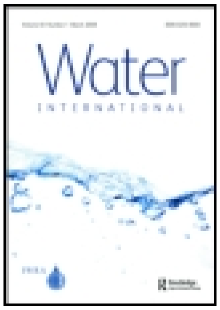

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Competing Freshwater and Ecological Services in the River Basin Perspective
An Expanded Conceptual Framework

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Abstract: *A river basin approach focusing on upstream/downstream conflicts of interest has to involve attention both to the services that water itself provides to society, and to water-related ecosystem services, terrestrial as well as aquatic. Besides "blue water" flow, i.e., liquid water flows in rivers and aquifers, attention has to be paid to "green water" flow, i.e., the water vapor flow involved in plant production. Basically, the rainfall over the basin is what must be shared between those upstream and those downstream. To satisfy societal needs, humans have to manipulate various landscape elements. These manipulations — due to fundamental water functions — will produce side effects ("environmental impacts"). In an integrated basin approach, it is necessary to include side effects of water-impacting land use conversions upstream on water-dependent activities and ecosystem health downstream. A fundamental challenge is therefore to find ways and mechanisms by which reconciliation can be developed among land use, water use, and ecosystem health, and between upstream and downstream activities.*

Keywords: *Blue water services, green water services, water-impacting land use conversions, ecological services, upstream/downstream conflicts of interest.*

Needed Renewal of the In-the-Box Thinking

The world is running into more and more complex water problems, but much of the debate tends to concentrate on one thing at a time: water supply, sanitation, water treatment plants, irrigation, water storage, hydropower development, sectoral pricing, etc. Moreover, the approach to freshwater has been highly incomplete with its focus on water itself, rather than on the services that the water provides. And many politicians continue to be "water blind" without much preparedness for the looming water crisis.

Already in the 1980s, the IWRA Committee on Water Strategies for the 21 Century started to address this "water blindness." Major contributions included two special sessions at IWRA Congresses, both leading up to widely circulated IWRA Statements: the first after the Ottawa Congress in 1987, severely criticizing the Brundtland Commission for its water blindness, the second after the Rabat Congress in 1991, drawing attention to the problems of an intensifying water scarcity with links to land use problems and the deteriorating ecological fabric in the semi-arid tropics and subtropics.

A deepening quantity/quality dichotomy among professionals, legislators, and institutions has further led to a widespread neglect of water pollution and its implications for future water use. Water quality has been addressed separately from water quantity and the dilution flow that it contributes. In Western countries, there is almost a paralysis to such non-technical problems as eutrophication and non-potable levels of nitrate in groundwater. The diffuse sources of these problems in traffic and agriculture both remain largely unabated.

In developing countries, water pollution is addressed by reliance on an inverted U-curve, which implies that a society should wait for GNP to rise enough to allow the financing of pollution abatement structures. A characteristic of the monsoon climate is, however, the lack of dilution water during the dry season. This approach may therefore produce societal collapses ahead of the intended GNP rise. The consequence is that large parts of the world are moving towards a widespread "hydrocide," i.e., a situation where the available freshwater cannot be used for any societal purpose (Lundqvist, 1998).

In recent years, a rising interest has been paid to the freshwater-marine water continuum. Increasing attention has been devoted to land-based sources of pollution contributing to coastal ecosystem degradation. It is, in other words, increasingly realized that coastal waters cannot be protected without analysis of the causal chain to human activities in the catchment and the pollution that these activities generate.

The conceptual framework inherited from the past turns out to be insufficient as a tool to address the increasingly complex water-related problems of tomorrow.

The result can be seen in the general paralysis, quantity of lip service, and large redundancy in the water policy debate. This includes an overreliance on policy principles developed some ten years ago (the so-called Dublin principles — more or less institutionalized in the instructions to the Global Water Partnership). Especially disturbing is the general laissez-faire attitude in relation both to land use and to water pollution, which is continuously reducing the use options of the available water. Equally disturbing is the poor bridging between water management and ecosystem health.

