ENVIRONMENTAL, ECONOMICAL AND SOCIOLOGICAL CONSEQUENCES OF RIVER USE: CASE STUDIES IN SOUTH AMERICA

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ABSTRACT

Despite initiatives by many conservationists, the riparian ecosystems of the world are facing increasing degradation due to inadequate patterns of river use. An accelerating loss of biological diversity is undermining sustainable development opportunities and the future for a diverse food supply. Fisheries dependent on riparian ecosystems have been the main sustainable economic activity along the human history. However, currently river regulation, mining and disposal of industrial and agricultural wastes affect them. Therefore, immediate actions have to be taken in the short term. These actions will require participation from a diverse range of members of society who should consider solutions in a regional context. Negative environmental impacts of river use in the riparian corridor of one country might potentially have negative consequences on those located downstream in another country if the river networks are interconnected. Therefore, it would be an economical and political issue to be addressed in a pan-national context. This poster analyses the environmental, economical and sociological consequences of river use that are related to important industries for the economy of Venezuela and other countries in South America. Case studies of industries that will be examined in a regional context are the oil industry in the Orinoco basin (Colombia -Venezuela), gold mining in the Esequibo (Venezuela - Guyana). Cases of river regulation (Uruguay – Argentina - Paraguay), and river navigation (Colombia- Venezuela, Argentina-Brazil-Venezuela) are shown as related to industrial development. A qualitative model for explaining riparian forest biodiversity is used for the analysis of conservation priorities. Sustainability and green opportunities for industries involving river use will be analysed considering the differences and similarities of the different cases.

Key words: South America, Orinoco River, Amazon River, La Plata River, riparian corridor, ecosystem approach

1. INTRODUCTION

Rivers have been used along the whole history of humanity. Primitive uses, such as fishing, providing protein intake, or fluvial navigation, which have always being a means of transport, communication, cultural exchange and trade, have been the basis for the development of ancient civilisations along the Nile, the Tigris-Euphrates and the Ganges-Brahmaputra rivers. In South America, approximately 70 million Amerindian people inhabited the subcontinent before the arrival of the Europeans, their cultures being developed along the rivers (Gines and Vázquez 1990; Colchester 1997). The XXI century South Americans, with a minority of Amerindian populations are concentrated in big urban spaces, usually in cities located along coastal areas. For them, the perception of 'the river' has lost the primitive meaning. The common perception of a river for the urban people is as a source of water, electricity, irrigation or use in leisure activities. The countryside in South America is extensive, with relatively small urban cities and rural settlements, where rivers are still required for their basic needs. The development of larger urbanised cities, following the industrialisation, has been dominated by upstream industries, characterised by basic transformation of natural resources. From a political point of view, although federalism is the dominant characteristic of the geopolitical distribution of the South American countries, with some laws giving sorts of autonomy to the states, centralisation still dominates the economical and political arena. Urban citizens, having access to better education, health, services, have been those who rule the economical development and the politics of the inland territories. A lack of sensibility for natural resources and environment is evident if we observe the development plans that local governments have established in different states within different countries. Rural and indigenous people, for whom the rivers are in many cases the main source of protein intake, have low to very low levels of education and their participation in decision making plans or strategies for their own lands is usually through some community leaders or non-governmental organisations. Few have reached more than secondary education, usually at technical levels, without a comprehensive understanding of the global and regional issues where they are embraced. Their struggle for land rights in many cases is used as compensation mechanisms offered by the governments, when the use of part of their lands is considered a challenge for the country's development.

Regarding fisheries only, it is possible to distinguish differences in river values between old but relatively big cities with large urban areas and the new industrialised ones, dominated by urban spaces. In the former, like Manaus in Brazil or Ciudad Bolivar in Venezuela, close to large rivers as the Amazon and the Orinoco, the consumption of freshwater fish is high, which is not the case in the last ones, where there is a marked preference for marine fish, more related to the migratory origin of their inhabitants.

