Riparian forests and cattle management problems in Andean subtropical streams: in the search of water quality sustainability

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➤ **Resumen** — Quiroga, P. A.; H. R. Fernández; M. D. Sirombra; E. Domínguez. 2011. "Los bosques ribereños y los problemas del manejo de ganado en los ríos andinos subtropicales: en busca de una calidad de agua sustentable". *Lilloa* 48 (1). Las montañas del sur de la cordillera de los Andes alberga la cabecera de tres grandes cuencas sudamericanas (Plata, Salí-Dulce y parte de Amazonas). Estas son afectadas por diferentes actividades humanas, muchas de las cuales son demasiado complejas para ser abordadas desde una sola perspectiva. Se sugiere que las actividades de ganadería domésticas causan una serie de impactos directos e indirectos. El paisaje ribereño en los subtrópicos andinos es afectado por el tipo de manejo del ganado empleado. Aquí presentamos los cambios observados en un río y sus alrededores, de una cuenca estudiada durante diez años. Se proponen incluir al QBR-MR (una modificación del Índice de Calidad de ríos de Europa), el impacto del ganado sobre vegetación ribereña de montaña. Se realizo un estudio detallado de la vegetación ribereña (el porcentaje de especies exóticas/nativas y la evaluación visual de diferentes impactos provocado por el ganado) y se aplico un índice biológico de calidad del agua en cada una de las estaciones. La información esta resumida en un mapa, de fácil interpretación para los diferentes actores políticos. La combinación de índices de calidad de áreas ribereñas y de agua es un instrumento promisorio para identificar problemas en cuencas subtropicales.

Palabras clave: Índices ribereños de calidad, especies introducidas, uso del Suelo, valles Intermontanos, América del Sur.

➤ **Abstract** — Quiroga, P. A.; H. R. Fernández; M. D. Sirombra; E. Domínguez. 2011. "Riparian forests and cattle management problems in Andean subtropical streams: in the search of water quality sustainability". *Lilloa* 48 (1). Subtropical Andes harbor the headwaters of three huge South American basins (Plata, Salí-Dulce and part of the Amazon). They are affected by numerous different human activities, many of them too complex to approach from punctual perspectives. It has been suggested that domestic cattle activities result in a set of direct and indirect impacts. Riverine landscapes in Andean subtropics are affected by the type of cattle management used. Here we present the observed changes in a river and its surrounding area, from a basin studied for ten years. We concluded that cows can be considered as landscape engineers of the riparian zone. The QBR-MR (a modification of the European River Quality Index) is proposed, to include the cattle impact on Mountain Riparian forests. A detailed station by station description of the Riparian forest (percentage of exotic/native species and visual evaluation of different cattle impacts) and biological index based water quality are presented. The information is summarized in a map, easily accessible by policy designers. Combined quality indices for water and riparian areas are promissory tools to identify problems and biomonitoring in subtropical basins.

Keywords: Riverine quality indices, Introduced species, Land uses, Intermountain valleys, South America.

INTRODUCTION

Important headwaters in South America are located in the subtropical Eastern Andes, either forming major rivers such as the Amazon or the Plata, or creating endorheic drainages, such as the Salí-Dulce basin, wherein the Lules river and San Javier stream are found (Fig. 1). Conservation of upper reaches of those rivers for involved countries should be the most important goal considering them as water sources. In relation with this, a good

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condition of the headwater basin vegetation is fundamental for water sources conservation, at least in the riparian zone (Karaus, 2004; Naiman *et al.,* 2005).

In spite of advancement in our understanding of human impacts on Neotropical stream ecosystems, we consider that the huge and heterogeneous South America continent still has a lot of particular problems to solve. Also, besides the environmental complexity, we agree about the importance to integrate the sociology among water issues (Falkenmark and Folke, 2000). Social aspects of Andean areas must be especially considered in a realistic approach to any sustainable goal. That is a very concerning issue for the «water producer» zone of the Northwestern Argentina (NWA) mountain area, which supplies approximately 90% of the population and agriculture. This status pushed the NWA region in a delicate situation about environmental aspects because they are particularly complex and diffuse in this region. Social units must be considered if we are looking for a holistic approach towards solutions in these basins (Fernández and Molineri, 2006).

It was proposed the forest transition concept in Latin America which should have a direct impact on conservation policies (Aide and Grau, 2004; Grau and Aide, 2007). Also, it has been suggested that in NWA there exist processes of forest restoration and/or lower deforestation rates (Grau *et al.*, 2007). Despite this, it is yet possible to observe in some NWA basins important modifications due to land uses and different types of livestock management.

Introduced herbivores were documented in temperate forests of South America as capable to strongly affect understory community structure and composition through a variety of mechanisms, involving both direct effects such as browsing and trampling and several kinds of indirect effects (De Pietri, 1992; Vázquez, 2002).

Since 17^{th} century the cattle presence was observable in many NWA mountain areas, and Saravia-Toledo (1996) pointed out the impact on riparian vegetation.

Recently in NWA, the collaboration between limnologists and terrestrial ecologists allowed the detection of real environmental modifications around streams and rivers produced by cattle management: erosion, soil compacting, overgraze, etc.

In this paper we describe the situation in a small intermontane valley with several environmental particularities, including population increase.

The particular type of cattle management used on Andean riparian forest impact through predation of native species and dispersal of exotic trees. We also hipothetize that those impacts can be evaluated using the stream water quality. The understanding of these special situations gives a new perception to look for holistic solutions, many of them applicable to other basins in the region. In this line, a modified index of riparian quality is developed for a subtropical basin with different land uses.

STUDY AREA

Mountains area in NWA, with approximately 450 000 Km^2 is a very heterogeneous area, comprising a wide extension of mountain rain forest called «Yungas». Grau and Brown (2000) and recently Izquierdo and Grau (2008), summarized the region characteristics and particularities, analyzed the disturbing factors and suggested management strategies for the future, including new protected areas. The Yungas, particularly, contain the headwaters of important basins and include many intermountain valleys used for agriculture and pastures, in fragile conditions of slope, soil and climate.

In NWA (Fig. 1), the ecological conditions from 500 m to 1 000 m a.s.l., correspond attitudinally to the middle reaches of the basins, and their protection must be a priority. The Lules River is one of these basins, where a dam construction is projected. This new reservoir will affect the lower area of different subbasins but especially the small sub-basin of San Javier Stream (Fig. 1).

