Towards the Renaturalization of Riparian Areas in South America Through an Interdisciplinary Approach: Management Opportunities*

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Summary

Approximately 47 % of the Earth's freshwater flows through South America. However, South America has problems related to the rehabilitation of its riparian areas, which are degraded by deforestation, intensive agriculture, development of many hydropower plants, urban concentration and navigation channels. Preliminary aspects to consider a novel, interdisciplinary approach in management projects over riparian areas is presented. A case study, representative of 300,000 km^2 in South America, with renaturalization opportunities is outlined. The first steps of a Stream Protection Strategy and management opportunities are discussed.

Keywords : Renaturalization - Riparian Areas - Interdisciplinary approach - South America

Introduction

Almost 47 % of the Earth's freshwater flows through South America, carrying 13 % of the total suspended solids delivered by all rivers to the oceans. South America is an asymmetrical continent, with a continuous mountain chain, the Andes, and two high cores: the Guayana and the Brazilian Basaltic Fan. The remaining surface is generally flat. There are three main hydrological systems: the Amazon and Orinoco in tropical latitudes, and the Paraná-Uruguay rivers (La Plata System) in subtropical and temperate regions. However, complex interactions between geomorphologic, biological and hydrological factors of South America's rivers promote new management attitudes towards natural resources conservation. The aim of this paper suggests renaturalization opportunities as one possible management topic, using the approach developed by Kobiyama et al (1998) in representative biomes of South America and through a Stream Protection Strategy with REBRUSH assumptions (Mendiondo et al, 1999).

'Re-managing' of South America rivers: Linking the gap between Amerindian's practices and real needs of having 'lessons learned'

Before the arrival of the Europeans on 1500s, approximately 70 million Amerindians inhabited South America without seriously affecting their immediate environment (Ginés and Vásquez, 1990). For indigenous people of the Amazon, Orinoco and La Plata Systems, the rivers were ever the lifeline. Many archaeological deposits, dated before the 1500's Spaniard and Portuguese arrival in South America, confirmed the long tradition of indigenous people of hunting and travelling along watercourses. Amerindian people thought rivers were 'architects of nature' because the high diversity of fauna and flora live in. For that reason, indigenous people called rivers as 'living routes' (Geobiohydrology Forum, 1998, pers.comm.). Furthermore, two centuries ago, Alexander von Humboldt's *Voyage aux régions équinoxiales du Noveau Continent*, according to the German version from Lamuv *Die Reise nach Südamerika*, said:

> *„Die periodischen Überschwemmungen, besonders die Trageplätze, über die man die Kanoes von einem Nebenfluß zum anderen schafft, dessen Quellen in der Nähe liegen, verleiten zur Aunahme von Gabelungen und Verzweigungen der Flüsse, die in Wahrheit nicht bestehen. Die verschiedensten Indianerstämme,welche dieses Wasserlabyrinth befahren,geben den Flüssen ganz verschiedene Namen, und diese Namen werden durch Endungen,welche »Wasser, großer Wasser, Strömung« bedeuten, unkenntlich gemacht und verlängert. Wie oft bin ich beim notwendigen Geschäft,die Synonymie der Flüsse ins reine zu bringen,in größter Verlegenheit gewesen, wenn ich die gescheitesten Indianer vor mit hatte und sie mittels eines Dolmetschers über die Zahl der Nebenflüsse, die Quellen und Trageplätze befragte! "*

Five centuries after, the inhabitants of South America are challenged not only with an ever increasing population -near 80 % inhabitants living in urban areas -, but also with the task of developing methods for using the natural resources which will prevent irreversible ecological damage, with emphasis in river management. Nowadays, South America population has a growth of 2.4 % /year, with the 20 % of the world's exploitable hydro-power potential - approximately 3,300,000 GWh /year, but only 10 % of this is used-. About 70 % of total water use is for human activities, and 90 % of irretrievable losses are due to irrigated agriculture. However, deforestation in South America is due to development programmes involving resettlement agriculture. Contrary to Europe in which industry has the major river-demands (DFG, 1995), in many tropical and subtropical regions agriculture is the biggest water-user.