Under the new global environmental and political scenarios, indigenous and rural community's participation in environmental conservation or management projects is expected to be encouraged. However, given the low education levels, the feasibility of success is low. Global strategies to create funds for the improvement of the environmental conditions should necessarily involve, in non-urban areas, the formal education of the people. That education should allow the people, at all levels in the society, to understand of what is mean by local, regional and global issues, the needs to incorporate clean technologies and the social and economic advantages for them by participating in improving or preserving their environments. If a strategy for greening industries is invoked, it is important to recognise that although market-based policies have been successful in developed countries, in developing nations with large informal sectors, other policies –capacity-building, overall policy reform, community participation, investments in education and health care, are needed. Initially, these may be more effective than market-based mechanisms (GEF 2000). Cases of subsidy reduction and targeted subsidies, environmental taxes, performance bond/deposit-refund systems and credit and tax incentives for environmentally related investments, have been shown as market-based policies that, introduced as a supplement to traditional government regulations, prove to help the nations in accelerating the transition to sustainable development. The revenues can be used in subsidised education and health programs in a decentralised scheme. It is found that revenues from tourism in national parks for example, are not improving the welfare of local people. Moreover, elimination of corruption is strictly necessary, and the control mechanisms have to be continuously monitored.

2. A RIPARIAN CORRIDOR CONCEPT AS A FRAMEWORK FOR THE DEVELOPMENT OF GREENING OPPORTUNITIES

In the analysis for actions and investments for a 21st century, the Queen Noor of Jordan (in GEF 1998) acknowledges that the major challenge which remains now, is to mobilise people and institutions at different levels, local, nationally, and globally to make the political decisions required to achieve three long term goals: responsibility, accountability, and sustainability. That is a scaling-up of the social and economic relationships of the people with the environment.

Based on a scaling-up of the spatial distribution of riparian forest biodiversity as a target, this paper approaches the selection of conservation and management areas to establish the possibilities for acting on a local, national, regional or global-scale. It uses a study of riparian forest biodiversity within a basin and between the Orinoco and Amazon river basins, an scaling-up qualitative model for explaining riparian forest biodiversity proposed by Rosales (2000) is used in this paper. The author established a socioecological concept of riparian corridor as: "the main river channel and its surroundings from their headwaters to the riparian confluences. Biologically and hydrologically, surroundings would include the present and Pleistocene-Holocene floodplain; in addition, those areas where groundwater and/or surface water are influenced by the main channel's flood pulse. Sociologically, the corridor is defined to include those areas of human use (e.g. cities, agricultural fields) that directly influence or are influenced by the biological and hydrological corridor".

2.1. The environmental, social, and economic basis

The countries signatories of the Convention of Biological Diversity, in the meetings of the Conference of the Parties concluded that an ecosystem approach is needed to be followed under principles of sustainability. Although sustainability has three components: ecosystemic, social and economic, Entrepreneurs and governments usually give more attention to the economic aspects. Figure 1 shows the basic relations needed to reach sustainability.

Sustainability of the ecosystem relies on sustaining the integrity of the system in terms of its structure, composition (species composition and biological diversity), and ecological processes (biogeochemical cycles, productivity), as well as the environmental services it provides (local like drinking water or global like carbon sequestration). The social component implies human health, education and life quality which has been recognised, hardly rely in the elimination of poverty and a more equitable distribution of the countries net annual incomes.

When developing strategies for regional issues, such as those involving different rivers shared by different countries, a regional multinational strategy can be based on the ecosystem approach under the principles proposed in the Biodiversity Malawi Conference in 1998. Following these principles, the overall strategy needs to make the environmental management of riparian ecosystem biodiversity an important and integrated part of the social and economic activities of the local people, the governments and the industries. It is only possible to achieve this with an understanding of social individualities of each of the human populations that directly benefit from, or are negatively impacted by the dynamics and commodities associated with the physical and biological riparian corridor system. The individualities of the riparian landscapes are not only associated with the physical and biotic differences of the riparian ecosystems, but also with the social identities of the human populations and the values they give to the riparian system. Such values depend on the degree of commodities that the human populations find in the riparian system. Therefore, a regional strategy for conservation of the South American rivers should based on the ecosystem approach.

An ongoing process of research relating to the hydrology, geochemistry and ecology of large South American rivers has currently produced a relatively good level of understanding of the composition, structure and dynamics of the riparian ecosystems (Paolini 1990; Lewis et al. 1995; Rosales et al. 1999a). Approximately 66 % of the South American subcontinent is drained by six large fluvial systems, producing about 8,000 Km^3 of freshwater. The Amazon, La Plata and the Orinoco fluvial systems are the first three more extensive with approximate surfaces of 6.3, 2.6 and 1 X 106 KM^2 respectively (Paolini, 1990).