One effort to try to break this apparent standstill is the world-wide action of the World Water Council in terms of the presentation of the World Water Vision 2025 at the Second World Water Forum in The Hague in March 2000. The Vision is aimed at the broadest possible consensus. It therefore had to build on the conventional "in-the-box" thinking. What was new was the large interest paid to driving forces and so-called "out-of-the-box" developments (biotechnology, information technology, economy, institutions).

Neglected Water Use: Rainfed Plant Production

A fundamental problem with the dominating in-the-box thinking is the concentration on water itself, neglecting water use in water-driven plant production, e.g., in rainfed agriculture, pasture, and forestry. The reason for this neglect is the temperate-zone bias that still seems to dominate much of the general debate. Dry climate countries with warm or hot climate have come to realize the hard way that there is a close connection between the water vapor consumed in plant production and what remains of the rain to produce groundwater and river runoff. Australia suffers from large-scale water logging and salinization as a result of deforestation. South Africa even introduced a system of permits for foresters with reforestation or afforestation in mind.

The link between vegetation and vertical transport of water vapor first attracted wider general attention in the discussions around the climate change in the humid tropics and the possible influence of clearing tropical rainforests with their considerable vapor flows. The reason why these flows have much larger relevance in the tropics than in the temperate zone is the much larger potential evapotranspiration due to a hotter atmosphere.

A recent article by Rockström et al. (1999) reports on efforts to bridge ecology and hydrology in order to clarify the key roles played by water in humanity's life support system. The water cycle functions as the bloodstream of the biosphere. Life started in water and has through the millenia developed from basic preconditions in terms of availability of water and mineral salts. Life itself has been modified, and thereby the preconditions have been modified, as illustrated by today's effects of deforestation, afforestation, alien vegetation, etc. As will be shown in this paper, plants are not just water wicks transmitting a water flow to the atmosphere, but are active in the water partitioning itself.

This insight has made it more and more evident that what has to be shared between human activities and ecosystems upstream and those downstream in a river basin is not the water currently going in the river as codified by the UN Convention on Non-navigational Uses of International Water Courses, but rather the rainfall over the river basin. As a consequence, sustainable water-dependent socioeconomic development will not be possible unless an integrated perspective is taken on all water-related activities in a river basin, water-dependent as well as water-impacting. This paper will discuss a number of issues that have to be taken into account in order to arrive at a more credible vision of how to attain a sustainable world when seen from a water perspective.

Freshwater – The Bloodstream of the Biosphere

Freshwater is in reality a key element in the biosphere, where it transports nutrients to and waste products away from cells. Through its physical, chemical, and biological involvement, water has absolutely fundamental balancing functions in the natural landscape (Ripl, 1995). Water dissipates the solar energy pulse in space and time through three main processor properties of water: physically through the interaction between evaporation and condensation, chemically through the interaction between crystallization and dissolution, and biologically through the interaction between cleavage of the water molecule in photosynthesis and the reassemblage through respiration.

These fundamental roles of freshwater make it essential to develop a conceptual framework that pays adequate attention to all the main roles played by this substance. The neglect of the interaction between freshwater and the life support components of humanity did not become alarming until humanity had grown in scale so that the ultimate resilience of the ecological fabric started to cause concern (Falkenmark et al., 2000). Figure 1 is a macro-scale mental image of the freshwater circulation in the water cycle, acting as the bloodstream of the biosphere with its water-dependent, nested ecosystems. Society depends both on the freshwater services provided by the direct use of water in rivers and aquifers and on the ecological services provided from the ecosystems. The latter include the indirect water services provided through plant production, an enormously water-consuming process (see Gordon and Folke, this issue).