The need for a interdisciplinary approach to the recovery of degraded river corridors: the case of the Geobiohydrology approach (Kobiyama et al, 1998).

Could interdisciplinary management on riparian, degraded ecotones be addressed as a new 'hot spot'? This answer relates to some factors which are emerging in scientific teams, often interdisciplinary, about the river management. Rivers are systems in which water, nutrients, sediments and organisms pass through a certain section at a certain speed (Neiff, 1996). Therefore, these pulsatile systems present biological variability during the flood-phase (potamophase) and dry-phase (limnophase). South America´s rivers have two characteristics. First, large rivers are dominated by transverse interactions between the main channel and the adjacent floodplain. Secondly, there is the dependence on the riparian and floodplain zones.

A characteristic of rivers is that maximum ecological diversity and productivity are associated with river´s margins as an *ecotone* system. This ecotone is a zone of transition between two ecological systems (Boetzalaer et al, 1991), having a set of characteristics uniquely defined by space and time scales and by the strength of interaction between adjacent ecological systems. In management area, the role of the ecotone concept is to focus attention on the terrestrial system-lotic system boundary. So, three actions to promote are: i) flow management and ii) channel management to sustain ecotone processes at large scales, and iii) channel management, controls on biota, and controls on human activities for management at smaller scales.

Based on international as well as South America 'lessons to be learned', with emphasis in river environment, Kobiyama et al (1998) encourage the approach of *Geobiohydrology* (the name is merely to pursue an idea of interdisciplinary work with scientific teams come from geo-, bio- and hydrological sciences) as a novel strategy in order to relate three elements: man, nature and technology. These elements are strongly related on riparian areas and pay attention in three *attitudes*. Firstly, there are necessary political parameters which could create constructive relations between the South America populations and their rivers, in a more friendly manner and not only as an exploitation way. Secondly, and because of the former, there is a common sense in researchers to re-evaluate the knowledge stored by the Amerindian tribal societies who have interacted with the river systems for over 10,000 years. And thirdly, there is an urgency to analyse meticulously, as well, the success and the failures which the non-Indian population has accumulated over the past 500 years.

An example: opportunities of renaturalisation on 300,000 km^2 of degraded, subtropical riparian areas on headwaters of La Plata System

South America has twice the size of Europe and many heterogeneities between her three large systems (Amazon, La Plata System and Orinoco). The emphasis in this section is on the La Plata System, which has a total discharge equal to (Neiff, 1996) 85 % of *all* European rivers together. There are two regions of headwaters of La Plata system where restoring measures are possible: the Upper Paraguay River, draining to the Pantanal System, and the Paraná-Uruguay headwaters.

The Parana-Uruguay transboundary rivers form the second and largest hydrological basin of South America and are the most intensively developed, with 100 million inhabitants. Also, they are the focus for most development by large dams over the next decades by MERCOSUR countries: Argentina, Brazil, Paraguay and Uruguay. The headwaters are covered by the South Brazilian Basaltic Fan, representative of 300,000 km^2, between 49^o-56^o W and 24^o - 30^o S in Southern Brazil, Northeast Argentina and a small part of Paraguay. Hence, 70 % of inhabitants and 50 % of GNP of MERCOSUR countries are from this area.

In the past, this humid subtropical biome was characterised by varied forest, dense drainage and rich clay soils. Throughout the last 25 years, the area has been mainly transformed by

Soya bean production in 1970s. But today, less than 10 % of natural vegetation remains as riparian forest in the incised valleys of headwaters (Mendiondo, 1996). In average, this area has aproximately between 1.8 to 2.7 hectares of natural forest per capita. Forest clearance, poor cultivation practices and excessive use of agrochemicals have caused problems of soil erosion and water quality in streams.

