HUMAN INTERACTION WITH LAND AND WATER: A HYDROLOGIST'S CONCEPTION

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Summary

This paper presents an overview of key relationships between humans and the water flowing through the landscape where they live. The basic water resource is the precipitation supporting vegetation, society, and ecosystems with water. Out of the precipitation over the catchment, one part goes back to the atmosphere as vapor flow or green water flow while the other part goes as liquid flow or blue water flow above and below the land surface. Water is an extremely complex resource with many different functions: it has a health function for humans, a habitat function for aquatic biota, production functions both in terms of biomass production (food, fodder, fiber, fuelwood and timber) and socioeconomic production (industrial production, energy). Water finally acts as a mobile solvent, picking up everything that is water soluble and carrying it along. In their activities, humans tend to alter landscape components in order to be able to meet various societal needs (water, food, energy, goods, etc). Water thereby generates changes both physically in the green/blue water partitioning and chemically

through the introduction of pollutants along the water pathways. As a result, water, when moving through the landscape, acts as a silent messenger, translating human activities into unintended side effects, so-called environmental impacts. Water mobility links upstream activities in a catchment with downstream problems and opportunities. As seen from a strict water resources perspective, downstreamers are in a way "prisoners" of the upstreamers.

Humanity's genuine dependence on freshwater is reflected in particular development problems experienced in dry climate tropics and subtropics. Water management is a crucial component of socioeconomic development and improved quality of life in these countries. Most of the low-income countries are in fact lying in the water-deficient region. In view of the soils and the climate full crop yields can seldom develop there unless extra water is added through irrigation. In terms of blue water availability, the world can be divided into five regional clusters with radically different water resources. Mobilizing a larger part of the available blue water resource depends on access to reservoirs, energy, coping capability including trained manpower, and money to finance the structures involved.

The multiple functions of water force many different sectors of society to get involved in water management, each with its own perspective. Different professions differ in their water interests and perspectives. Each must participate in developing an integrated approach to the linkages between land, water, and ecosystems, and cultivate an holistic, rather than purely disciplinary, view. The overall challenge is a hydro-solidarity where people accept the need to peacefully share the water that the precipitation brings to the landscape or river basin/catchment.

1. Freshwater: Our Joint Lifeblood

Civilization on our planet is fundamentally water-based. In that sense, water plays a number of constructive roles in supporting life. At the same time, however, it plays destructive roles. Water is a main agent in the generation of environmental side-effects from human activities, and in causing problems related to both water shortage and crop failures, and to surpluses of water, floods, and inundations.

1.1 Water and Life

Water is a key substance in both human and societal life. It determines where people can live and where cities can be located. Water is a key operator both in the human body, in the vegetation and the landscape in general, and in society. All life genuinely depends on freshwater. Water conditions in a landscape are reflected in the patterns of both vegetation and habitation. And cities are located where water can be provided for all its water-dependent functions: in households and for sheer survival of the inhabitants, for industrial processes, in hospitals, etc. Cities cannot survive without a flow of water passing through.

Man's water dependence has forced society to seek ways to cope with natural water-related constraints: this is the origin of human civilization. Engineers developed early the art to channel water in pipelines and canals, to pump water from rivers to higherlocated irrigation schemes, and to build reservoirs where water could be stored from the rainy period when there was surplus, to the dry period when there was deficiency.

One of water's functions in the natural landscape (until now not much focused upon) is as a mobile solvent, picking up everything that is water-soluble (for instance, waste products or agricultural chemicals not taken up by the plants), and carrying it along. Since flora and fauna are also genuinely water-dependent, the result is that higher-order side-effects tend to develop wherever polluted water is moving around above and below the ground surface. In that sense, the water in the landscape plays the role of a silent messenger, translating human activities into unintended side effects, spoken of as environmental impacts.

More people means more food needed, which means larger consumptive use to produce that food, which means less usable water left in rivers and aquifers. More people also means more pollution, adding to the dilemma of less usable water. With less usable water, water supply problems will follow, leading to increased morbidity and mortality, partly balancing population growth.

Figure 1 sketches in a system-based way the interaction between a growing population and the water-based life support system. The system contains a demographic pressure branch, a socioeconomic production branch, a pollution branch, and a life support feedback branch There are, in other words, several links joining population and the amount of usable water:

- increasing population pressure on a finite resource reduces the amount per capita (branch d);
- more people produce more waste, polluting the water and reducing the usable amount (branch c);
- with wealth goes increasing amounts of industrial waste, further reducing the amount of usable water (branch b);
- the polluted water will impact on body functions and fertility (branch e);
- the polluted water will also impact on ecological services in the natural ecosystems and on food production depending on those services (branch f);
- the polluted water finally impacts on water-dependent socioeconomic production (branch g), and therefore on wealth production.

