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Floristic associations and filtering ability of riparian vegetation strips

Asociaciones florísticas en franjas de vegetación ribereña y sus capacidades de filtrado

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Abstract. The analysis of lateral flow runoff of superficial nutrients and sediments from an agricultural origin and their retention by infiltration of riparian vegetation strips are of great importance in reducing the agricultural externalities on surface water quality. The aim of this study was to relate soil infiltration to the main biophysical properties of riparian environments in the Pampa Austral of Argentina, defined by the composition of its plant community and the coverage of exotic species. We explored the relationships between hydraulic conductivity (K_s) and aboveground, litter and root biomasses, organic matter concentration, terrain slope, soil bulk density, texture and electrical conductivity. We determined eight floristic associations through the classification of 65 censuses of vegetation. Three of the associations were dominated by native grasses, three by exotic grasses and two presented a layer of exotic willow trees in combination with native and invasive grasses. The mean K_s in soils from the floristic associations with trees and from the associations of native grasses without trees were higher than in soils from the associations of exotic grasses without trees. Significant relationships were found between K_s and the soil properties that are sensitive to the influence of vegetation, suggesting that the relationships between floristic composition and infiltration could be explained partly due to causal relationships.

Keywords: Riparian floristic associations; Riparian vegetation strips; Riparian ecosystems; Ecosystem services; Pampean streams.

Resumen. El análisis de flujo lateral, por escorrentía superficial de nutrientes y sedimentos de origen agropecuario y su retención vía infiltración por las franjas de vegetación ribereña, son de gran importancia para reducir las externalidades en cuerpos de agua superficiales. El objetivo de este estudio fue relacionar la infiltración de los suelos con las principales propiedades biofísicas en los ambientes ribereños de la Pampa Austral, definidos por la composición de su comunidad vegetal y la cobertura de especies exóticas. Se exploraron las relaciones entre la conductividad hidráulica (K_s) con la biomasa aérea, de mantillo y de raíces, la concentración de materia orgánica, la pendiente, la densidad aparente, la textura y la conductividad eléctrica del suelo. Mediante la clasificación de 65 censos de vegetación se reconocieron 8 asociaciones florísticas. De éstas, 3 fueron dominadas por herbáceas nativas, 3 por herbáceas exóticas y 2 presentaron un estrato arbóreo de un sauce exótico en combinación con herbáceas nativas e invasoras. La media de la K_s en los suelos con presencia de asociaciones florísticas con árboles y las herbáceas nativas sin árboles fueron mayores que en los suelos con presencia de herbáceas exóticas sin árboles. Se encontraron relaciones significativas entre K_s y las propiedades del suelo sensibles a la influencia de la vegetación, lo que sugiere que las relaciones entre composición florística e infiltración podrían ser explicadas parcialmente por relaciones causales.

Palabras clave: Asociaciones florísticas ribereñas; Franjas vegetación ribereñas; Ecosistemas ribereños; Servicios ecosistémicos; Arroyos pampeanos.

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INTRODUCTION

Water bodies in agricultural landscapes are variably exposed to non-point pollution from sediments, nutrients, fertilizers and biocides that are transported by surface runoff. Despite the efforts of different agricultural practices to improve the infiltration capacity of soils and to reduce the sediment and pollutant loads in the runoff, the incomplete adoption of such practices and the disproportional pollution from marginal farms, severely restrict their utility at the watershed scale (Birnie et al., 2002). Therefore, environmental management of agricultural watersheds cannot entirely rely on the adoption of agricultural practices, but it also requires riparian environments that can retain (or "filter") most of the leaked sediments and pollutants.

The ability of riparian environments to reduce the incidence of externalities from agriculture on the quality of surface water bodies is widely valued (Dodd et al., 1994; Large & Petts, 1994; Syversen, 2005). The filtering capacity of riparian environments strongly depends on factors such as climate (e.g. recurrence and intensity of storm events), topography (e.g. terrain slope, size of the collector area), soil (e.g. water infiltration capacity), and vegetation (e.g. influences on soil infiltration and hydraulic roughness) (Daniels & Gilliam, 1996; Patty et al., 1997; Tomer et al., 2009). These factors are capable of modifying the filtering capacity by affecting one or more of the basic retention mechanisms, such as infiltration, sedimentation, absorption and adsorption (Dillaha et al., 1989; Barling & Moore, 1994; Mayer et al., 2007; Arora et al., 2010).

The riparian properties that contribute to the runoff-filtering capacity are the reduction in runoff volume and superficial flow velocity (Arora et al., 2003), and the increase of the soils water infiltration capacity (Le Bissonnais et al., 2004; Borin et al., 2005; Deletic & Fletcher, 2006). The vegetation influence in the runoff-filtering capacity of riparian environments has been related to the reduction of the volume and flow velocity. This can be attributed to the resistance of vegetation against water flow (Arora et al., 2003). The presence of vegetation increases rugosity (Van de Kamp et al., 2013), hydraulic resistance, infiltration rate (Le Bissonnais et al., 2004; Borin et al., 2005; Deletic & Fletcher, 2006), and reduces erodability (Camporeale et al., 2013).

The reduction of runoff volumes by infiltration within riparian environments can vary between 40 and 100% (Patty et al., 1997; Borin et al., 2005). In contrast with the well-known influences of riparian vegetation on runoff flow velocity, the effects on water infiltration are less understood. For example, it is not clear to what extent plant life forms and the plant species composition of riparian vegetation can affect the water infiltration rate. However, there is evidence of strong links between soil properties and grassland species composition that may influence water infiltration (Dix & Smeins, 1967; Schimel et al., 1985; Gibson & Hulbert, 1987; Belski, 1988; Perelman et al., 2001; Burkart et al., 2011).