The main areas with hydropower potential are on the upper Paraná River and on the River Uruguay. For instance, Brazil´s energy is largely supplied by hydropower (93%), and between 1965 and 1985 many dams were built for energy production on the Paraná River which yields more than 50 % of all Brazil´s energy production (Tucci and Clarke, 1998). In an area of 300,000 km^2, water corridors have great differences between them but they also have the same characteristic: they all maintain different kind of lifeforms. Another reason, is that only small portions of natural rivers corridors remain in their natural state but with increasing degradation due to the high pressure from agriculture (Mendiondo, 1998), urbanisation and hydropower generation and withdrawal demands (Tucci and Clarke, 1998).

Experiences on representative catchments of the 300,000 km^2 of South Brazil Fan shows that, for long as well as wet periods, the total streamflow production per unit area from basins with riparian vegetation is lower than basins without this coverage (Mendiondo, 1996). The discharge coefficient of nested basins, monitored together, provides a key factor to re-create short- and long-term scenarios of recovery, through alternative approaches, i.e. as presented by Kobiyama et al (1998). Some of the methodological questions of this approach are presented in Table 1, accordingly to the example above and friendly-manner options related.

Innovative measures for good practice in river management.

Some principles of friendly-based options are: to leave existing habitat untouched as far as possible ; where this cannot be done, to retain al least part of the habitat, from which plants can recolonise degraded areas; and to leave such areas as physically diverse and uneven as possible, in order to speed up recolonization by wildlife (Purseglove, 1988). Good river management also aims at maintaining, and in many places extending, a buffer for wildlife between the actual watercourse and the adjacent land. Some measures could be done, i.e. working from one bank and maintaining the other bank untouched; untidy banks; living riverside margins with over-widening the channel; pools within the river and riffles; meanders retained ; flood relief channels ; riverside buildings; ponds and bank reinforcement with trees.

Relating to traditional engineering experience in prismatic or regular channels, Purseglove´s summarises (p.171): ”*Engineers who train machine-drivers to produce such impeccable crafted neatness must be frustrated pyramid-builders; they certainly do not think very hard about the true nature or rivers”*. Moreover, this comes from another hydrological experience: when an engineer has to design and build riverside measures as part of his scheme, he can adopt an approach will reduce the expense of the project. Anyway, these commentaries pay attention in what engineer´s practice tells when working on water project: the creative, environmentally-based engineering is consequence of an integral work *with* the river and its margins.

Biologically-based engineering.

The term biological engineering was first formulated at the end of the 1930's (Pflug, 1982). Since then, it has come to be used to cover aspects of civil engineering which emphasises techniques based on the science of biology, particularly using the knowledge gained through biological and ecological studies of landscapes in the construction and maintenance of earthworks, water engineering and shorelines. The aim of these *biologically-based engineering* measures, called as BioBE, is about the plants or parts of them could be utilised as living construction materials which, in the course growing together with earth and groundwater, afford greatest contribution to permanent protection and preservation of a whole system. Construction measures using biological engineering are based on technical skills. For many years, these measures have been applied in the light of experience (Kirkwald, 1964 ; Kern and Nadolny, 1986), with systematic scientific research, improvements and with new developments have been undertaken also (Tönsmann, 1996), into the way of operation, effectiveness, especial cares and maintenance.

In South America, isolated efforts on BioBE methods are scarce. BioBE measures in water courses, if correctly applied and maintained, are in many cases far superior to comparable methods using inanimate building materials. The growth of vegetation cover resulting from BioBE methods not only meets technical demands but also serves aesthetic considerations for the landscape, as well as a ecological function. The suspicion which engineers who have preferred to see vegetation-free runoff channels have felt with regard to the use of trees and shrubs alongside the running waters is lessening, as a direct result of a growing awareness of the need for environmental protection, in favour of greater approval.

Renaturalization in Context of BioBE Measures

The Research Agenda of IAHR (1993) divided in three parts: river processes, re-naturalization of river environment and long-term evolution. Related to the second one, the restoration of riparian and floodplain habitats, including the floodplain forests, is a major focus for both scientists and river managers in many European countries. Thus, that was the subject of a recommendation of the Committee of Ministers of the Council of Europe, in 1982. For example, between 1983 and 1993, 46 % of German hydraulic research projects were dedicated to problems of naturalization of river and creeks (DFG, 1995).