Agriculture, forestry and mining related industries provide the main per-capita income in the countries sharing the Amazon, La Plata and Orinoco basins. The oil industry is the principal source of income in Venezuela and an important part of this production takes place within the Easter Plains draining to the lower Orinoco River and its Delta. More than 70 percent of the country's energy is generated by hydroelectricity in dams located along the Caroní River. It also sustains an important industry based on the exploitation of iron and bauxite in lands draining the Guayana territory at the right margin of the lower Orinoco River. Crude oil and gas production is also an important business area in Colombia in the jurisdictions of the Arauca, Casanare and Eastern Llanos (Plains), Apiay, Villavicencio (Meta), all areas draining the Orinoco basin. Being within the riparian network of the Orinoco basin, the contamination from oil spills is a potential hazard for the system.

Gold mining in the Venezuelan Guayana is dominated by rudimentary methods giving an important source of sediments and mercury to the Orinoco's tributaries. The toxic effects of mercury have been thoroughly studied in the literature (Vinson et al. 1997). In the Sierra Imataca and Upper Cuyuni River, it is located one of the biggest gold industry in the Easter Venezuelan Guayana. The impacts downstream of the exploitation in the Cuyuní River basin, a tributary of the Esequibo, have yet to be evaluated, although health problems like malaria and contamination of the people for consuming contaminated fish are increasing. Accompanying high rates of deforestation is also one of the related impacts. A political claim of Venezuela for the territory at the west margin of the Esequibo still keeps the activities in the area in a non-clear status. The Amerindians who dominate the population in the area being the most affected Colchester (1997). In La Plata River basin, the two major tributaries, the Paraná and the Uruguay rivers are regulated and some studies have demonstrated important ecological and social negative effects (Bonetto et al. 1989, Quiros, 1990).

River navigation is considered a need for industrial development in South America. That is the assertion in the projects-funding strategy of the Andean Community of Nations (CAF), who together with the Southern Cone Common Market (Mercosur), integrate common economic interests in South American countries: “as has been the case in Europe for centuries, the development of river navigation could contribute to strengthen Latin America's commercial and economic progress. It could also promote the region's international competitiveness by reducing transportation costs for large volumes of raw materials and industrial goods, and it could likewise contribute to linking existing or potential overland and river transportation systems”. In Venezuela, the Orinoco-Apure project, consisting in the initial development of the Orinoco-Apure River system by making year round navigation feasible between Puerto Nutrias, on the Apure River, and its confluence with the Orinoco River is one of the strongest projects of the 2000-Venezuela’s new government. The final objective is to provide reliable, low cost transportation between Western Venezuela, its South-eastern Guayana region, and the Atlantic Ocean to the north and Northeast, as well as laying the groundwork for future river integration and navigation with Brazil and Colombia.

Furthermore, the Paraguay-Paraná Hidrovia is a proposal to convert 3,400 KM of the Paraguay and Paraná River system of South America into an industrial shipping channel. The project, which has been called "the backbone" of Mercosur, is part of a broader plan to expand agribusiness and mining activities. Two other waterways project being prioritised by the Brazilian government are the Madeira-Amazonas and Tocantins-Araguaia.

2.2. Freshwater fisheries, a resource related to riparian flooded forests

Studies in freshwater fisheries of South American large rivers demonstrate that they are hardly dependent on riparian ecotones (Goulding 1980; Welcomme 1990, Machado-Allison 1990), which include the frequently flooded riparian forests within the influence of rivers and streams. River regulation and navigation engineering work has been demonstrated to impair fisheries through loss of habitat and fragmentation of riparian flooded forests (Quiroz 1990). Furthermore, rural settlements and Amerindian populations, who directly depend on fisheries along the riparian corridors, are also negatively impacted through impoverishment of the fisheries.