The rate of agricultural intensification and loss of natural ecosystems in different regions of the world are not frequently encompassed by similar rates in the development and adoption of good agricultural practices (De Fries et al., 2004). This is the case of the Argentinean Pampas, where agrochemical inputs increased 2-fold in the last 10 years, while grasslands, cultivated pastures and wetlands and, in consequence, their ecosystem services are being continuously lost (Pampas Group, 2014). In this context, it is important to study the filtering ability of different types of riparian vegetation in order to establish simple management recommendations and policy instrumentation for the prevention or reduction of agricultural impacts on water bodies.

Therefore, the objectives of this study were to characterize the main riparian environments of the Austral Pampas through different biophysical variables and to explore the suitability of the vegetation structure (presence vs. absence of a tree layer) and floristic associations as indicators of the water infiltration capacity of soils.

MATERIALS AND METHODS

Study area and sampling sites. This study was carried out along seven permanent streams -Dulce, Del Junco, El Crespo, Orellano, Del Medio, Seco and Claromecó- running along the Austral Pampas of Argentina (Fig. 1, Appendix 1). The native vegetation of the Pampas consists of temperate grasslands (Cabrera, 1971; León, 1991), which have been replaced mostly by field crops and are currently restricted to fragments remaining in some relict environments and riparian areas. The only native tree species present before the European colonization was the native willow (*Salix humboldtiana Willd.*), which was limited to riparian areas along streams (Hudson, [1918] 1963).

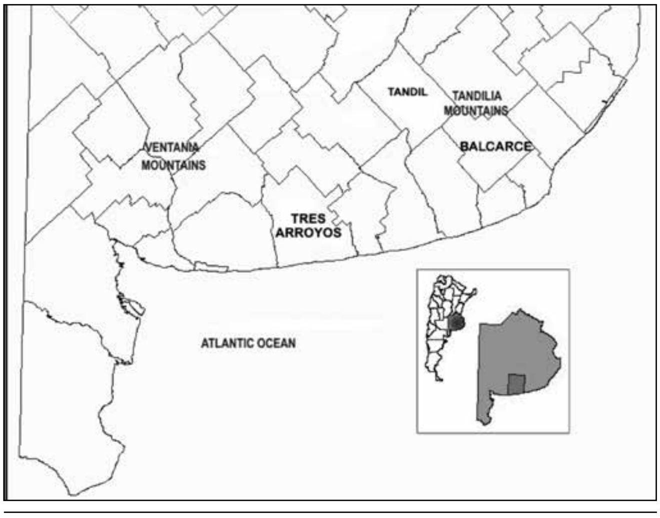

Fig. 1. Location of the study area at regional, provincial and national scales inside the Austral Pampa.

Fig. 1. Ubicación del área de estudio a escala regional, provincial y nacional dentro de la Pampa Austral.

The sampling sites were selected according to their accessibility along the seven selected streams. The samples were taken at a distance of more than 10 m from the watercourses, and avoiding places which presented clear signs of recent disturbances (loss of vegetation cover and soil compaction by intense livestock use or stream channelization).

Floristic census and soil sampling. A total of 65 plots of 1 m^2 were surveyed in the riparian areas of the selected sites between November and January (Spring), at the species bloom stage of developmental morphology, allowing the identification of the grass species following Zuloaga et al. (2008). The plots were placed within homogeneous vegetation sites (stands), following the Zürich-Montpellier School of Phytosociology method (Braun Blanquet, 1979). The presence and abundance (cover) of species per plot (census) were estimated in percentage terms (Knapp, 1984), except for the shrubs and tree species, which were only registered as present or absent. All the aboveground biomass of the grassy layer, including litter, was harvested within each plot to determine dry matter. Samples of root biomass were taken at 0 - 20 cm depth, using a soil core sampler of 3 cm in diameter. Soil cores were sieved using a 20 mm mesh screen. The recovered material, mostly roots and rhizomes, were dried and weighted.

After analysis of the vegetation data, the infiltration capacity of soils was estimated without removing the aboveground biomass of the grassy layer and the biomass litter. The infiltration capacity of soils of each floristic association was characterized by the hydraulic conductivity at saturation (K_s), as estimated by the double ring method (Bouwer, 1986). The inner cylinder had a diameter of 22.86 cm and a height of 23 cm. The outer cylinder had a diameter of 35.46 cm and a height of 40 cm; its function was to prevent the lateral expansion of the infiltrated water and to maintain a unidirectional water flow from the inner cylinder. Water was poured into the inner cylinder, which had a graduated stick in a vertical position, until the height of the water sheet reached 12 cm. The infiltration capacity and its variation over time were estimated by measuring the time that it took for the water in the inner cylinder to infiltrate. The water infiltration was measured until a constant infiltration rate (K_s) was obtained. Several authors (Green & Ampt, 1911; Cabria, 1996) assume that the final infiltration at 120 minutes does not significantly differ from the K_s; therefore, readings were not performed at less than this time period. The K_s determinations were performed with four replicates per floristic associations to reduce variability.

We estimated the terrain slope for each sampling plot (McIntosh & Laffan, 2005), outlined by a perpendicular line from the stream water edge to the border of the adjacent plot. Therefore, the terrain slope was characteristic of each floristic association in particular.

Soil samples were analysed for soil texture (Soil Conservation Service, 1972), bulk density (Blake & Hartge, 1986), organic matter (Walkley & Black, 1934), and electrical conductivity (Warrick & Nielsen, 1981) in the Laboratory of Soils of the EEA INTA Balcarce.