We selected this sub-basin to check land uses change effects, and their impacts on the

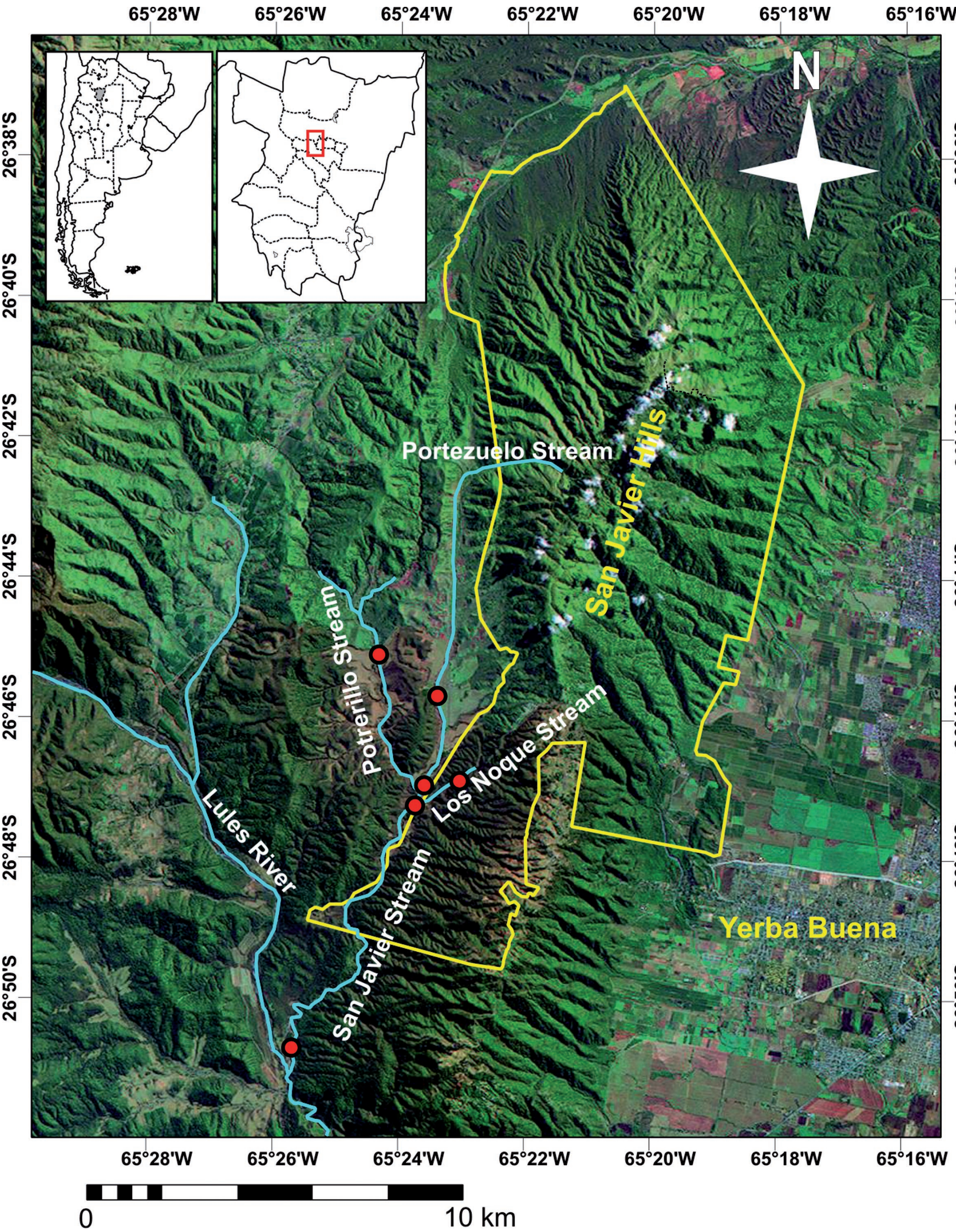


Fig. 1. Geographic position of San Javier Stream and San Javier hills. White circles represent sampling sites. White line encloses a protected area administrated by National University of Tucuman and white circle inside represents the reference site. In the west side arise Calchaquies Mountains and in the east side are the lowlands with the main cities and agriculture lands. Inset is South America showing the localization of Argentina and Tucuman Province in black showing the position of the study area.

water quality of the stream because it will be one of the main tributaries to the projected reservoir and is an accessible scale to approach. At this scale, we use the Ward's *et al.* (2002) definition of riverine landscapes, or river corridor, as «surface area composed of interacting terrestrial and aquatic units that are directly influenced by the river». It is recognized that lateral aquatic habitats (tributaries, backwaters, and parafluvial ponds) are among the least-investigated habitat types along river corridors (Karaus, 2004).

The San Javier Stream is a small water course (mean discharge = 0.58 $m^3 s^{-1}$; S = 0.357 at site B) running through the little La Sala valley (Fig. 1). The Stream flows for 20.14 km from the headwaters in the Eastern part of San Javier hills, reaching the Lules River in Potrero de las Tablas locality (Fig. 1). San Javier Basin (113 km^2 lat 26°42'S, long 65°23'W) is under an intensive impact, changing the mountain forest for vegetable farms and crop lands. Real state activities increased in the last four years and the access to services such as electricity, paved roads, etc. has enabled population settlement in the valley. The Eastern part of San Javier Basin is within a protected area that covers the Northern part of the San Javier Hills (Fig. 1).

Recently was documented an existing case of forest transition in the southern sector and the eastern foothills of San Javier Hills, but dominated by exotic tree species (Grau *et al.,* 2008).

Fig. 2. Sampling site B in drought period showing a denuded and eroded soil. See a fence through the stream and some cows. On the terrace there is a grayish first line of *Gleditsia triacanthos* trees without leaf and behind is the subtropical mountain forest (Yungas). In the center - left can be observed an eroded track used in outdoor activities (mountain bikes and off-road motorcycles). Inset: The normal practice used in this region is to release the cattle in the forest. For vagrant cattle, the best possible area is in the vicinity of water courses, especially in drought period (April to October).

Impacts in San Javier Basin

Izquierdo and Grau (2008) noted that over 90% of Argentina, including the more important areas for basins conservation and invaluable zones for tourism and recreational use are not affected by modern agriculture. On the other hand, they affirm that extensive livestock is not considered but affects larger parts of the country, including Yungas ecorregion in NWA and needs special consideration for conservation.

