = *Punctelia microsticta*, CELA = *Ramalina celastri*, COLL = *Collema* sp.

Análisis de correspondencia detendenciado (ACD) de las muestras. Las muestras se diferencian de acuerdo con la exposición al cultivo. Letras A, B y C indican agrupaciones (ver en el texto). Especies = CAND: *Candelaria concolor*, PILO: *Parmotrema pilosum*, ALBI: *Heterodermia albicans*, ENDO: *Hyperphyscia endochrysea*, LEPT: *Leptogium cyanescens*, RETIC: *Parmotrema reticulatum*, AIPO: *Physcia aipolia*, ERUM: *Physcia erumpens*, UNDU: *Physcia undulata*, MICR: *Punctelia microsticta*, CELA: *Ramalina celastri*, COLL: *Collema* sp.

Table 3. Indicator species analysis for the patches exposition. Only species with $P < 0.05$ in the Monte Carlo test are shown.

Análisis de indicador de especie para la exposición de los parches. Sólo se muestran especies con $P < 0,05$ en la prueba de Monte Carlo.

Species with $P < 0.05$	Category of exposition	Observed indicator value	Expected indicator value	Standard deviation	P
<i>Candelaria concolor</i>	Isolated	20.1	7.8	2.57	0.0020
<i>Leptogium cyanescens</i>	1 border	28.4	9.3	2.85	0.0002
<i>Physcia aipolia</i>	1 border	18.2	8.8	3.05	0.0116
<i>Physcia erumpens</i>	1 border	15.5	7.2	2.53	0.0096
<i>Ramalina celastri</i>	1 border	13.6	7.8	2.83	0.0450
<i>Collema</i> sp.	1 borders	18.4	7.3	2.30	0.0016
<i>Parmotrema pilosum</i>	2 borders	31.6	17.0	3.36	0.0018
<i>Hyperphyscia endochrysea</i>	2 borders	22.4	9.5	2.81	0.0008
<i>Parmotrema reticulatum</i>	2 borders	17.6	7.8	2.59	0.0048

studied, this coverage was dominated by few species tolerant to environmental conditions of the patches. These results show that the coverage of lichens -without discrimination of species- has little importance in the assessment of disturbed ecosystems. Similar observations have been noted by Rosentreter and Eldridge (2002).

The dominant species in the patches are *Physcia undulata* and *Parmotrema pilosum*, with high levels of coverage. The other characteristic species of the contiguous forest studied by Estrabou (2007) are in a very low coverage in the patches, except for *P. pilosum*.

Particularly, *R. celsi* has a minimum coverage in tree trunks but a superior coverage in branches (unpublished data). Stoffer *et al.* (2006) found the decline of fruticose species in farmland environments. However more data are needed to evaluate the performance of these species as sensitive in these environments, especially considering branches or shrubs.

The exposure of the patch to the crops explains partially the differences found among patches. Patches with one border exposed have a community whose best indicator species are cyanolichens (*Collema* sp., *Leptogium cyaneoscens*), fruticose (*Ramalina celsi*) or less frequent species (*Physcia erumpens*, *P. aipolia*). The indicator species of patches with two borders exposed to crops (*Parmotrema pilosum*, *P. reticulatum* and *Hyperphyscia endochrysea*.) have been described as indicators of deterioration processes in Chaco forests (Quiroga *et al.* 2008, Rodríguez *et al.* 2009). Finally, *Candelaria concolor* is a strong indicator of the patches on isolated patches. It is a micro-foliose species, resistant to high radiation and tolerant to contaminated sites (Estrabou *et al.* 2005, 2011).

While *Physcia undulata* does not appear to display significant values in the Indicator Analysis, the DCA makes a closer relationship with isolated patches. This species is present in good coverage in almost all patches not being associated with any particular feature. This species, together with *Candelaria concolor*, would indicate the highest degree of deterioration as in other studies in the region (Estrabou *et al.* 2005, 2011).

According to Van Haluwyn and Van Herk (2002) the macro-environmental change in the characteristics resulting from the agricultural land use may not affect the species that require light, but it could cause loss of lichens species typical of the Chaco forest. The results indicate that there would be a degradation gradient marked by the impact of the edges on the remaining forests. There is a trend towards more homogeneous communities, formed by species resistant to these boundary conditions and with high coverage. In general the community in patches was composed by foliose species such as *Parmotrema pilosum*, *Physcia undulata*, *Hyperphyscia endochrysea* and *Candelaria concolor*. The community in these areas under agricultural use is similar to the one studied in urban environments with the same dominants: *Physcia undulata* and *Hyperphyscia endochrysea*, which was described as resistant to pollution (Estrabou 1998).

Based on the obtained results we suggest that the main response to forest patches conditions is that the diversity of the lichen community decreases. Secondary there is a replacement of some lichen species belonging to the original forest environments and finally there is an increase in the cover of few species mostly tolerant or resistant to the new conditions.

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