The review of the literature about riparian flooded forests of the Orinoco and Amazon river basins (Rosales et al. 1999a) revealed that three factors were related to alpha (local level, within habitat), beta (sector level, between habitats), and gamma (riparian landscape level, regional) riparian forests species biodiversity:

1. uniqueness, which relates to the proportion of unique taxa (endemic or rare at the regional level) associated with unique habitats,
2. succession which relates to the dominance of community stages, and
3. "terrestrialization" or upland similarity that relates to the floristic resemblance to non-riparian forest ecosystems dominating the surrounding uplands.

The driving ecohydrological forces controlling these factors being flooding intensity (i.e. flood duration and depth), channel dynamics (i.e. rate of channel change), and fertility (i.e. nutrient status of the riparian forest soils and floodwaters).

An study conducted by the author in the Caura River, a tributary of the Orinoco draining the Venezuelan Guiana Shield, can be helpful in exemplify the diversity relationships. It revealed that diversity variables of the riparian corridor's forest communities were correlated to inundation depth and soil physics and chemistry. In the lateral gradient, number of species (S) and the diversity index (H') were higher in the river banks (levees geomorphic units) of constrained bed-rock dominated riparian sectors. Inundation depth and available phosphorous concentration were the most significant variables in explaining the species number and the diversity index (H'). In the Northern area, the riparian landscape also presents an ecohydrological confluence zone, determined by backwater effect of the Orinoco white and rich waters over the Caura, black and poor waters (Rosales et al. 1999b; Rosales et al. in press.). At this confluence riparian landscape, human settlements are dominated by rural communities of "criollos" (the result of a mix of Amerindian-European-Africans), whereas in the Southern area of the basin, upstream the lowermost rapids of the river, La Mura, Amerindian from the ethnic groups Ye´kwana and Sanemá dominate.

The land use pattern of the 'criollo' and Amerindian populations differs, but for all of them it is highly related to fisheries and use of the riparian forests (Rosales et al. submittedB). It has been proved completely unsustainable however at the confluence zone. Similar ecohydrological relationships as those found along another river draining the Guiana Shield. For example, in the Atabapo and Upper Orinoco Rivers. At the confluence zone of these rivers with the Guaviare River, draining from the Llanos of Colombia, it is located Santa Maria de Atabapo, a 'criollo' settlement. Amerindian settlements of the etnias Curripaco, Ye'kwana and Yanomami inhabit the upstream territories of the river basins.

In the Negro River, a tributary of the Amazon River, the confluence zone has the same ecohydrological patterns aforementioned for the Caura (see Worbes 1997). The 'criollos', call in Brazil "Caboclos", are the dominant population, whereas the borders upstream Las Analvilhanas are inhabited by Amerindian populations. These patterns of distribution have to be taken into account when planning conservation, sustainable uses, or greening strategies. Indigenous communities in all of the 'criollo' settlements are in most of the cases in social disadvantage in comparison with the 'criollos'. In the regions draining the Llanos of the Orinoco basin, confluence zones presenting the same ecohydrological patterns are found, but these rivers differ in the way "criollos" are established not only in the lower riparian landscapes, but also along the whole basin. Amerindian groups have been integrated or displaced, and in some cases, even exterminated by ranchers.

Along longitudinal gradients, higher tree species richness in the riparian corridors seems to be associated with intermediate locations downstream in the rivers (Rosales 2000). In particular, the reaches upstream from the confluence zones present higher species richness, which may be reflecting not only higher fluvial disturbance but also historical landscape disturbances related to changes in fluvial dynamics along the Pleistocene and Holocene. Those patterns are also important in long-term strategies, because the possibility of changes in patterns of precipitation and sea level can occur as a consequence of climate change.

The higher flood intensity at the confluence zones, although resulting in lower species richness if compared with upstream sectors plays an important role in determining a relatively unique set of species.

At a regional level, an interbasin evaluation (Amazon and Orinoco tributaries) of the riparian corridor tree species richness of some Leguminosae genus in the Ingeae subtribe has produced important results to be considered in the development of regional strategies (Rosales et al. submitedA). Uniqueness was reflected in high rarity values for the Negro River and the Upper Orinoco-Casiquiare, that in agreement with existing phytogeographycal studies is within an ecologically very distinctive region having the poorest waters and soils and that in the past have a history of fragmentation-connectivity.