Complementarity and Redirection of Green and Blue Water Flows

The conventional water resources approach has been focused on blue water, i.e., liquid water flows in rivers

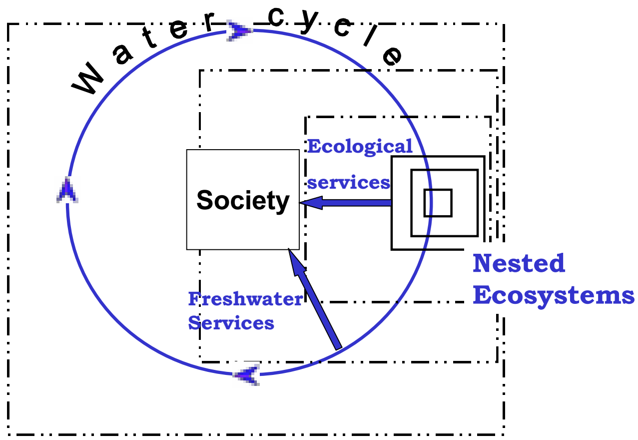

Figure 1. A macro-scale image of key relations between society, the freshwater services, and the ecological services on which its activities depend. Source: Falkenmark et al., 2000.

and aquifers. A fundamental expansion from this approach is the introduction of green water, i.e., water vapor flows (Figure 2). Human livelihood security is related to safe access to household water, to water-dependent ecosystem services including food production (crops, fish), and to income generation (industrial production, cash crop production). All depend on human interventions with green as well as blue water flows.

Society, in other words, benefits directly from both branches: from the green for biomass production (food, fiber, pasture, fuelwood, timber) and from the blue for water-dependent societal water uses (water supply, industry, irrigated agriculture, hydropower). It also benefits indirectly through a multitude of other ecosystem services provided by both the green and the blue branches.

The relevance of the complementarity between the green and the blue water flow branches becomes evident

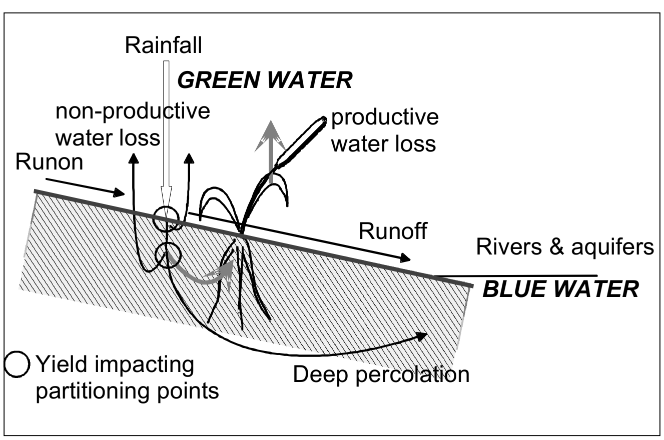

Figure 2. Partitioning of rainfall into two main branches: the vertical branch of green water flow (water vapor) and the semihorizontal branch of blue water flow (liquid water) passing through aquifers and rivers.

when addressing the need for rapidly expanded food production in regions where most of the crops are rainfed and many of the farmers are illiterate. Upgrading rainfed agriculture will call for improving both the infiltrability and water holding capacity of the soils, and the water uptake capacity of the roots by protection from dry-spell-related plant damage (Rockström and Falkenmark, 2000). The crucial question here is to what degree the green water flow will have to increase to intensify food production in the poverty-stricken dry climate countries, which are those with the most rapid population growth. The question is crucial because a green water increase is equivalent to a blue water decrease, i.e., a river and/or groundwater depletion.

As already indicated, forestry has a clear effect on blue water production in dry climate countries. Typically, deforestation on the one hand increases the runoff due to a decreased green water flow, while on the other impermeabilizes the soil, thereby reducing groundwater recharge and therefore dry season river flow (Sandström, 1995). The consequence here is a dry season river depletion combined with wet season floods. It has been suggested that the massive river depletion reported from China's Yellow River may reflect this combination.

Conceptualizing Land-Water-Ecosystem Interactions

Ecological services can be decomposed into elementary services, some of them physical, others chemical and biological (Falkenmark et al., 2000). Physical services include enhancement of soil permeability through macropore formation by the roots, soil surface protection by the vegetation cover, and sedimentation where the uplift of rapidly moving water down a river ceases. Chemical services include phenomena such as oxygen production and carbon dioxide uptake through photosynthesis, denitrification through the action of microorganisms, and nitrogen uptake by certain plants, widely used in agriculture. Biological services include phenomena such as pollination by insects, a key component in plant production; biomass production through photosynthesis; and seed dispersal by birds. These and other elementary ecological services tend to combine into long chains and fabrics of ecosystem components. Birds, for instance, depend on water-dependent terrestrial and aquatic habitats.