Data analysis. Census data were organized into a 55 species x 65 census, and species showing less than 5% frequency were not considered (Gauch, 1982). Eight floristic associations were identified by combining the phytosociological method and cluster analysis using Euclidean distances and Ward's liking method (Ward, 1963).

The denomination of each floristic association followed the frequently used binomial system, which is expressed as the dominant species separated by a bar from the species that follows in abundance (e.g., *Salix fragilis / Festuca arundinacea*). In the cases with one vegetation stratum or with a high dominance of one species, the secondary species was omitted (e.g., *Paspalum quadrifarium*).

The floristic associations were divided into three groups composed by (i) native and/or exotic grasses with trees, (ii) native grasses and (iii) exotic grasses. In order to compare the effects of the presence of trees in the infiltration capacity, the floristic associations were also classified into two large groups according either to the presence or absence of trees.

Biophysical and chemical variables were compared among floristic associations using analysis of variance (ANOVA) for a completely randomized design and a balanced sample size (N=4). Multiple comparisons (Tukey test) were performed for those variables that were significantly different. Since the K_s values were not normally distributed, they were log transformed before the ANOVA and Tukey test (Nielsen et al., 1973).

The variation in K_s, as related to the different biological, physical, chemical and topographical attributes of the plots, was studied by a stepwise Multiple Linear Regression analysis for all the studied sites, and for separate data sets (with and without trees). Since the variables had different units, we estimated the Cramer contingency coefficients in order to compare their explanatory values. All statistical analyses were performed using InfoStat Professional (Di Rienzo et al., 2011).

RESULTS AND DISCUSSION

While 27% of the surveyed vegetation consisted of a grassy layer, the rest of the stands were composed by mixed grassy and woody layers. The grassy layers were composed by different combinations of 47 species, from which only 13 were native species (Villamil, 2008; Ispizúa, 2008; Zuloaga et al., 2008). The woody layer was mainly dominated by the naturalized willow, *Salix fragilis*, with presence of the unique native woody species *Salix humboldtiana* (Villamil, 2008; Ispizúa, 2008) and the shrubs *Cytisus scoparius*, *Cestrum parqui*, *Colletia paradoxa* and *Baccharis salicifolia* (Appendix 2).

We identified eight floristic associations (Appendix 3); three of them were dominated by the native grasses *Paspalum* *quadrifarium* (PAQU association), *Bromus auleticus* and *Juncus balticus* (BRAU/JUBA), or the sedge *Carex rupicola* (CARU association). Three other floristic associations were mostly covered by monospecific stands of the exotic *Festuca arundinacea* (FEAR association) or in combination with two other exotic grasses, such as *Phalaris arundinacea* (FEAR/PHAAR association) and *Thinopyrum ponticum* (THIPO/FEAR association). The remaining two floristic associations were mostly covered by one exotic willow species (*Salix fragilis*) in combination with an exotic grass, *Cynodon dactylon* (SAFRA/CYDA association) or *Festuca arundinacea* (SAFRA/FEAR association).

The results of the K_s for each floristic association are shown in Table 1. The highest K_s value was found in SAFRA/FEAR association, while the lowest was for THIPO/FEAR. The infiltration capacity was related to the terrain slope, aboveground biomass of grassy layer, litter biomass, root biomass, organic matter, bulk density and sand (Fig. 2, Table 1).

When the floristic associations were divided into three groups, the highest K_s values were registered in the groups with trees and in the native grasses without trees. On the other hand, the lowest values of K_s were found in exotic grasses without trees association. The main variables associated to K_s were terrain slope, bulk density, sand, electrical conductivity, organic matter, aboveground biomass of grassy layer, and litter biomass (Fig. 3, Table 2). Giaccio et al. (2016) reported that the runoff reduction in plots with trees was of 63% and 31% in plots without trees. These values were related to the soil properties that are mainly influenced by the vegetation, such as root biomass, litter biomass, organic matter and bulk density. Carroll et al. (2004) found that the infiltration rate was 60 times higher in areas forested with young trees compared to adjacent grasslands. However, in another study (Gumiere et al., 2011), the authors report that the herbaceous vegetation increases the infiltration capacity of soils.

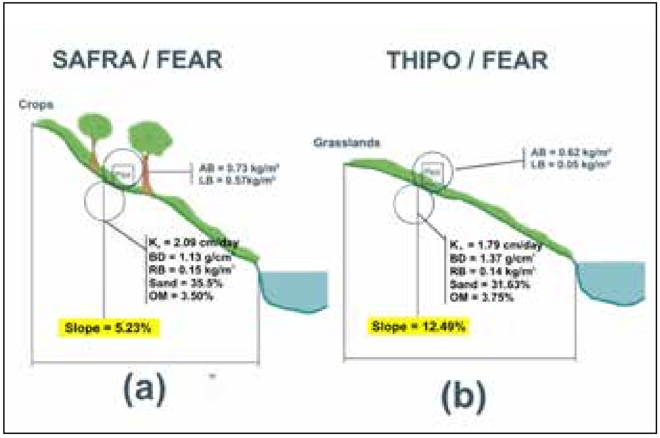

Fig. 2. Representative plot profiles of the measured hydraulic conductivity (K_s) in the floristic associations (a) SAFRA / FEAR: Salix fragilis / Festuca arundinacea and (b) THIPO / FEAR: *Thinopyrum ponticum* / *Festuca arundinacea*. AB: aboveground biomass, LB: litter biomass, BD: bulk density, RB: root biomass, OM: organic matter content of soils.

Fig. 2. Perfiles representativos en las parcelas en relación a la conductividad hidráulica (K_s) en las asociaciones florísticas (a) SAFRA/FEAR: Salix fragilis / Festuca arundinacea y (b) THIPO/FEAR: *Thinopyrum ponticum* / *Festuca arundinacea*. AB: biomasa aérea, LB: biomasa de mantillo, BD: densidad aparente, RB: biomasa de las raíces, OM: concentración de materia orgánica de los suelos.