Based on the analysis of data regarding spatial variability in riparian forest's species diversity, the theoretical relationships shown in Figure 2 were derived. Variations in inundation intensity (depth), disturbance, fertility and local (alpha) tree diversity along longitudinal gradients all can be adjusted by polynomial functions where intermediate levels in the controlling factor seem to be related to the highest diversity. In that figure, a density dependence curve is shown for the regional (gamma) diversity, a maximum number of species SI, gamma or landscape diversity is expected for a determined ecogeographical region. It indicates similar saturation values in similar riparian landscapes, or grouping of sectors with similar characteristics. A carrying capacity in the number of species for a specific landscape may be a result of phytogeographical history and it can support the hypothesis about how regional diversity may control community saturation (Connell and Lawson 1999).

From a study conducted by Rosales (1990), in the riparian forest of the Mapire River, a tributary of the Orinoco, it is found that a pool of species is able to reach all the functional units in the floodplain (geomorphologic zones). However, given different ecological constraints (physical and biological), the germination, survival, and maintenance of healthy populations of the species will separate the adult compositional groups. Using the Sorensen Index, the author reported high species-similarity at the level of seedlings (up to 63 %), in comparison with trees above 1.5-m height (down to 3%), after evaluating different flooded forest communities located in different habitats (geomorphologic zones).

Habitat-generalists are known to dominate riparian habitats characterised by unpredictable environmental conditions (Kalliolla 1992). A different maximum number of species would be found under different conditions, which involves speciation but also migration and extinction (Terborgh 1992) thus producing S1, S2 … to Sn associated with different riparian landscapes. Disturbance is an important factor in the riparian environment, given that a rate of disturbance in the communities can potentially reach saturation and will be in different successional stages.

An important driving variable related to disturbance is Channel Dynamics (CD) of the river. It describes a disturbance factor as suggested by Kalliola (1992) in the Upper Amazon studies. However, it is important to consider that in different geological regions the energy dissipation of the channel will affect the riparian vegetation differently. In unconstrained channels, or rivers with high sediment load and low gradients, the CD can have high rate values. In constrained bed-rock dominated channels such as the sampled Caura River it seems to have an effect on the successional status of the riparian vegetation of the banks. The CD is therefore related to fluvial disturbance. High levels of disturbance seem to diminish the local diversity but at intermediate levels of disturbance, local diversity is maximised.

The people inhabiting different riparian landscapes will also have different fluvial dynamics and biota compositions to cope with, and being established for many years are able to manage and comprehend the variability of the fluvial environment. As an example, we know that along the centuries, after the colonisation, the 'criollos', settled along the Orinoco or the Amazon rich waters, have been able to adapt cultivation to the times of the year during low waters. (Changes in water level of these rivers can be as high as 17 m.). Also to know where are certain herbivorous fish species according to the tree species that has fruits. That is why, local community participation is basic in achieving sustainable use, as well as traditional knowledge.

2.3. The conceptual model for analysing riparian forest diversity

The conceptual model for analysing riparian species diversity in the context of conservation and management is shown in Figure 2. It includes as major determinants of hydro-geomorphological and water-geochemical variations at a regional scale, known general factors such as climate and geology (Baker 1986). Through evolution of the biota along geological time, it also determines the existence of different phytogeographical regions where the river basins are also evolving. Regarding the physical environment, the hydro-geomorphological variables discharge, sediment load, and gradient associated with valley type, drive the channel dynamics and inundation intensity (depth, duration) in a riparian landscape. The water-geochemistry relates to the potential fertility of the soils, through the sediments deposited in each flood event. Furthermore, the phytogeographic region drives the potential maximum pool of species that can colonise a given riparian landscape. These ecological processes are also related to changes through geological time in the main driving variables, climate and geology. Each river basin is subdivided in several riparian landscapes. Therefore, a module that describes the interactions at the riparian landscape level constitutes the basic unit of the model in which a strategy for management should be based at the local level upon the participation of the local people. It assumes that the diversity values at different levels within a riparian landscape are driven by the Physical variables I = Inundation, CD = Channel Dynamics and Fs = soil fertility effecting through ecological functions (Terrestrialization, Uniqueness and Succession) to regulate the diversity component parts: α = alpha (within habitat) diversity, = beta (between habitats) diversity and γ = gamma (total regional landscape diversity). In the analysis between basins, the scaling-up from the level of functional units, to riparian sectors and riparian landscapes, is considered important when valuing riparian biodiversity conservation in national or regional strategies. All of the relationships shown are related to natural potential variations, whose predictability is physically and biologically determined. However, human use introduces unpredictable events that would affect the potential values. It is here where management actions can be monitored.