To satisfy societal needs for water, food, energy, goods, and services, humans generally have to manipulate various landscape components (soil permeability, slope, water courses, river flows, water tables, etc.) [Falkenmark, 1997]. Due to special properties of water, these manipulations will produce side effects (generally spoken of as environmental effects). Side effects can occur as a result of changed water partitioning at the ground surface, influencing both the water flow down the catchment and the vapor flow to the atmosphere, and perhaps even the vapor flow producing precipitation downwind. Water's function as a carrier of solutes and silt contributes to the transport of substances in the landscape and affects water quality. The side effects manifest themselves in changes in water quality and quantity, with higher order effects on water-dependent flora, fauna, and biodiversity. Finally, water cycle continuity generates chain effects proceeding from the atmosphere to the land and the terrestrial ecosystems, to groundwater, rivers and lakes, and aquatic ecosystems, to coastal waters and ecosystems.

Due to water's many parallel functions in the natural landscape, it is deeply involved in generating ecological changes in both terrestrial and aquatic systems. Figure 3 visualizes water-related causal chains between key ecosystems goods (biomass harvests) and services (biodiversity) and human activities in the landscape related to food, water and energy supply, and the generation of income. Two types of landscape manipulations are important: on the one hand, direct manipulations of water flows and quality (flow control, water withdrawals), and on the other, manipulation of land and vegetation, thereby influencing soil permeability and rainwater partitioning and, consequently, water flow changes.

In clear wording, this means that the attention that is currently being concentrated on direct, visible changes of wetlands and other ecosystems is incomplete. It will have to be complemented by attention also to indirect, invisible, creeping changes that are linked to water's movement and quality transformations as it moves through the catchment, above and below the ground surface. It goes without saying that successful protection of a certain ecosystem such as a wetland depends on sufficient understanding of its water dependence and the particular threats from which it must be protected. Similarly, to protect a certain species, the habitat of that species has to be protected against invisible, creeping changes linked to the water-dependent dimension of that habitat.

Both Vertical and Horizontal Perspectives Needed

In an integrated approach covering both land use and water use, and both upstream and downstream human activities, side effects of upstream water-impacting land use conversions on water-dependent activities and ecosystems downstream have to be carefully considered. Land use influences water partitioning between green and blue water flows and, therefore, water quantity and pathways through the landscape. It may also involve introduction of polluting agents along water pathways and therefore influence water composition and quality.

Human activities in a river basin have to be categorized in order to clarify the main conflicts of interest. Conflicting stakeholder interests in a river basin can be schematically systematized into water-impacting activities upstream, which involve land and water manipulations and influence water flow and quality, and water-dependent activities and systems downstream, which are influenced by water flow and quality characteristics (Figure 4).