When the floristic associations were grouped according to the presence or absence of trees, the higher values of K_s corresponded to areas with trees (Table 3). This was related to the terrain slope, root biomass and sand (Fig. 4, Table 3).

The K_s variation of the full data set combining plots with and without trees was better explained by a multiple regression model (Table 4). The values of Cramer's coefficient indicated that the variables were independent (Balzarini et al., 2008) (Table 4). The terrain slop decreases the water flow rate, thereby increasing infiltration (Naiman & Decamps, 1997). Bulk density affects negatively the K_s, since at lower bulk density there is a higher soil porosity that in turn, increases infiltration (Sobieraj et al., 2004). On the other hand, Sands et al. (1979) reported that organic matter has a positive effect on K_s since it preserves soil structure. According to Arora et al. (2003), the aboveground and litter biomass reduces runoff flow by retaining water and therefore, increasing the infiltration rate (Le Bissonnais et al., 2004; Borin et al., 2005; Deletic & Fletcher, 2006).

The most important variables explaining the variability in K_s were restricted to those that are known as most sensitive to the influence of vegetation (i.e. root biomass and aboveground biomass) (Dao, 1993; Azooz & Arshad, 1996; Denoia, 1996; Rose et al., 2003). This suggests that the relationship between the floristic composition and infiltration is explained partly because of causal relations. Dense and spatially homogeneous root systems have a long-term effect on soil structure, increasing its permeability (Rose et al., 2003).

These results represent one of the few studies that show the variations in the water infiltration capacity of soils from different floristic associations, and the relationship with soil physical properties, biological properties of the floristic associations and the presence or absence of woody vegetation. Floristic associations can be used as indicators of the ecosystem function runoff reduction and it provides valuable information in order to preserve or restore the vegetation adapted to these types of environments. Also, riparian vegetation has acquired high relevance as a filter mechanism of sediments, nutrients and biocides coming from crop fields towards superficial water bodies.

CONCLUSIONS

The floristic variability of the riparian vegetation typical of streams from the Austral Pampas allowed us to distinguish eight floristic associations that were mostly composed by invasive spe-

Table 1. Mean values and multiple comparisons of biophysical and chemical variables among riparian floristic associations. Standard error values are shown between brackets. In each row, values followed by different letters within each column indicate significant differences between environments ($P \leq 0.05$).

Tabla 1. Valores medios y comparaciones múltiples de variables biofísicas y químicas en asociaciones florísticas ribereñas. Los valores de error estándar se muestran entre paréntesis. Los valores seguidos por letras diferentes en cada columna indican diferencias significativas entre ambientes ($P \leq 0{,}05$).

Floristic associations	Log K_s (cm/day)	Terrain slope (%)	Aboveground biomass of grassy layer (kg/m^2)	Litter biomass (kg/m^2)	Root biomass (kg/m^3)	Organic matter (%)	Bulk density (g/cm^3)	Sand (%)
THIPO / FEAR	1.79 (0.01) (a)	12.49 (1.8) (abc)	0.62 (0.2) (a)	0.05 (0.2) (a)	0.14 (0.04) (ab)	3.75 (1.3) (a)	1.37 (0.05) (b)	31.63 (3.27) (a)
FEAR	1.84 (0.01) (ab)	14.5 (1.8) (bc)	0.63 (0.2) (a)	0.19 (0.2) (a)	0.14 (0.04) (ab)	4.00 (1.3) (a)	1.23 (0.05) (ab)	38.83 (3.27) (bc)
FEAR / PHAAR	1.86 (0.01) (bc)	14.9 (1.8) (c)	0.50 (0.2) (a)	0.13 (0.2) (a)	0.13 (0.04) (ab)	3.88 (1.3) (a)	1.37 (0.05) (b)	38.80 (3.27) (bc)
SAFRA / CYDA	1.88 (0.01) (bcd)	6.6 (1.8) (ab)	0.37 (0.2) (a)	0.07 (0.2) (a)	0.26 (0.04) (b)	5.60 (1.3) (a)	1.27 (0.05) (ab)	33.00 (3.27) (b)
BRAU / JUBA	1.92 (0.01) (cde)	7.52 (1.8) (abc)	0.61 (0.2) (a)	0.29 (0.2) (a)	0.15 (0.04) (ab)	14.10 (1.3) (b)	1.17 (0.05) (ab)	48.93 (3.27) (c)
PAQU	1.93 (0.01) (de)	8.99 (1.8) (abc)	1.85 (0.2) (b)	1.46 (0.2) (b)	0.05 (0.04) (a)	6.80 (1.3) (a)	1.16 (0.05) (ab)	50.1 (3.27) (c)
CARU	1.96 (0.01) (e)	6.90 (1.8) (abc)	1.27 (0.2) (ab)	1.10 (0.2) (ab)	0.17 (0.04) (ab)	8.30 (1.3) (ab)	1.18 (0.05) (ab)	47.93 (3.27) (bc)
SAFRA / FEAR	2.09 (0.01) (f)	5.23 (1.8) (a)	0.73 (0.2) (a)	0.57 (0.2) (ab)	0.15 (0.04) (ab)	3.50 (1.3) (a)	1.13 (0.05) (a)	35.5 (3.27) (bc)