Some definitions are necessary, like the meanings of disturbance, resilience/resistence and the family of renaturalization concepts. Firstly, *disturbance* is any relatively discrete event, in time, that disrupts ecosystem community or population structure and changes resources, substrate availability or physical environment. Secondly, *resiliency* could be the ability of a disturbed community to recover to a state before the disturbance. Conversely, *resistance* as a related form of system stability, is the ability of a community to initially resist a disturbance.

Finally, but not least, we have definitions on the recomposition of disturbance –called as the renaturalization´s family concepts, i.e. recovery, enhancement, restoration / reclamation, rehabilitation and renaturalization, each of them with slightly but important differences. *Recovery* is the process of species returning to *normal* population levels after disturbance, in a normally way. In other hand, *enhancement* means to improve the current state of the ecosystem without reference to its initial state. However, *restoration* is a process that involves management decisions and manipulation to enhance the rate of recovery. In this context, river restoration is a recovery enhancement and considers a technique to enable disturbed river ecosystems to stabilise at a much higher rate than through natural and biological recovery processes of habitat development and colonisation. In this context, the term *rehabilitation* is probably a mixture of enhancement and restoration.

Furthermore, if a natural condition could be defined, the measures that help a system to back to nature in a naturalistic way is usually refereed as *renaturalization*. The question that takes place is to recognise the difference between terms as *natural* and *naturalistic*. The former relates to a virgin-non-disturbed habitat with a characteristic ecosystem, either in flora or fauna. However, the later refers to BioBE measures to rehabilitate or restore degraded riparian corridors due to, for example, intensive farming with pesticides and burn-and-slash incursions and, often, the crash of traditionally-engineered structures near rivers, causing breaking and piping of river levees, and flooding surrounding areas.

Obviously, there are another alternative purposes in water management further of the renaturalization concept (Flickinger, 1999 ; pers. comm.). But the research on renaturalization's measures provides a plausible way of evaluating some 'lessons to be learned' in consequence of a developing era that South America is still experiencing.

Renaturalization of riparian areas: a small-scale re-colonisation on river margins to counteract the degradation of extensive, degraded uplands

The latest global figures on forest cover (FAO, 1999) indicate that in 1995 there were 3454 million hectares of forests (including natural forests) world-wide. Between 1985 and 1995 the total area of forests decreased by 56.3 million hectares - the result of loss of 65.1 million hectares in developing countries and an increasing of 8.8 hectares in developed countries-. Major causes of forest cover change include: conversion of forests to agricultural land and large infrastructures and development in developing countries and, in contrast, forest growth on abandoned agricultural land in developed countries. Riparian habitats of developing countries could not be restored without an holistic management on basins and river together.

The layout and maintenance of riparian ecosystems follow, firstly, basic principles of silviculture but they present special problems. Of course, their location is very different from that of most chosen for silviculture. They are exposed to various influences of river pulses (Neiff, 1996) depending on their vertical occurrence and zonation choosing species, their culling and pruning, composition and conversion, accounting above all of floodwater discharge, bank stabilisation and water ecology factors. For this reason, only selected species, like the riparian indigenous ones, can be adapted to these factors.

Renaturalization related to riverside uncertainties: first REBRUSH assumptions (Mendiondo et al, 1999) as one alternative Stream Protection Strategy

In hydraulic research a growing number of investigations were dedicated to interactions between discharge, river bed geometry and vegetation. As more and more rivers were naturalised, this development became necessary to ensure the scientific basis of hydraulic dimensioning. River engineering shifts from pure utilisation technology towards biological structures and to hydraulic research.

More recently, Clarke et al (2000) show examples that South American rivers have errors in their hydrological database. Parts of these errors are source of imprecise, ill-posed and insufficient_knowledge of the dynamics of riparian area interactions, their successional behaviour before and after floods and, of course, the lack of communication between research areas. This framework produce inherent uncertainty in flow records and, in this way, in annual_water balance of freshwater in the World.