At the basins scale, Moyano and Movia (1988) described and classified vegetation from a physiognomic-structural point of view. They observed in this moment a low impact in forests and shrubs strata and some graze impact in the herbaceous strata, in upper creek areas, lower than 15° of slope. Riparian forests are still conserved in other upper zones, however cattle impact may be observed because they graze and search for water (Fig. 2). Native forests are also affected in the basin by progressive Pine plantations (*Pinus patula*) using all available land on the riparian strip. Some other unwanted introduced species are also found in patches along margins of San Javier Stream.

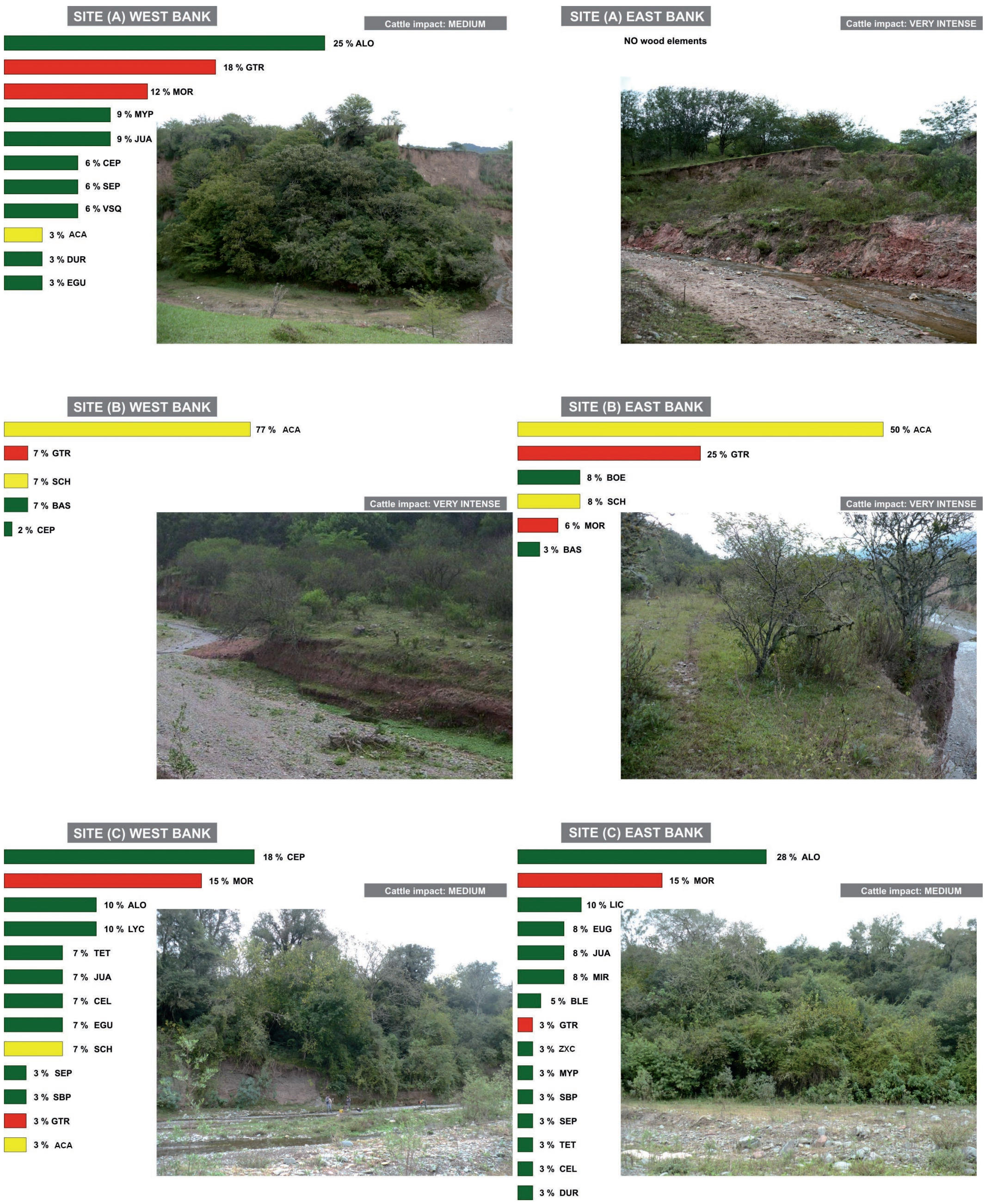
Ionic composition of San Javier Stream is influenced by saline little creeks and their small sources are used by vagrant cattle to obtain salt, destroying the surrounding fragile swamps (Fig. 3). This is an important aspect in relation to biodiversity conservation, because although lateral aquatic habitats cover only a small proportion of the total aquatic area, they contributed >50% to total species richness (Karaus, 2004).

In San Javier stream the presence of nutrients have been measured and evidenced by algae blooms (Fernández *et al.,* 2009). Phosphorous as phosphate, originated in the basin, produced phosphorous concentration peaks in the streams. The summer warmer temperatures coupled with increased solar radiation promot-

Fig. 3. Small natural sources of water in the lateral corridors of San Javier Stream. The small swamps developed around of them are frequently impacted by cattle looking for salt depositions.

ed the biological incorporation of this phosphorous (Fernández *et al.*, 2009).

Quick changes in the San Javier valley make it important the availability of a metric for monitoring the human impact in the area. Only an urgent action on basin restoration and management will permit us to maintain the sustainable development path



Figs. 4. and 5A. Species composition and relative importance in each site sampled. References: green: native species; yellow: native xerophyte species; red: exotic species. Species codes in Table 1.