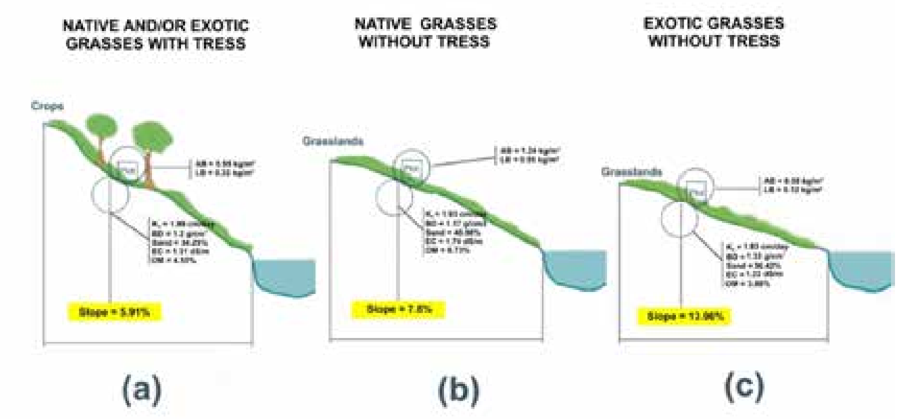

Fig. 3. Representative plot profiles of the measured hydraulic conductivity (K_s) in floristic associations composed of (a) native and/or exotic grasses with trees, (b) natives grasses without trees and (c) exotic grasses without trees. AB: aboveground biomass, LB: litter biomass, BD: bulk density, RB: root biomass, OM: organic matter content of soils.

Fig. 3. Perfiles representativos en las parcelas en relación a la conductividad hidráulica (K_s) en las asociaciones florísticas (a) herbáceas nativas y/o exóticas con árboles, (b) herbáceas nativas sin árboles y (c) herbáceas exóticas sin árboles. AB: biomasa aérea, LB: biomasa de mantillo, BD: densidad aparente, EC: conductividad eléctrica, OM: concentración de materia orgánica de los suelos.

Table 2. Mean values and multiple comparisons of biophysical and chemical variables among grouped floristic associations[1]. Standard error values are shown in parenthesis. Values followed by different letters within each column indicate significant differences between environments ($P \leq 0.05$).

Tabla 2. Valores medios y comparaciones múltiples de variables biofísicas y químicas en asociaciones florísticas agrupadas[1]. Los valores de error estándar se muestran entre paréntesis. Los valores seguidos por letras diferentes dentro de cada columna indican diferencias significativas entre ambientes ($P \leq 0,05$).

	Log K_s (cm/day)	Terrain slope (%)	Bulk density (g/cm^3)	Sand (%)	Electrical conductivity (dS/m)	Organic matter (%)	Aboveground biomass of grassy layer (kg/m^2)	Litter biomass (kg/m^2)
Native and/or exotic grasses with trees	1.99 (0.02) (b)	5.91 (1.2) (a)	1.2 (0.04) (a)	34.25 (2.26) (a)	1.31 (0.2) (ab)	4.55 (1.12) (a)	0.55 (0.18) (a)	0.32 (0.19) (a)
Natives grasses without trees	1.93 (0.02) (b)	7.8 (1) (a)	1.17 (0.03) (a)	48.98 (1.85) (b)	1.74 (0.1) (b)	9.73 (0.91) (b)	1.24 (0.14) (b)	0.95 (0.15) (b)
Exotics grasses without trees	1.83 (0.02) (a)	13.96 (1) (b)	1.32 (0.03) (b)	36.42 (1.85) (a)	1.22 (0.1) (a)	3.88 (0.91) (a)	0.58 (0.14) (a)	0.12 (0.15) (a)

[1] Native and/or exotic grasses with trees are composed by SAFRA/FEAR and SAFRA/CYDA floristic associations; Natives grasses without trees are composed by BRAU/JUBA, PAQU and CARU floristic associations; Exotic grasses without trees are composed by THIPO/FEAR, FEAR and FEAR/PHAAR floristic associations.

[1] Las herbáceas nativas y/o exóticas con árboles, están compuestas por las asociaciones florísticas SAFRA/FEAR y SAFRA/CYDA; las herbáceas nativas sin árboles están compuestas por las asociaciones florísticas BRAU/JUBA, PAQU y CARU; las herbáceas exóticas sin árboles, están compuestas por las asociaciones florísticas THIPO/FEAR, FEAR y FEAR/PHAAR.

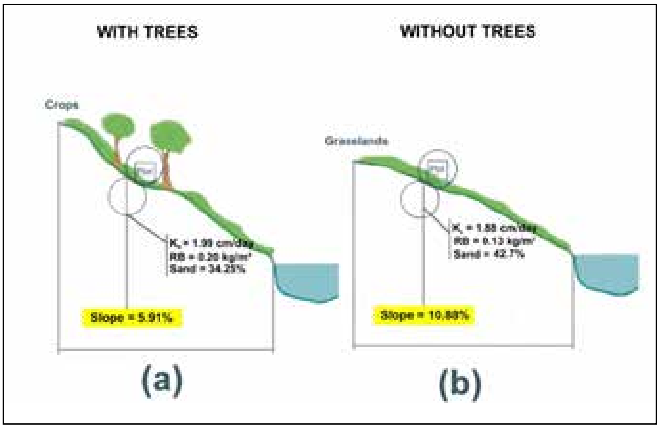

Fig. 4. Representative plot profiles of the measured hydraulic conductivity (K_s) in the floristic associations (a) with trees and (b) without trees. RB: root biomass.

Fig. 4. Perfiles representativos en las parcelas en relación a la conductividad hidráulica (K_s) en las asociaciones florísticas (a) con árboles y (b) sin árboles. RB: biomasa de las raíces.

Table 3. Mean values and multiple comparisons of biophysical and chemical variables among grouped floristic associations[1]. Standard error values are shown in parenthesis. Values followed by different letters within each column indicate significant differences between environments ($P \leq 0.05$).