The question is: Can we derive some insights on renaturalization measures from simple, standardised, transferable *but* uncertain data which are monitored on riparian ecotones?. This is *one* of the questions addressed in a Research Project between the Instituto de Pesquisas Hidráulicas, IPH-UFRGS, Brazil and the Wasserbau und Wasserwirtschaft, Univ. Gh Kassel, Germany. Questions like the above are addressed here by REBRUSH assumptions (Mendiondo et al, 1999). Nowadays, this approach is done through a multipurpose layout as the RUHE program, a German abbreviation of *Renaturierte Uferökosysteme mit Hochwasserabflußunsicherheits-Annäherung der Einzugsgebiete* (see Table 2).

There are two blocks in the RUHE program. The first of them, the RUHIG block, relates to hydraulic, biological and geomorphologic formulae, as part of the Geobiohydrology approach of Kobiyama et al (1998). The second block provides multipurpose management through the relationships of renaturalization topic as one of several conflicting uses of riverside areas. In the following words, we present only four REBRUSH assumptions.

First REBRUSH assumption

On Table 2, one plausible REBRUSH´s assumption is to relate part of these errors or variability to the main factor affecting the streamflow during floods: geometrical conveyance, roughness in the wetted perimeter and friction slope –the RAHMEN step on Table 2-. These *factors* are the result of using simple hydraulic formulae, since A.von Humboldt time (i.e. Chézy formula). For that reason, the total variance decomposition of these factor represents one starting point to relate the effects, say, of riparian vegetation (abundance, spatial frequency, zonation, etc.) to discharge.

Second REBRUSH assumption

The second assumption –the MEHR step of Table 2- is that in order to have a near-optimal condition of behaviour, we need to *mimic* normal disturbances of rivers in several ranges of potential responses. This hypotheses looks for range of errors in order in a free-manner as the river really responds to disturbances.

Third REBRUSH assumption

The third assumption –the FREUND step of Table 2- tells about in what way the natural mimicking of environmental responses, which has been decomposed by the inherent variance, expresses *resiliency* conditions (see above), but not to stability. Stability does not imply resiliency, which is the ability of a system to accommodate surprise and to survive or even to recover and thrive under unanticipated perturbation (Fiering, 1982). On one hand, Fiering´s concept of resiliency is similar to the property of robustness as applied to statistical estimators. In other hand, and merging Fiering´s resiliency concept with a law of propagation errors, it is equivalent to compare total derivatives with respect to partial derivatives (Fiering, 1982). If the partial derivative of, say, the geometrical conveyance of a cross-sectional area of a river is small, the system expressed by the discharge variance is robust, in Fiering´s words, with respect to geometrical changes.

Fourth REBRUSH assumption

The fourth REBRUSH assumption, implemented in the RUHIG block, is related to the process of management decisions aided by BioBE measures, over the cross-sectional areas of rivers, to produce a change on factors that affect river discharge –the BUSCH step, Table 2. Today, hydraulic and statistical approaches are made on this last step (Mendiondo et al, 1999).

Future actions: more resilient habitats related to uncertainty-addressed strategies

Firstly, in South America there are short- and long-term actions to be planned. In the short term, some of the most difficult challenges of implementing the initiatives occur at the interface between different sectors. For example, in April 1998, the Government of Brazil announced its intention to put 25 million hectares of rain forest, under protected area status (FAO, 1999). Nevertheless, cross sectional issues are complex to resolve because they require co-ordinated actions of different branches of government (OAS, 1999, p.22). The interface between water and health is only one set of cross-sectional issues, as well as sustainable agriculture, water and biodiversity, water and tourism development. Very often, these situations create conflicting uses that must be resolved by participatory teams (Flickinger, 1999, pers. comm.). But in the longer term, mechanisms must be set in place to define a vision of where the society wishes to be in the future. The World Water Council (WWC) established a World Commission on Water for the XXIst Century to provide over all direction to the creation of a Long Term Vision on Water, Life and the Environment in first quarter of the next century.