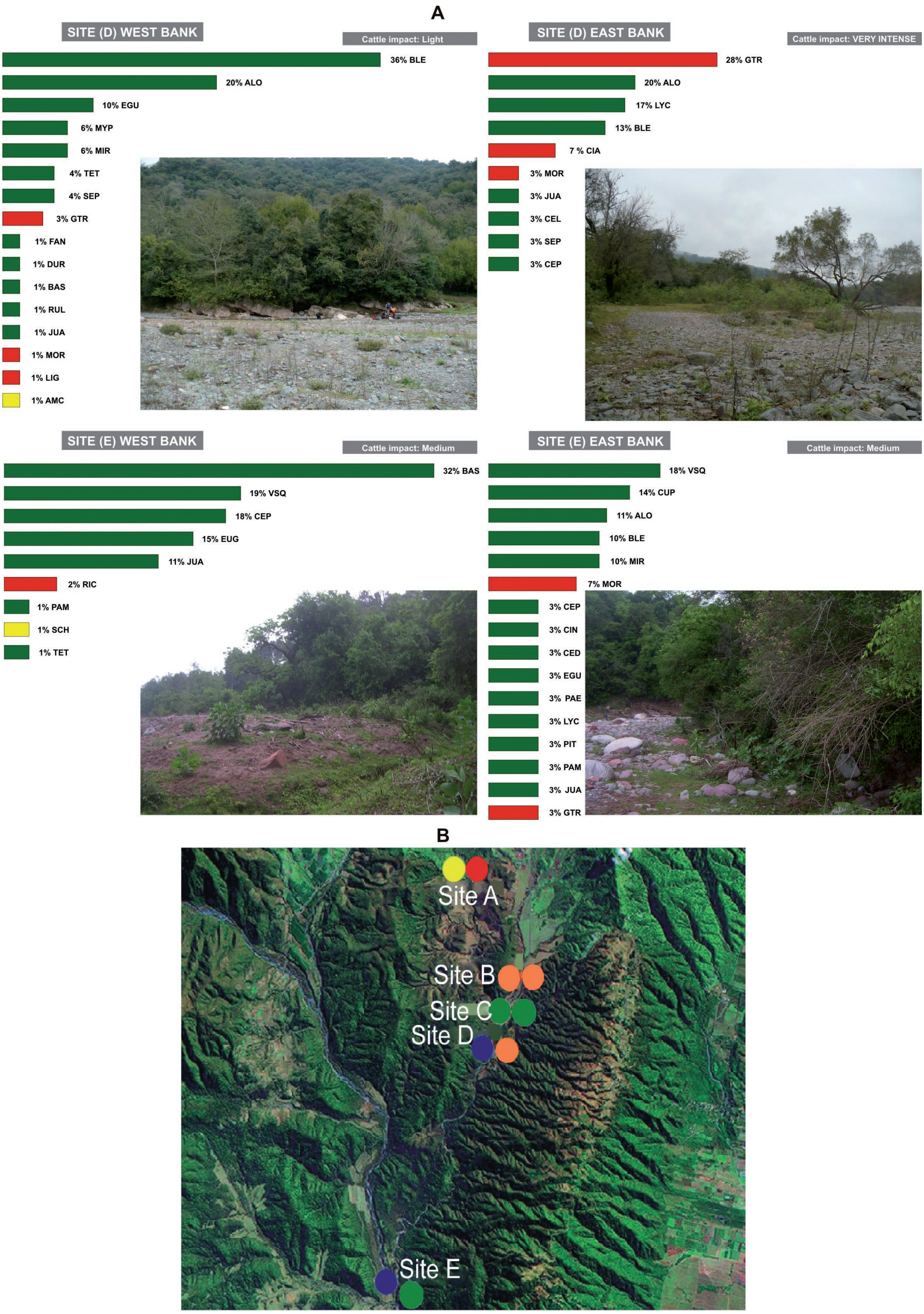


Fig. 5B. Riparian quality map using QBR-MR. Riparian conditions references: Blue: Very Good, Light blue: Good, Yellow: Fair, Orange: Poor, Red: Very poor.

in this strategic scenario. Any impact in San Javier Valley will affect directly the planned down stream reservoir in Lules River.

METHODS

We selected five stations along the middle and lower parts of San Javier Stream and their most important affluent, the Potrerillos Stream (Fig. 1). These parts of San Javier basin includes different levels of cattle presence (Fig. 2). In each site the riparian and water quality were measured with seasonal frequency during a two years period (2007-2008).

We used the Riparian Quality Index (QBR; Munné *et al.,* 2003) and their modified version for Patagonia (QBRp ; Kutschker *et al.*, 2009) named QBR-MR in reference to Mountain Rivers. We selected five accessible sites along San Javier Stream that represent longitudinal variation and different de-

Table 1. List of species plants and life form, collected in the river bank of San Javier Stream. Species codes are used in Fig. 4 and 5A.

Code	Species	Family	Life form
SCH	*Schinus bumelioides* I.M. Johnst.	Anacardiaceae	tree
EUL	*Eupatorium lasiophthalmum* Griseb.	Asteraceae	shrub
BAS	*Baccharis tucumanensis* Hook. & Arn.	Asteraceae	shrub
SEP	*Senecio peregrinus* Griseb.	Asteraceae	shrub
VSQ	*Vernonia squamulosa* Hook. & Arn.	Asteraceae	shrub
TAB	*Handroanthus impetiginosus* (Mart. ex DC.) Mattos	Bignoneaceae	tree
SBP	*Sambucus nigra* L. ssp. *peruviana* (Kunth) R. Bolli	Caprifoliaceae	tree
CEL	*Celtis iguanaea* (Jacq.) Sarg.	Celtidaceae	shrub
TET	*Terminalia triflora* (Griseb.) Lillo	Combretaceae	tree
RIC	*Ricinus communis* L.	Euphorbiaceae	shrub
GTR	*Gleditsia triacanthos* L.	Fabaceae	tree
ACA	*Acacia aroma* Gillies ex Hook. & Arn.	Fabaceae	tree
ECO	*Enterolobium contortisiliquum* (Vell.) Morong	Fabaceae	tree
PAE	*Parapiptadenia excelsa* (Griseb.) Burkart	Fabaceae	tree
XYL	*Xylosma pubescens* Griseb.	Flacourtaceae	tree
JUA	*Juglans australis* Griseb.	Juglandaceae	tree
CIN	*Cinnamomum porphyrium* (Griseb.) Kosterm.	Lauraceae	tree
CED	*Cedrela lilloi* C. DC.	Meliaceae	tree
MOR	*Morus alba* L.	Moraceae	tree
EGU	*Eugenia uniflora* L.	Myrtaceae	tree
MYP	*Myrcianthes pungens* (O. Berg) D. Legrand	Myrtaceae	tree
BLE	*Blepharocalyx salicifolius* (Kunth) O. Berg	Myrtaceae	tree
MIR	*Myrsine laetevirens* (Mez) Arechav.	Myrsinaceae	tree
PAM	*Pisonia zapallo* var. *zapallo* Griseb.	Nyctaginaceae	tree
LIG	*Ligustrum lucidum* W.T. Aiton	Oleaceae	tree
PIT	*Piper tucumanum* C. DC.	Piperaceae	shrub
RUL	*Ruprechtia laxiflora* Meisn.	Polygonaceae	tree
CIA	*Citrus aurantium* L.	Rutaceae	tree
ZXC	*Zanthoxylum coco* Gillies ex Hook. f. & Arn.	Rutaceae	tree
ALO	*Allophylus edulis* (A. St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl.	Sapindaceae	tree
CUP	*Cupania vernalis* Cambess.	Sapindaceae	tree
CEP	*Cestrum parqui* L'Hér.	Solanaceae	shrub
LYC	*Lycium cestroides* Schltdl.	Solanaceae	shrub
URC	*Urera caracasana* (Jacq.) Gaudich. ex Griseb.	Urticaceae	shrub
BOE	*Boehmeria caudata* Sw.	Urticaceae	shrub
DUR	*Duranta serratifolia* (Griseb.) Kuntze	Verbenaceae	shrub