Riparian flow predictability proposed by Junk (1997) as an important factor in the development of strategies to deal with environmental changes over evolutionary time scales is also considered in the model. Intermediate to long-term variability in discharge and/or sediment loads at different time recurrence intervals (from short to long-term) will affect flood timing and then predictability in flood intensity, i.e. flood duration and depth in each different habitat. Either effect will occur in channel dynamics (i.e. predictability in the rates of channel migration) or fertility (i.e. in the Amazon basin it means changes from Igapó forests - in floodplains of oligotrophic fluvial environments - to Várzea forests – in floodplains of nutrient-rich fluvial environments). These gradients of predictability will be modulating alpha, beta and gamma diversity through their action over physical and biological functions at different spatial and temporal scales. Patterns of pollination, phenology, herbivory, i.e. by fishes, dispersion, can also be predictable (Rosales et al. 1999a). Unpredictable events can be fire and cattle raising, logging, waste disposal, contamination or increase of sediments from mining activities. Both effects of predictable or unpredictable events in the system have to be analysed by specific studies.

Specific interactions between the physical functions and species diversity at the scales of landscape, sector and unit within the riparian landscape module of Figure 2 are synthesised in Figure 3, using the graphic approach of a qualitative loops method (Puccia and Levins 1985). The loops approach to complex systems stresses qualitative understanding as the primary goal, rather than numerical prediction. Qualitative analysis is used to determine which measurements are necessary knowing the direction of effect of one variable on another. Negative and positive links are mixed with self-effects to explain the nature of the interactions. As a whole, the model in Figure 3 represents a riparian landscape of 2, holding a number of sectors (m) differing in beta diversity, that contains a number of units (n) differing in alpha diversity.

The loop analysis indicate, firstly a cascade effect where gamma diversity has a potential maximum already determined by the historical evolution of the phytogeographical region (external to the module). Secondly, it has a positive effect on alpha diversity providing that the community reaches a saturation level Si. Inundation intensity has a negative effect, few species are able to tolerate or evade the harm effects associated with the flooding condition (Gill 1970). However as the community develops, a terrestrialisation process occurs (higher species and structural diversity increases the chances of sediment deposition) having a negative effect upon the inundation intensity itself.

Soil fertility increases the alpha diversity through increasing the potential source of resources. As the community develops towards a more diverse and structured type, its influences on the soil fertility are expected given that in later successional stages more nutrients are reserved in the system (Bazzaz 1996).

Channel dynamics (CD) is considered in this case the variable determining the number of functional units; CD determines a potential number of functional units. The number of units, together with the value of alpha (within-habitat) diversity for each unit will determine the final values of beta diversity. At the riparian landscape level, beta diversity will regulate positively the real gamma diversity of the system. The interactions can be synthesised by the following general equations:

$$\alpha_i = a\lambda - b(a\lambda) - cI - dCD + eFs$$

$$\beta_j = \sum \alpha_{i,\ (i=1,n)}$$

$$\lambda = (\sum\beta_{j\ =\ 1,\ m})^{(\sum\beta j\ =\ 1,\ m)/S}$$

n = number of habitats = f * CD*

m = number of functional sectors in a riparian landscape

α = alpha diversity
β = beta diversity
λ = gamma diversity
I = Inundation intensity (depth, duration)
CD = channel dynamics
Fs = soil fertility
S = Phytogeographic Saturation Level

The coefficients a, b, c, d, e and f incorporate ecological functions: (i) the coefficient a represents the maximum portion of the pool of species Si reached by the dominant community in the functional unit i, (ii) the coefficient b, biological factors structuring the dominant community in the functional unit i (competition, predation, pollination, dispersion, etc.), (iii) coefficient c, differential tolerance of different species to the inundation intensity harmful effect, (iv) the coefficient d, differential tolerance of different species to mechanical damage, (v) the coefficient e, differential efficiency in use of nutrients for different species. At the sector level, a coefficient f, determining the number of habitats, will be a function of discharge, sediment load and gradient in each sector. It would primarily regulate the number of functional units and the inundation intensities in each of the functional units.