Tabla 3. Valores medios y comparaciones múltiples de variables biofísicas y químicas en asociaciones florísticas agrupadas[1]. Los valores de error estándar se muestran entre paréntesis. Los valores seguidos por letras diferentes dentro de cada columna indican diferencias significativas entre ambientes ($P \leq 0,05$).

Type of vegetation	Log K_s (cm/day)	Terrain slope (%)	Root biomass (kg/m^3)	Sand (%)
With trees	1.99 (0.03) (b)	5.91 (1.5) (a)	0.20 (0.03) (b)	34.25 (2.98) (a)
Without trees	1.88 (0.02) (a)	10.88 (0.9) (b)	0.13 (0.02) (a)	42.70 (1.72) (b)

[1] With trees is composed by SAFRA/FEAR and SAFRA/CYDA floristic associations; without trees is composed by BRAU/JUBA, PAQU, CARU, THIPO/FEAR, FEAR and FEAR/PHAAR floristic associations.

[1] Con árboles está compuesta por las asociaciones florísticas SAFRA/FEAR y SAFRA/CYDA; sin árboles está compuesta por las asociaciones florísticas BRAU/JUBA, PAQU, CARU, THIPO/FEAR, FEAR y FEAR/PHAAR.

cies. These floristic associations showed significant differences in the physical properties of the soils (bulk density, sand, organic matter), and in vegetation sensitive properties such as, aboveground, litter and root biomasses. In particular, the average K_s had a wide range of variation between floristic associations.

The species composition of riparian communities may be considered as a possible indicator of infiltration and pollutant retention capacity of soils, whose usefulness should be validated

Table 4. Multiple Regression Models between hydraulic conductivity at saturation (K_s) and bulk density (BD), terrain slope (TS), root biomass (RB), aboveground biomass of grassy layer (AB), and sand concentration of soils (S).
Tabla 4. Modelos de regresión múltiple entre la conductividad hidráulica a saturación (K_s) y la densidad aparente (BD), la pendiente del terreno (TS), la biomasa de las raíces (RB), la biomasa aérea del estrato herbáceo (AB) y la concentración de arena de los suelos.

	With and without trees	**Without trees**
Equation	$K_s = 156 – 45.76$ BD – 1.74 TS	$K_s = 23.16 + 44.3$ RB + 7.61 AB + 0.97 S
n	32	24
P	<0.001	<0.001
R^2	0.38	0.77
Cramer's coefficient	0.17	0.20

through statistically independent evaluations. The necessity for this validation is particularly important for communities characterized by the presence of the main tree species *Salix fragilis* and an herbaceous stratum dominated by Fescue (*Festuca arundinacea*), in which the highest levels of K_s were observed.

The floristic associations composed by trees and the ones composed by native grasses without trees had the highest values of K_s, whereas the ones composed by exotic grasses without trees had the lowest K_s. All of them had significant differences in the soil physical properties (bulk density, sand, organic matter, terrain slope), and in vegetation related properties (aboveground and litter biomasses). The sites composed mainly by exotic grasses had lower values of $K_{s.}$ This may increase the potential of migration of contaminants into water bodies. Finally, in the wider group, the highest values of K_s were obtained in the floristic associations with trees and the lowest values in those without trees, related to the terrain slope, and to the sand and root biomass.

The influence of the soil biophysical variables sensitive to vegetation on the variability of K_s, suggests that the relations found between floristic composition and K_s could be explained partly, through causal relationships. Future experimental studies will allow us to explore the possibility of managing soil's infiltration capacity through the floristic composition. Even though sediments and adsorbed pollutants may be trapped into riparian environments by a reduction of the surficial flow and particle sedimentation, the water infiltration capacity of soils is a key filtering mechanism of dissolved pollutants.

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Appendix 1. Location of sampling sites.
Apéndice 1. Ubicación de los sitios de muestreo.

Site	**Stream**	**Latitude**	**Longitude**
1	Del Junco	S 37° 50' 29.3''	W 58° 08' 43.7''
2	Del Junco	S 37° 49' 57.1''	W 58° 07' 00.2''
3	Del Junco	S 37° 49' 59.7''	W 58° 07' 05.1''
4	Del Junco	S 37° 49' 59.4''	W 58° 07' 04.8''
5	Del Junco	S 37° 49' 13.7''	W 58° 05' 38.9''
6	Del Junco	S 37° 50' 03.3''	W 58° 07' 19.8''
7	Del Junco	S 37° 50' 00.0''	W 58° 07' 21.0''
8	Dulce	S 37° 52' 22.4''	W 58° 03' 20.0''
9	Dulce	S 37° 52´ 22.6´´	W 58° 03´ 21.8´´
10	Dulce	S 37° 53' 16.5''	W 58° 06' 32.7''
11	Dulce	S 37° 53' 16.0''	W 58° 06' 33.1''
12	Dulce	S 37° 53' 14.7''	W 58° 06' 32.3''
13	Dulce	S 37° 53' 14.5''	W 58° 06' 31.9''
14	Del Junco	S 37° 50' 02.9''	W 58° 07' 14.2''
15	Del Junco	S 37° 50' 46.7''	W 58° 06' 26.2''
16	Del Junco	S 37° 50' 43.4''	W 58° 06' 32.5''
17	Del Junco	S 37° 50' 43.2''	W 58° 06' 40.9''
18	Del Junco	S 37° 49' 51.3''	W 58° 06' 43.1''