grees of wilderness. Each site corresponds to a 30 x 50 m area of study in both riverbanks where vegetation was gathered: number of adult trees and saplings, species identification and cover rate.

QBR-MR is a method performed for a rapid evaluation or riparian zone based on attributes such as vegetation coverage, structure, species composition, wilderness and cattle activities impact. It measures four easily understandable variables, which are compared with their ideal conditions (Los Noque stream, site R labeled). It permits to obtain a useful metric for diagnosis of riverine habitat problems. For more detail about this index uses in Argentina see appendix in Kutschker *et al.* (2009).

We performed a multivariate analysis (DCA) of stations using a PC-ORD (vers. 4.25) using nutrients, conductivity, bankfull distance, exotic abundance, richness, EPT index and QBR-MR index as variables. We used the downweighting option and axes were rescaled. A regression analysis was applied to relate adult to sapling abundances of native and exotics species of plants. Also, we employed the EPT (Ephemeroptera, Plecoptera and Trichoptera) metric to assess San Javier Stream water quality (Fernández *et al.,* 2008). We used a 100 individual count in 10 minutes transect sample effort. The organisms collected were fixed and conserved in alcohol 70% and identified in laboratory.

RESULTS

The conditions of the riparian areas mentioned before are illustrated in Figs. 4 and 5A and the modified Riverine Quality Index for Mountain Rivers (QBR-MR) applied, in Fig. 5B. The Table 1 presents total species abundance and life form in each sampled site.

Riparian quality varies from regular to very poor in the upper zone studied and good to very good in middle and lower parts of the basin (Fig. 5B).

Most impacted station presents livestock fences creating a continuous grazing and do not allow vegetation recovery. Heavy grazing was observed in riverine geomorphology as deteriorated aspects such as much eroded banks, denuded soil, etc. (Fig. 2).

We collected a mean of 11 taxa of macroinvertebrates in benthic zone. Only one of the water quality indices used (EPT), indicated slightly impaired conditions (Table 2).

Nutrient contents diminished in site E, probably as a consequence of running through approximately 10 Km of a well conserved forest.

Multivariate analysis (Fig. 6) shows the influence of physical and chemical variables of the stream on stations. Total variance in the species data was 1.59 and the Eigenvalue was 0.656. Axis 1 represents extreme sizes of stream sites (bankfull distance), in this case between site E and site C. Nitrate and EPT index load on this axis too. Axis 2 shows site B differentiate of sites A and D. Site B was associated with quantities of fosfate present

Table 2. Variables measured in San Javier Stream and the reference (Site R): Mean richness plants in both banks and QBR-MR (right west bank/left bank) calculated. Water quality parameters and environmental variables measured in along the studied period (n=3).

	SITE A	SITE B	SITE C	SITE D	SITE E	R SITE
RICHNESS	11	7	18	18	20	20
QBR-MR	67/23	34/41	89/89	96/46	77/97	99/100
BMWP	49.3	68.3	74.3	62	52	78
ASPT	5	5.6	5.7	5.9	5.5	8.2
EPT	6.6	7.6	8.6	8.3	6.3	12
BANKFULL WIDTH (m)	15.4	30.1	14.6	41.9	122	16
CONDUCTIVITY (μS/cm)	1358	343	353	695	280	472
NITRATE (mg/L)	0.8	1.3	1.1	0.9	0.2	0.9
FOSFATE (mg/L)	0.25	0.48	0.37	0.22	0.23	0.22
NITRITE (mg/L)	0.006	0.005	0.005	0.007	0.006	0.007

in water. Conductivity variable was associated with sites A and D.

Exotic species presence was observed around the river corridors and terraces (Fig. 4 and 5A). In river corridors, small plants are observable but do not develop because annual floods periodically destroy them. One of the most important plants found in this basin is the introduced *Gleditsia triacanthos.* This spiny species from Florida (USA) is dispersed by cattle, showing an important adaptation capacity in NWA. Also, two other introduced spiny species *A. macracantha* (Tusca) and *Schinus bumeloides* are present in the riparian strip of San Javier Stream (Fig. 4, site B).

Results of regression analysis are showing positive tendencies in both groups of plants indicating strong relationships between variables. Sapling native species abundance showed no significant relationships with adults native abundance (R^2= 64.82% p= 0.1). Sapling exotic abundance showed significant relationships (R^2= 95.25%, p=0.024).

DISCUSSION AND CONCLUSIONS

It is recognized that land-use influences on physical changes in channel shape, sediment dynamics, lateral corridors and stream communities (Naiman *et al.,* 2005; Karaus, 2004). With regards to cattle management, Vazquez (2002) observed that many areas subject to grazing have partially or totally lost forest cover, which cannot always be attributed to grazing, being fire or logging an alternative. Also, Marty (2005) sustain that cattle is generally considered incorrectly as a threat to biodiversity. He sustain that in certain very disturbed regions, cattle may help to maintain diverse communities. In this regards, the determination of «how much» is «very disturbed» is a fundamental goal. Meanwhile, it is possible to consider South American basins as ecosystems threatened by cattle triggered factors and certainly in some regions they are more important than agricultural activities. South American Andean zones do not have a long history of grazing animals (Vázquez, 2002) as Marty (2005) advocate for California grasslands.