First, water-impacting human manipulations may be

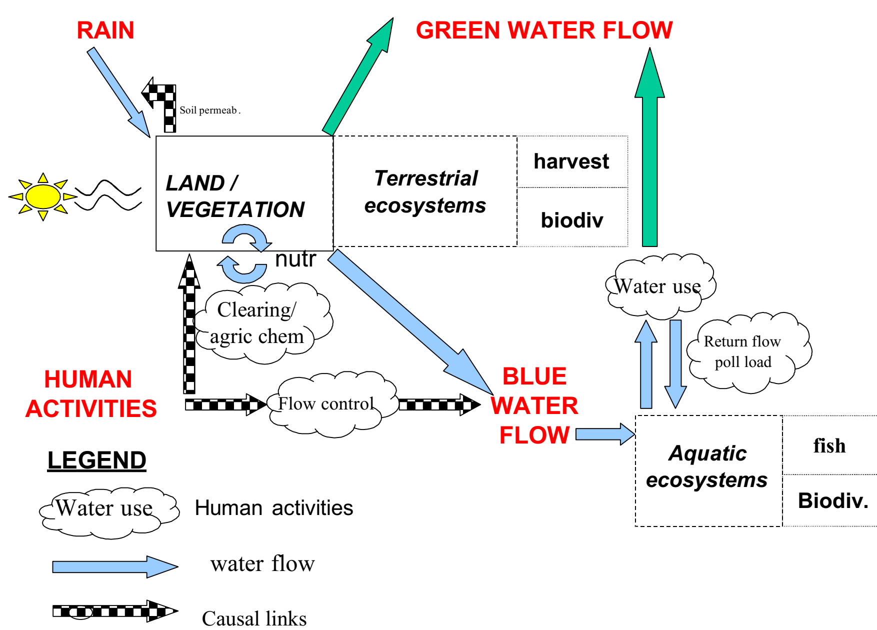

Figure 3. Water-related causal chains between key ecosystem goods (biomass harvests) and services (biodiversity) and human activities in the landscape related to food, water and energy supply, and the generation of income.

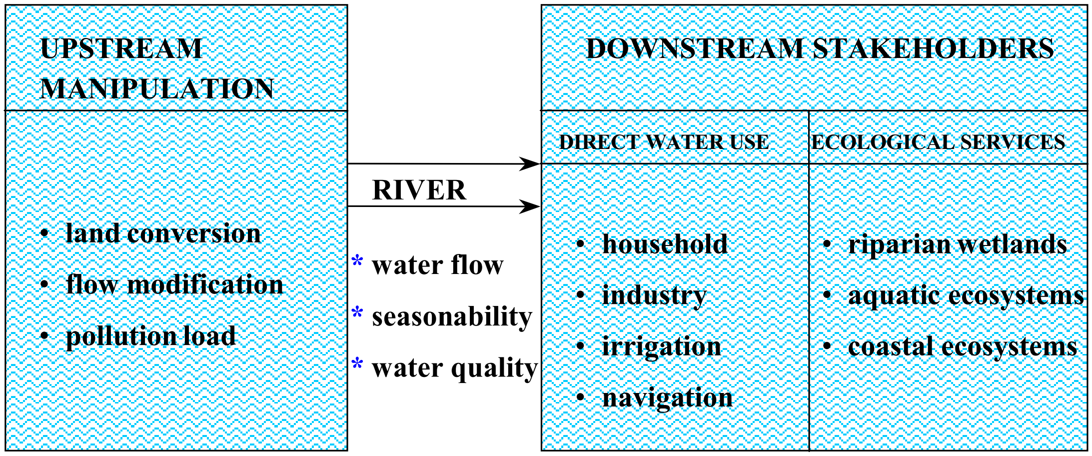

Figure 4. Schematic presentation of conflicting stakeholder interests in a river basin.

linked both to the land use and to the water use. As already stressed, land use has links to green water flows, and land use conversions may involve blue/green redirections of water flows. Typical examples from Australia and South Africa, relating to deforestation and reforestation, have already been mentioned. Such conversions are related to terrestrial ecosystems. Blue water use has to be categorized into return-flow-related uses, which generally include addition of a pollution load, and consumptive water use, which increases the green water flow. Second, water-dependent activities may be divided into direct blue water use (household, industry, irrigated agriculture, hydropower, etc.) and aquatic ecological services in riparian wetlands, fisheries, etc.

When blue water is used for irrigation, the part consumed by the crops respresents a blue-to-green redirection of water. The evaporative losses from canals and conveyances involved in the irrigation system add to such redirections. The depletion of the Aral Sea or the downstream Colorado River in the U.S. (in both cases after correction for the effect of out-of-basin transfers) are both downstream manifestations of river depletion by blue-to-green redirections.

The traditional rice farming system in Bali was, in fact, based on such redirections. River depletion was controlled by an intricate set of institutions where religion and the involvement of priests and temples played a central role (Lansing, 1991). The task was to allocate the blue water in the water course so that there was still enough left for the most downstream rice farmer. The same thinking can be heard from many dry climate developing countries where blue water leaving to the sea is seen as a waste. Interestingly, in the Bali case, the blue water was not only used to optimize water use efficiency in the rice fields but also for ecological services like pest control.