Site	Stream	Latitude	Longitude
19	Dulce	S 37° 51' 43.5"	W 58° 02' 02.3"
20	Dulce	S 37° 49' 47.9"	W 58° 00' 26.3"
21	Dulce	S 37° 49' 44.9"	W 58° 00' 19.3"
22	Dulce	S 37° 49' 42.8"	W 58° 00' 16.9"
23	Dulce	S 37° 51' 43.0"	W 58° 01' 56.7"
24	El Crespo	S 37° 41' 07.7"	W 58° 20' 38.4"
25	El Crespo	S 37° 41' 07.9"	W 58° 20' 38.4"
26	El Crespo	S 37° 41' 09.5"	W 58° 20' 38.5"
27	El Crespo	S 37° 41' 11.6"	W 58° 20' 39.5"
28	El Crespo	S 37° 44' 16.9"	W 58° 21' 03.2"
29	El Crespo	S 37° 44' 20.6"	W 58° 21' 04.2"
30	El Crespo	S 37° 45' 51.9"	W 58° 22' 02.2"
31	El Crespo	S 37° 45' 51.4"	W 58° 22' 02.4"
32	El Crespo	S 37° 45' 49.0"	W 58° 22' 01.2"
33	El Crespo	S 37° 45' 48.3"	W 58° 22' 00.0"
34	Del Medio	S 38° 05' 16.1"	W 60° 17' 30.2"
35	Del Medio	S 38° 05' 18.3"	W 60° 17' 30.2"
36	Del Medio	S 38° 10' 58.3"	W 60° 18' 07.6"
37	Del Medio	S 38° 10' 56.5"	W 60° 18' 06.2"
38	Del Medio	S 38° 20' 27.2"	W 60° 15' 48.0"
39	Del Medio	S 38° 20' 26.7"	W 60° 15' 48.3"
40	Orellano	S 38° 18' 08.1"	W 60° 13' 02.3"
41	Orellano	S 38° 18' 10.6"	W 60° 13' 05.4"
42	Orellano	S 38° 21' 31.1"	W 60° 14' 31.2"
43	Orellano	S 38° 23' 03.2"	W 60° 14' 50.5"
44	Seco	S 38° 13' 45.2"	W 60° 21' 02.8"
45	Seco	S 38° 13' 43.9"	W 60° 21' 04.8"
46	Seco	S 38° 13' 49.2"	W 60° 21' 00.8"
47	Seco	S 38° 13' 47.7"	W 60° 21' 01.9"
48	Claromecó	S 38° 50' 41.0"	W 60° 05' 11.5"
49	Claromecó	S 38° 50' 42.3"	W 60° 05' 11.8"
50	Claromecó	S 38° 50' 27.7"	W 60° 05' 19.7"
51	Claromecó	S 38° 50' 25.3"	W 60° 05' 20.4"
52	Claromecó	S 38° 49' 32.0"	W 60° 05' 51.2"
53	Claromecó	S 38° 49' 31.9"	W 60° 05' 51.2"
54	Claromecó	S 38° 42' 08.4"	W 60° 10' 07.3"
55	Claromecó	S 38° 42' 08.1"	W 60° 10' 06.7"
56	Seco	S 38° 21' 05.0"	W 60° 18' 33.4"
57	Dulce	S 37° 53´ 00.9´´	W 58° 00´ 25.8´´
58	Dulce	S 37° 51´ 43.5´´	W 58° 01´ 57.8´´
59	Dulce	S 37° 51´ 44.7´´	W 58° 01´ 57.8´´
60	Seco	S 38° 38' 30.0"	W 60° 30' 00.5"
61	Orellano	S 38° 39' 76.4"	W 60° 24' 89.9"
62	Orellano	S 38° 39' 83.2"	W 60° 24' 92.0"
63	Claromecó	S 38° 42' 05.6"	W 60° 26' 52.2"
64	Claromecó	S 38° 49' 34.9"	W 60° 05' 47.6"
65	Seco	S 38° 03' 03.5"	W 60° 24' 50.5"

Appendix 2. Composition of riparian species.
Apéndice 2. Composición de especies ribereñas.

Species	Vegetation	Origin	Family	Cycle
Amaranthus albus	Grassy	Exotic	Amaranthaceae	Annual
Amelichloa ambigua	Grassy	Exotic	Poaceae	Perennial
Ammi majus	Grassy	Exotic	Apiaceae	Annual
Baccharis salicifolia	Shruby	Native	Asteraceae	
Bromus auleticus	Grassy	Native	Poaceae	Perennial
Carduus acanthoides	Grassy	Exotic	Asteraceae	Annual
Carex rupicola	Grassy	Exotic	Cyperaceae	Perennial
Centaurea calcitrapa	Grassy	Exotic	Asteraceae	Annual
Cestrum parqui	Shruby	Native	Solanaceae	
Chenopodium album	Grassy	Exotic	Chenopodiaceae	Annual
Colletia paradoxa	Shruby	Native	Rhamnaceae	
Conium maculatum	Grassy	Exotic	Apiaceae	Annual
Cortaderia selloana	Grassy	Native	Poaceae	Perennial
Crepis capillaris	Grassy	Exotic	Asteraceae	Annual
Cynodon dactylon	Grassy	Exotic	Poaceae	Perennial