Comparatively, cows can be considered as landscape engineers of the riparian zone as Harper & Pacini (2008) proposed with regards to some African mammals. Cattle activities are complemented with human facilities: e.g. abandoned improvised circular fences or «corrales» that develop in differentiated vegetation patches. It was also ob-

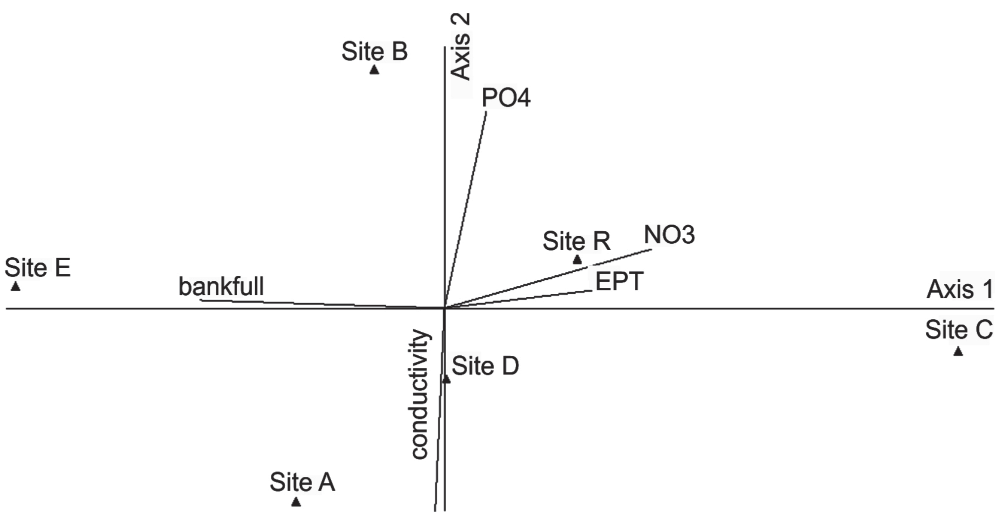


Fig. 6. Biplot of sampling sites and environmental variables in relation to the first two ordenation axes of DCA (eigenvalue axe 1 = 0.65; eigenvalue axe 2 = 0.1).

served that confined livestock create continuous grazing that do not allow for recovery of the vegetation (De Pietri, 1992; Walker *et al.,* 1999).

It is recognized that lateral habitats are among the first that disappear as a consequence of river regulation (Naiman *et al.,* 2005; Karaus, 2004), but in Latin American countries, other drivers of changes such as cattle, must be added. On the other hand, these impacts on vegetation are not detected by Satellite Image Analysis as is in agricultural uses, because riparian forests may appear intact in images. For this reason we consider important the field measurements as a complement and the metrics developed here requires that.

Vegetation changes observed around San Javier Stream show dryer characteristics than expected in this valley (yellow bars species in Fig. 4 and 5A). We attributed this to the presence of cattle, and probably an enclosure study would test this idea.

The original QBR was developed in Italy and Spain (Braioni *et al.,* 1994; Munné *et al.,* 2003), where riparian areas are different in use type and intensity, due to strict regulations on livestock management. Some modifications were necessary to adapt it to the different conditions found in NWA. For this reason, we developed the modified QBR-MR that reflects better the local conditions (See Appendix).

It is important to define alternatives to the cattle management in NWA, because the carrying capacity has been exceeded in many areas. One alternative could be the reduction of cow head number, which was proposed in the basin ten years ago (P. Perez «pers. com.»).

Fernández and Molineri (2006) proposed urgent actions (removing cattle) to protect upper water sources of Lules River but certanly cows are just part of a bigger problem that needs a deeper analysis. In a Northern range, in the upper Bermejo River, Grau and Brown (2000) suggested the involvement of

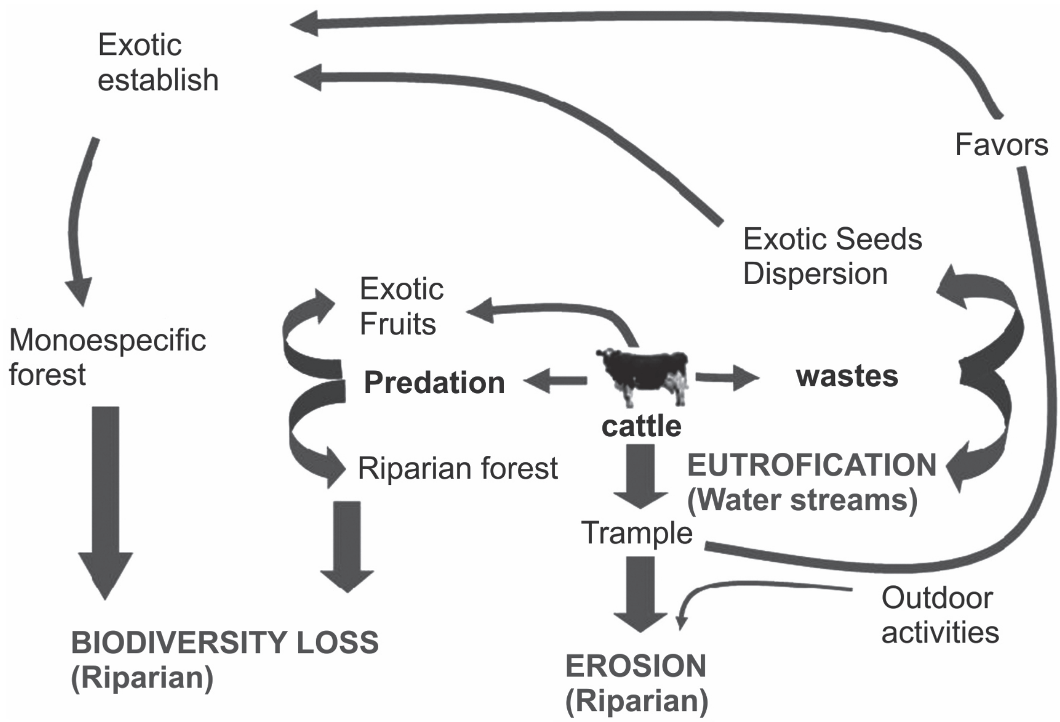


Fig. 7. Simplified model of peasants' cattle management effect produced in San Javier Basin, indicating the most important impacts.

peasants for a sustainable forest management of remaining forest after the areas were protected.