At the level of the communities in a functional unit, the variable alpha diversity starts from a saturated community where there is a maximum diversity determined by the phytogeographical region. Alpha diversity will be then self-regulated by biological processes acting at the scale of the community and it is negatively affected by inundation intensity. The community density associated with mechanical resistance regulates a negative effect for channel dynamics (CD). In addition, CD can induces processes of silting, therefore changing the inundation intensity in ecological time scales and indirectly promoting a higher alpha diversity. In the case of fertility, although it would promote an increase in alpha diversity through the increase of opportunities for species to use the resources, the internal regulation in the community through competitive exclusion would decrease alpha diversity values.

Considering inundation as a stress factor, channel dynamics as disturbance factor and soil fertility as a productivity factor, the theory indicates intermediate levels of these variables to optimise species diversity (Bazzaz 1996; Begon et al. 1996). High levels of stress and low productivity would promote uniqueness and high levels of disturbance would influence successional stages.

3. CONCLUSSIONS AND RECOMMENDATIONS

The development of a body of answers about what, where, and how to implement a network of in situ conservation areas can benefit from the conceptual model presented. Moreover, it can be helpful in defining conservation priorities based on the assessment of freshwater ecoregions proposed by Olson et al. (1995). Further studies have to be done in developing specific relationships in different phytogeographical regions, which needs to be approached with the participation of nations, NGO's, regional stakeholders with responsibility in sustainable development and the local people.

At the local and landscape level, the significance of the model relationships for predicting diversity or structural variables in a floodplain is high. A potential avenue for management arises and in floodplains, the effect of environmental management trough restoration of floodplains, fire-suppression activities, elimination of cattle raising from the floodplain borders on the alpha diversity can be used to monitor the effectiveness of management activities. Also it can be used to model and predict how changes in flood dynamics (depth, duration, frequency) associated with dams construction, navigation or climate change, might affect the local and landscape total diversity of the flooded forests.

At the basin or interbasin scales, comparison of diversities between rivers and the assessment of uniqueness of different riparian landscapes or sectors will be important for analysing conservation values. Furthermore, based on the scaling-up of ecosystem properties, at the level of a basin, riparian sectors and riparian landscape redundancy within ecogeographic boundaries can be estimated as a valuable measure of resilience of the network riparian system (following Walker 1992). A network of unique sectors for *in situ* conservation combined with an adequate management of redundant functional sectors can optimise riparian biodiversity conservation.

Given the political divisions of the major watersheds in South America, that are shared between different countries, and based on a holistic reasoning, a regional multinational strategy for the conservation and sound management of the riparian corridors is needed. It should start with an agreement between the countries that share the basins for: (i) a network of confluence areas, visualised as a network of modular riparian landscape nodes, including the longitudinal potential transition zone to the limit of the confluence node. In doing this, the maintenance of heterogeneity is secured through the maintenance of gamma and beta diversity of the lowlands, (ii) the inclusion of a range of pristine basins representative of different geological regions, (iii) the establishing mechanisms for the integration of local human populations to activities of conservation and management for sustainability of the riparian network. In doing this, education has to be a priority.
Local or trans-national industries currently using energy or navigation commodities, as well as natural resources in the rivers should apply a concept of riparian responsibility. Locally, to diminish industrial wastes and paying taxes, but through a market-based policy, the revenues should be used for research and riparian landscapes management, generating employment to local populations. International or regional industries directly involved in the river use or indirectly through business relations with local industries, should pay attention in helping regional governments to develop an strategy for improving urban's awareness of their riparian environmental responsibilities. Furthermore, the implementation of a network of riparian areas and the development of a regional or pan-national strategy for the conservation of riparian ecosystems. However, political stability is needed to make this work. If government and policies change frequently then continuity will be lacking. This is not a quick fix. Something can be destroyed in seconds and take years to rejuvenate.Through encouragement incentives and penalisation taxes, governments can help industries to think and act 'green'. By providing training facilities for environmental management, companies will be able to employ or have access to relevant resources with skills and information to enable them to make appropriate policies.
Local University programmes could undertake research and training funded by world banks, regional stakeholders, NGOs or associations with national industries.

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