The widely experienced fact that forest plantations in the temperate zone have tended to lead to a decreased river flow or water table is an example of indirect blue-to-green redirection in the sense that the biomass production reduces the rainwater surplus left to form blue water. Conversely, the large-scale deforestation throughout the past millennium over the Hungarian Plain has been suggested to explain the water logging through a rising water table. This forced the Hungarians to introduce large-scale drainage systems in the 19th century in order to bring down the water table (Szesztay, 1994). The huge Working for Water project now going on in South Africa (van Wilgen et al., 1998) is another example of this type of redirection. The goal is to clear away the alien water-consuming vegetation that lacks natural enemies and therefore rapidly spreads over the landscape. By this operation, the Ministry of Water Affairs and Forestry expects to gain an additional 10 percent of runoff, which is badly needed to secure safe water supply for the whole population.

As already indicated, land use change and conversion may also have consquences on downwind rainfall. If the atmosphere receives an increased input of water vapor flow, there is more water that can condensate and form rain further away in the downwind direction. This effect may be particularly relevant far away from the coast where the vapour content of evaporated marine water in the atmosphere is already exhausted and the atmospheric vapour flow contains only continentally evaporated water (Savenije, 1995).

Compromise Seeking on the Way Towards Hydrosolidarity

Summing up the main points in this paper, a fundamental challenge towards less unsustainable socioeconomic development in a river basin is to find ways and mechanisms by which reconciliation can be developed between upstream and downstream activities. The starting point for such an approach has to be the rainfall over the river basin. Humankind's dependence on water is not a merely technical issue, involving water supply and irrigation, but is much broader. Land use is not only water-dependent but also water-impacting. Consequently, upgraded water concepts are needed as a base for the conflict analyses and discussions.

But the discussion in this paper suggests that the river basin approach has to involve attention not only to direct and indirect freshwater services, but also to water-related ecosystem services, terrestrial as well as aquatic, direct as well as indirect. Direct terrestrial services are involved in biomass production of socioeconomic importance, in particular crop production, pasture, and forestry. Indirect ones are related both to services performed by insects and birds, of importance for seed dispersal and pollination, and to biodiversity, protecting the life support system against disturbances by offering resilience. Similarly, direct aquatic ecological services are linked to fish production and income generation among fishermen populations, while indirect ones are related to wetlands of importance for bird flyways, recreation, etc.

Ultimately, societal freshwater and ecological services will have to be seen in a river basin context within a new hydrosolidarity thinking. Upstream vegetation changes have flow consequences for downstream freshwater and ecological services. Upstream land use changes as well as water uses involving the introduction of pollution loads will influence the quality of the water on which downstream activities and ecosystems depend. It is therefore essential to find ways to seek balance and compromises between upstream and downstream interests and ecosystems.

There has been a tendency in the past to pay large attention to the respective claims on the river between upstreamers and downstreamers with reference to formal water rights. When the water competition sharpens, a more "palatable" approach will be to pay adequate attention to the water needs of both the upstream and the downstream populations (equitable share). Upstreamers will have to pay adequate attention to the ways in which their activities influence downstreamers. This is an issue of water ethics. Downstreamers have to look out for the way upstream activities may influence their water-dependent activities. This is an issue of national security.

Also downstreamers will have to practice water ethics: they will have to adapt their expectations to what will be realistic in terms of the constraints that those expectations will imply for upstream activities. They will also have to provide motivation for the upstreamers to constrain their activities, both in terms of the pollution load introduced and the water-consuming biomass produced, i.e., activities that would otherwise pollute and/or deplete the river on which the downstreamers and their aquatic ecosystems depend.

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Malin Falkenmark, Professor of International Hydrology, Swedish Natural Science Research Council, is a widely recognized, future-oriented water scientist with global interests. She is tied to the Department of System Ecology, Stockholm University and the Swedish International Water Institute (SIWI). Professor Falkenmark initiated and chaired the IWRA Committee on Water Strategies for the 21 Century, active in the late 1980s and early 1990s, and has received several international prizes. She is a member of the UN Committee on Energy and Natural Resources for Development. Email: malin.falkenmark@ siwi.org.

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