More recently, Izquierdo and Grau (2008) suggested the integration of the settlers dedicated to cattle practice, to new activities such as introduction of modern agriculture and sustainable use of natural forests. The vagrant cattle activity used since historical times is not acceptable today in NWA basins (Saravia-Toledo, 1996). Despite corresponding to a survival practice, it must be avoided. Provision of food and water in restricted areas would be an alternative, although impractical in NWA considering food prices. Another alternative would be a shift from the domestic livestock of cows to pigs as done in lowland regions. Pigs are well maintained in reduced spaces consuming different kinds of food as well as feedlots. However, this should be planned carefully because these systems include high concentrations of animals producing punctual organic wastes. Recently Herrero and Gil (2008) remarked the existing environmental risks in Argentina, in a growing intensive animal production (cow meat production peaked 25 % in 2005). Especial consideration deserves nutrients and pathogens in feces at the basin scale that ends in water bodies (Herrero and Gil, 2008). Some failed intents in the area, point to the need of sociological studies before alternative projects are proposed (Fernández and Molineri, 2006).

Bigger rodeos need different strategies because they impact on river water through enrichment with nutrients of organic wastes. In this situation maintaining an intact and wide riparian strip could be sufficient to reduce nutrients in water runoff. The determination of how wide should be that strip to be efficient under subtropical conditions is our challenge for the future.

As Fernández *et al.* (2008) observed, nutrients presence in Lules River affluents is preoccupant in perspective. The incorrect management of nutrients produced in upper zones of the basin could reduce dramatically the functional period of the projected reservoir located down water.

As is observed in fig. 5B and nutrients in table 2, the site located near Lules River confluence is in good conditions. This is because the last segment of San Javier stream flows through a steep valley and a protected area. However, nutrients depletion observed in the last site is promising because mineralization of nutrients is attributed to the filtering service of a well conserved riparian forest plus a lower number of cows. Noticeably, benthic community did not reflect the improvement, impairing its capacity as a water quality indicator.

Ordination of sites shows excellent quality in water measured as EPT in reference site and fair quality in site C. The B site was differentiated in axis 2 from other two sites (A and D) influenced by conductivity. Position of Site B in upper part of analysis, associated with phosphate in water shows a particular condition of this Site. Salts concentration in Potrerillo stream (site A) is strongly affected by geology, influencing site D in San Javier stream. Surprisingly, the abundance of exotic plants did not influence the analysis.

However, introduced species deserve especial consideration, because riparian corridors may be favorable zones for exotic plant invasions (Naiman *et al.,* 2005). We observed some established old *G. triacanthos* monospecific wooded areas as source of seeds and it may be observed in saplings abundance (Table 1). Cattle graze their fruits, dispersing the seeds wherever they move. However, small plants are not grazed by cattle and *G. triacanthos* use is almost negligible for settlers (e.g. plank, fruits, etc.), although sometimes its wood is used because other species of trees have already disappeared as a natural resource. Sapling production of exotic plants are well related with adult abundance plants, as regression analysis demonstrated. The absence of sapling native species relation with adult plants is attributed to the sapling mortality due to predation by cattle.

Acacia macracantha and *Schinus bumellioides* are characteristic of lowlands in dryer zones of Northern Central Argentina, but its presence in the Yungas landscapes such as San Javier valley, is restricted to cattle altered areas (Saravia-Toledo, 1996). These species are reflecting the rougher conditions drove by cattle presence, modifying the structure and morphology of river margins, affecting the riparian landscape and finally water availability. Also their dominance in Site B caused a distortion of our regression analysis, because they are native in origin but unexpected in our study area.

Our observations are synthesized in a model around cattle impact in the riparian zone and the river, applicable to most of subtropical Andean basins (Fig. 7).

Also, new studies were suggested in this area to determine possible consequences on hydrology in exotic-dominated forest considering water consumptions (Grau *et al.,* 2008).

Basin management

Fluvial landscapes are among the most threatened systems in the world and at the same time, they are most frequently ignored within water management schemes (Naiman *et al.,* 2005). As a first priority, the protection of water quality and quantity in any basin should be the goal. A good diagnosis of social components, water quality availability and its riparian protection, at least, must be considered by governmental agencies in an integrated way.

It is important to remark the importance to focus on a basin scale, in which San Javier basin is included. San Javier Valley problems are not the same of higher altitude intermountain valleys (Fernández and Molineri, 2006). San Javier Valley is populated by small farmers while at higher altitudes a few owners have thousands of hectares. Nevertheless, it is clear that the basin is an integral unit of those valleys from water sources to middle reaches in a continue way and in this context, healthy riparian areas are the key for a good river management.

Water quality monitoring policy must be defined urgently in Lules Basin, as well as in all Province basins, and for this reason, a more accurate index or metric using sensible organisms must be developed (Fernández *et al.,* 2008). Frequently macroinvertebrates in these streams are indirectly beneficiated because nutrients presence favors algae growth, creating an important source of food. In this way a functional measure (e.g. percent of functional feeding groups) combined with a biotic index could be a good multimetric approach. Riparian index must be complemented with other systems such as LANDSAT images.

It is also important to define a reforestation plan following a designed pattern, absent from governmental offices at the moment, which are using mainly intuitive systems. In the meantime, while studies to determine how the natural riparian forest is performing, we propose the use of *Salix humboldtiana* +*Erytrina crista-galli* and *Tessaria integrifolia* species as the closest line of trees in lowlands. The last one should be used in the first line due to its fast growth and vegetative propagation. Nevertheless, the reforestation plan needs previously a cattle management to avoid grazing in reforested areas.

The observations here presented are valid to a much wider scale, as the type of economic activities repeats in a regional scale, reaching even neighboring Andean countries, and reflecting a socio-economic-environmental continuum.

Considering a temporal scale, riparian landscapes and associated populations are among the most affected systems by El Niño events. Knowledge about the complexity of this phenomenon is very important in basin management but the absence of continuous environmental data makes it impossible any predictive models. It is fundamental to adopt a historical perspective to link environmental and cultural systems in order to predict and improve the future of our river landscape (Naiman *et al.,* 2005). In this sense, the lack of basic information and derived planning maintain the underdeveloped countries inhabitants in disadvantage facing a changing world.

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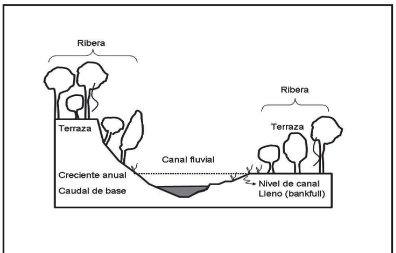
Appendix. Modified QBR index applied to the middle basin area of Lules river. It is presented in Spanish language because tecnicians could be capable to use it directly from the appendix. Diagram of stream is based in NWA water courses.