Cytisus scoparius	Shruby	Exotic	Fabaceae	
Dactylis glomerata	Grassy	Exotic	Poaceae	Perennial
Dipsacus sativus	Grassy	Exotic	Dipsacaceae	Bi-annual
Echinodorus grandiflorus	Grassy	Native	Alismataceae	Perennial
Eleocharis nudipes	Grassy	Native	Cyperaceae	Perennial
Festuca arundinacea	Grassy	Exotic	Poaceae	Perennial
Foeniculum vulgare	Grassy	Exotic	Apiaceae	Perennial
Holcus lanatus	Grassy	Exotic	Poaceae	Annual
Hordeum stenostachys	Grassy	Native	Poaceae	Perennial
Hydrocotyle bonariensis	Grassy	Exotic	Apiaceae	Perennial
Jarava plumosa	Grassy	Native	Poaceae	Perennial
Juncus balticus	Grassy	Native	Juncaceae	Perennial
Lolium multiflorum	Grassy	Exotic	Poaceae	Annual
Lotus glaber	Grassy	Exotic	Fabaceae	Perennial
Marrubium vulgare	Grassy	Exotic	Lamiaceae	Perennial
Matricaria matricarioides	Grassy	Exotic	Asteraceae	Annual
Medicago arabica	Grassy	Exotic	Fabaceae	Annual
Medicago sativa	Grassy	Exotic	Fabaceae	Perennial
Melilotus officinalis	Grassy	Exotic	Fabaceae	Annual
Mentha spicata	Grassy	Exotic	Lamiaceae	Perennial
Nassella melanosperma	Grassy	Native	Poaceae	Perennial
Paspalum quadrifarium	Grassy	Native	Poaceae	Perennial
Phalaris arundinacea	Grassy	Exotic	Poaceae	Perennial
Phragmites australis	Grassy	Native	Poaceae	Perennial
Plantago lanceolata	Grassy	Exotic	Plantaginaceae	Perennial
Polycarpon tetraphyllum	Grassy	Exotic	Caryophyllaceae	Annual
Populus alba	Woody	Exotic	Salicácea	
Ranunculus trichophyllus	Grassy	Native	Ranunculaceae	Annual
Rapistrum rugosum	Grassy	Exotic	Brassicaceae	Annual
Rumex pulcher	Grassy	Exotic	Polygonaceae	Perennial
Salix fragilis	Woody	Exotic	Salicácea	
Salix humboldtiana	Woody	Native	Salicácea	
Salpichroa origanifolia	Grassy	Native	Solanaceae	Perennial
Senecio bonariensis	Grassy	Native	Asteraceae	Perennial
Tamarix ramosissima	Woody	Exotic	Tamaricaceae	
Taraxacum officinale	Grassy	Exotic	Asteraceae	Perennial
Thinopyrum ponticum	Grassy	Exotic	Poaceae	Perennial
Trifolium repens	Grassy	Exotic	Fabaceae	Perennial
Triglochin striata	Grassy	Exotic	Juncaginaceae	Perennial
Typha latifolia	Grassy	Exotic	Typhaceae	Perennial

Appendix 3. Composition of floristic associations. Values of coverage area presented for grassy vegetation, while for shrub and woody vegetation we only state its presence (P).
Apéndice 3. Composición de las asociaciones florísticas. Valores de área de cobertura para vegetación herbácea, mientras que para arbustos y vegetación leñosa sólo se establece su presencia (P).

Species	SAFRA/ FEAR	FEAR	THIPO/ FEAR	FEAR/ PHAAR	SAFRA/ CYDA	CARU	BRAU/ JUBA	PAQU
Salix fragilis	P	0	0	0	P	0	0	0
Festuca arundinacea	80.0	74.0	37.0	32.0	4.0	2.0	2.0	0
Conium maculatum	5.0	0	0	1.0	0	0	5.0	0
Dactylis glomerata	4.0	1.0	0	0	0	0	0	0
Hydrocotile bonariensis	2.5	1.5	0	0	0	4.0	4.0	0
Lotus glaber	2.5	2.5	0	3.0	0	6.0	0	0
*Eleocchari*s *nudipes*	2.5	0	0	0	0	0	0	0
Bromus auleticus	2.5	0	0	0	0	4.0	45.0	0
Lolium multiflorum	1.0	0.5	0	0	0	0	0	0
Thinopyrum ponticum	0	4.0	43.0	0	0	0	0	2.0
Dipsacus sativus	0	3.0	0	7.0	0	0	2.0	0
Phalaris arundinacea	0	3.0	0	32.0	0	0	0	0
Senecio bonariensis	0	2.0	0	3.0	0	4.0	0	0
Rumex pulcher	0	2.0	3.5	7.0	0	0	0	0
Typha latifolia	0	2.0	0	0	0	0	0	0
Chenopodium album	0	1.5	0	1.0	0	0	0	0
Cestrum parqui	0	P	0	0	0	0	P	0
Plantago lanceolata	0	1.0	0	1.0	0	0	0	0
Melilotus officinalis	0	1.0	0	0	0	0	0	0
Juncus balticus	0	0	7.0	0	0	4.0	19.0	0
Ranunculus trichophyllus	0	0	3.5	3.0	0	0	0	0
Polycarpon tetraphyllum	0	0	3.0	0	0	0	0	0
Phragmites australis	0	0	3.0	0	0	0	0	0
Marrubium vulgare	0	0	0	3.0	0	0	0	0
Triglochin striata	0	0	0	7.0	0	0	0	0
Cynodon dactylon	0	0	0	0	94.0	0	0	0
Cytisus scoparius	0	0	0	0	P	0	0	0
Foeniculum vulgare	0	0	0	0	2.0	0	0	0
Carex rupicola	0	0	0	0	0	72.0	0	0
Medicago arabica	0	0	0	0	0	4.0	2.0	0
Taraxacum officinale	0	0	0	0	0	2.0	2.0	0
Matricaria matricarioides	0	0	0	0	0	0	12.0	0
Amaranthus albus	0	0	0	0	0	0	2.0	0
Paspalum quadrifarium	0	0	0	0	0	0	0	97.0
Colletia paradoxa	0	0	0	0	0	0	0	P
Baccharis salicifolia	0	0	0	0	0	0	0	P
Salpichroa origanifolia	0	0	0	0	0	0	0	1.0

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