Secondly, it must be recognised that riparian areas are fragile ecosystems. Although these forests generally have relatively low timber value, their important social and environmental function have been increasingly recognised in Management Decisions. Forests role in Water Conservation is expected to give more prominence as international attention increasingly turns to freshwater resource issues. Some of the management opportunities could be:

(i) Focus attention of riparian areas as "hot spots" with opportunities to sustainability and as ecotones for living, i.e. from a *geobiohidrological attitude*

(ii) Preserve river ecotones and habitat integrity, many of them which have high archeological, historical importance;

(iii) Recover, in a BioBE manner, some degraded, riparian habitats in South America, i.e. the representative area of 300,000 km^2 of MERCOSUR countries presented in this paper;

(iv) Re-integrate the fragmented riparian corridors, enhancing these natural detention areas when high floods occur;

(v) Recover the riparian and floodplain forests, especially the indigenous, rarest gallery forests, promoting rational and BioBE measures, allowing for the uncertainties;

(vi) Renaturalizate floodplains in a way to filter and mitigate the rapidly sediment- and nutrient migration from headwaters to the main rivers;

(vii) Provide environmentally flood protection by a Stream Protection Strategy, like the REBRUSH assumptions or another ones, with a natural sequence mimicking the Hydrological Cycle: from headwaters to lowlands; so, the main key for this project is a strong strategy in the headwaters first, working in a small scale, and then, to continue in the following, downstream reaches, and so on.

(viii) Promote the beginning of these actions in representative catchments of the large biomes of South America;

(ix) In a secondary term, the above actions will help as better source of recreation, preserving the ground and surface water for other purposes, relating to the other conflicting uses.

Finally, South America countries are deeply depended of flood protection. River regulation and hydro-power plants have contributed throughout the last twenty years to a loss of biodiversity of South America rivers. Today, there is an urgent need of linking the gap between three vital components: i) people's communities -as small villages and farmers-, ii) government surveys and iii) scientific research staffs. As a result, modern water management relies on flood protection by leaving flood areas with three potential actions : i) with amelioration by usually hard engineering works, ii) undeveloped, i.e. without works, or iii) with BioBE and Stream Protecion Strategy through renaturalization measures through Geobiohydrology and REBRUSH assumptions. So, measures which increase flows will be avoided, while natural retention areas must be preserved and, in many cases, restored.

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Table 1. Methodological questions on renaturalization from Geobiohydrology's approach

Factor	Description
Renaturalization	How the renaturalization of wildlife habitats, riverine and riparian strips is addressed in master planning projects, to identify a Stream Protection Strategy in Brazilian, Argentinian and Paraguayan headwaters?
Stream Protection Strategy	In what manner the Stream Protection Strategy planning allows that landscape restoration would be the target to ensure the ecological engineer's objective of fragmented habitats?
Resilient Devices	How habitat reconstruction can be addressed, regarding in maintaining "ecologically river stages", to resist "flood extreme events" and to minimize economic costs of naturally- designed protection devices, as a way of a resilient management option ?
Quantification	How to measure habitat quality of restored landscapes? What is the restoration impact of management on species of conservation?
Cooperation	What kind of International Research Projects could be addressed for ?

Table 2. The RUHE program as part of REBRUSH assumptions (Mendiondo et al, 1999)

RUHE Program	*Renaturierte Uferökosysteme mit Hochwasserabflußunsicherheits-Annäherung der Einzugsgebiete*
RUHIG Block:	*Renaturierte Ufergebiete bei Hochwasserabflußunsicherheit im Gerinnesystem*
Step 1	RAHMEN: *Rauhigkeit-, Abflußkapazität- und hydraulische Gefälle-Modellzerlegung in der Eichkurven-Naturähnlichkeit*
Step 2	MEHR: *Mimik-Eichkurve mit hydrodynamischer Randsimulation*
Step 3	FREUND: *Feuchtgebiet-Reaktion bei Empfindlichkeit und Umweltbelastbarkeit der Nebenfluß-Daten*
Step 4	BUSCH: *Bachauen- und Uferwaldrenaturierung mit Schutz vor Hochwasserabfluss*
FREIGABE Block:	*Fließgewässermehrzweckmanagement mit Renaturierung und eichender Umgestaltung der Gerinnesystemnutzungs-Änderung und Bachauen-Entwicklung*