Aplicación del Índice QBR-RM, para el tramo medio del río Lules y San Javier

Clasificación de la zona de ribera de los ecosistemas fluviales
La puntuación de cada uno de los 4 apartados no puede ser negativa ni exceder de 25

I- Grado de cobertura vegetal en la zona ribereña

Puntuación	
20	> 80 % de cubierta vegetal leñosa en la zona ribereña
15	50-80 % de cubierta vegetal leñosa en la zona ribereña
10	10-50 % de cubierta vegetal leñosa en la zona ribereña
5	< 10 % de cubierta vegetal leñosa en la zona ribereña
+5	Si la conectividad entre el bosque de ribera y el ecosistema forestal adyacente es total
+2	Si la conectividad entre el bosque de ribera y el ecosistema forestal adyacente es superior al 50 %
-2	Si la conectividad entre el bosque de ribera y el ecosistema forestal adyacente es entre el 25 y 50 %
-5	Si la conectividad entre el bosque de ribera y el ecosistema forestal adyacente es menor al 25 %

II- Estructura de la cubierta vegetal

Puntuación	
18	Cobertura de árboles superior al 75 %
15	Cobertura de árboles entre el 50 y 75 % o cobertura de árboles entre el 25 y 50 % y en el resto de la cubierta los arbustos superan el 25 %
10	Cobertura de los árboles inferior al 50 % y el resto de la cubierta con arbustos entre el 10 y 25 %
5	Sin cobertura de árboles y arbustos menos del 10% en la ribera, con predominio de vegetación herbácea
+5	Si en la orilla la concentración de helófitos o arbustos es el óptimo
+2	Si en la orilla la concentración de helófitos o arbustos es inferior al óptimo
+2	Si existe una proporción 60/40 entre la zona de arbustos y la de árboles con sotobosque
-1	Si existe una distribución regular (linealidad) de los árboles y el sotobosque recubre más del 50 %
-1	Si los árboles y arbustos se distribuyen en manchas, sin una continuidad
-1	Si se observan caminos, o sendas producto de la actividad antrópica
-2	Si existe una distribución regular (linealidad) de los árboles y el sotobosque recubre menos del 50 %
-1	Si se evidencia depredación de las especies vegetales, por parte del ganado

III - Calidad de la cubierta (véase la determinación del tipo geomorfológico de la zona de ribera)

Puntuación	
15	Número óptimo de especies arbóreas autóctonas
10	Número de especies arbóreas autóctonas inferior al óptimo
5	Sin especies arbóreas autóctonas
+5	Si la comunidad forma una franja longitudinal continua adyacente ala canal fluvial en mas del 75 % de la longitud del tramo
+2,5	Si existe una continuidad de la comunidad a lo largo del río , con como mínimo 3 m de ancho, uniforme y ocupando más del 75 % de la ribera
+5	Si el número diferente de especies de arbustos es **Tipo 1** + 3 **Tipo 2** + 5 **Tipo 3** + 7
-2,5	Si existe alguna especie de árbol introducido (exótico) de forma dominante
-5	Si existen algún tipo de aprovechamiento forestal

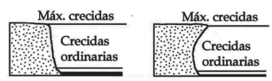
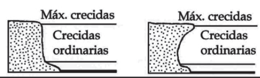
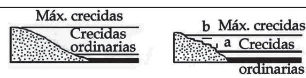
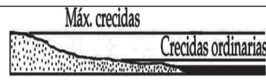
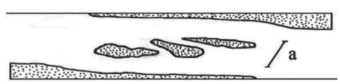
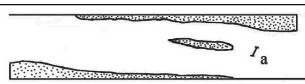
IV- Grado de naturalidad del canal fluvial

Puntuación	
25	El canal del río no ha sido modificado

20	Modificaciones de las terrazas adyacentes al lecho del río sin reducción del canal fluvial
15	Modificaciones de las terrazas adyacentes al lecho del río con reducción del canal fluvial
10	Extracciones de áridos o rocas del canal fluvial
5	Vertidos de desechos industriales y residuos sólidos
0	Río canalizado en la totalidad del tramo
Puntuación final (suma de las puntuaciones anteriores)	

Determinación del tipo geomorfológico de la zona ribereña

Sumar el tipo de desnivel de la derecha y la izquierda de la orilla y sumar o restar según los otros apartados

		Puntuación	
Tipo de desnivel de la zona de ribera		Derecha	Izquierda
Vertical/cóncavo (pendiente > 75º), con una altura no superable por las máximas avenidas		6	6
Igual pero con pequeño talud u orilla inundable periódicamente (avenida ordinaria)		5	5
Pendiente de entre 45 y 75º, escalonado o no. La pendiente se mide con el ángulo formado por la horizontal y la recta que enlaza la orilla con el ultimo punto de la ribera $\Sigma a > \Sigma b$		3	3
Pendiente entre el 20 y 45 º, escalonado o no. $\Sigma a < \Sigma b$		2	2
Pendiente < 20 º, ribera uniforme y llana		1	1
Existencia de una isla o islas en medio del canal fluvial		**Puntuación**	
Anchura conjunta "a" > 5 m		-2	
Anchura conjunta "a" entre 1 y 5 m		-1	
Porcentaje de sustrato duro con incapacidad para que se enrai zar una masa de vegetación permanente			
	> 80 %	No se puede medir	
	60-80 %	+6	
	30-60 %	+4	
	20-30 %	+2	
	> 5 – 20%	+ 1	
Puntuación total del tipo geomorfológico:			

Tipo geomorfológico según a puntuación		
> 8	Tipo I	Ribera cerrada, normalmente de cabecera
Entre 5 y 8	Tipo II	Ribera, tramo medio de los ríos
< 5	Tipo III	Ribera, tramos bajos de los ríos

PUNTUACION FINAL QBR	

NIVEL DE CALIDAD	QBR	COLOR REPRESENTATI VO
Bosque de ribera sin alteración, calidad muy buena, estado natural	≥ 90	Azul
Bosque ligeramente perturbado, calidad buena	70-90	Verde
Inicio de alteración importante, calidad intermedia	50-70	Amarillo
alteración fuerte, calidad mala	25-50	Naranja
Degradación extrema, calidad pésima	≤ 25	Rojo