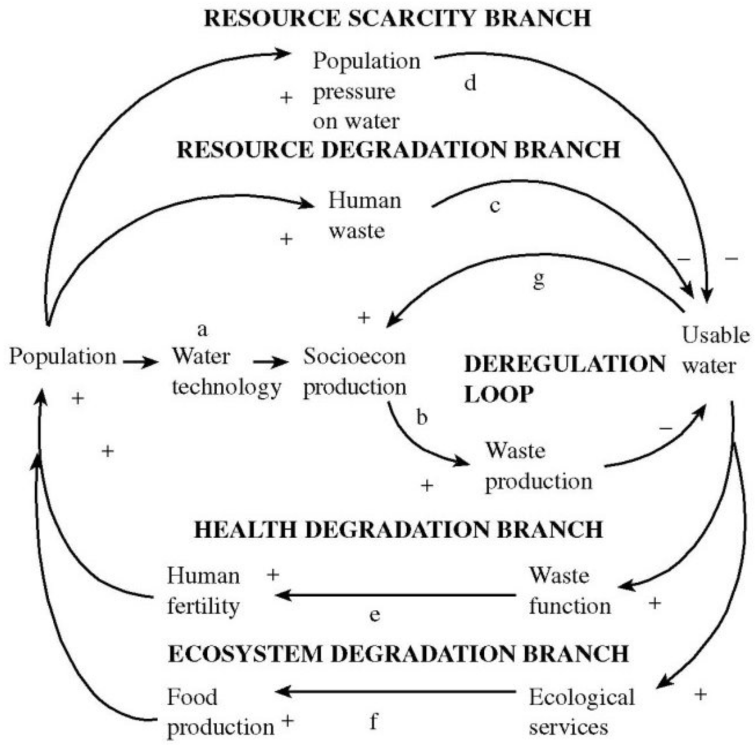

Figure 1: The interaction between a growing population and the water-based life support system

1.2 The Ongoing Paradigm Shift

Human ingenuity has supported the growth and socioeconomic development of society. As human populations have grown and welfare increased, people have moved to urban areas in ever-growing numbers. In so doing many have lost their heritage of acquaintance with the landscape and its products and reactions. Over time, as societal leaders increasingly became urbanites and got used to technology-based life support conditions where the household water came out of a faucet in the wall or the yard, their water illiteracy tended to grow to dangerous levels. They got caught in ever more serious pollution problems, endangering the life support system on which societal stability is based. In poverty-stricken regions, population grew more rapidly than the farmers' ability to grow food and the politicians' ability to cope with water supply and sanitation needs.

Modern water management developed essentially in the temperate zone. Key components were technology and sectorized water management, concentrated on water supply, large-scale irrigation, and hydropower production. In developed countries, growing water pollution from human and industrial waste was abated by waste water treatment plants. Biologists developed an increased understanding of water as a habitat for aquatic ecosystems.

All this focus was on the liquid water in rivers and aquifers, what we now speak of as *blue water flow*, and how to manage its quantity and quality. When emigrants brought this blue water focus to Australia, it however became evident that the paradigm was partially misleading. A new category of environmental problems developed, that were linked to the large evaporative demand of the atmosphere consuming most of the precipitation and leaving only a very limited runoff to recharge the river. Vegetation changes, like clearing for pasture and agriculture, caused a rising water table, water logging and salinization (today a dominant water problem which is very difficult to cope with). Experience in South Africa indicated similar problems. There turned out to be evident linkages between forestry and river flow. A permit system was therefore introduced for afforestation projects.

In the 1980s, growing interest was directed at similarities and differences in hydrological conditions in different climatic regions of the world within the field of comparative hydrology. In the early 1990s, the earlier blue water-centered paradigm was complemented with attention to vapor flow, the *green water* branch of the local water cycle. This includes the water flow that is linked to plant production.

This paper gives an overview of key relationships between humans and the landscapes on which their life support depends. It leans heavily on more than 20 years' of research by the author, performed in close cooperation with a number of colleagues with different orientations (natural science, engineering science, and social science). Based on the emerging paradigm, the aim is to present a state-of-the-art framework, incorporating both the blue liquid water flow supporting societal needs and aquatic ecosystems, and the green vapor flow involved in plant production and terrestrial ecosystems.

According to the view presented here, the basic water resource is in other words NOT the water that goes in aquifers and rivers, but the precipitation over the catchment supporting both vegetation, society, and aquatic ecosystems.

2. Man and the Water Cycle

The genuine water dependence of humanity forces close interaction with the water that passes through the landscape. Human populations need water for household functions, water-dependent food to eat, water for various industrial functions, and water-generated energy to run the industries. Water is accessible in the natural landscape where it moves around above and below the ground surface on its way from the precipitation that fell over a sloping landscape to the flow of surface water, and as groundwater towards the river mouth at the coast or in a desert lake.

2.1 Biosphere and Technosphere Share the Same Water

Whether people are involved or not, the incoming precipitation, when reaching the ground, is partitioned between a vapor flow back to the atmosphere linked to evaporation from wet surfaces and transpiration of plants and vegetation systems, and a liquid flow of groundwater and river runoff, flowing downhill towards the river mouth. The vapor flow includes the water consumed in plant production and in the life of terrestrial ecosystems. Biomass production represents a huge water demand in terms of a truly consumptive use of water.

A recent calculation, biome by biome in temperate and tropical zones, shows that almost 90 percent of the evaporation from the continents is linked to photosynthesis in these vegetation systems (tropical and temperate forests, grasslands, wetlands, and croplands). This water vapor flow is moreover twice as large as the liquid water flow through aquifers and rivers. In other words, out of the precipitation over the continents, two-thirds goes back to the atmosphere as vapor flow and one-third goes as liquid flow (as surface water and groundwater flows). This liquid flow is the basis for societal water use for different purposes: offstream after withdrawal for households, industry and irrigated agriculture; instream for evacuation of waste products, navigation, hydropower production, etc.

Societal use is dominantly non-consumptive in the sense that after use the water ends up as a return flow, often loaded with pollutants. Principally, this water can be reused further downstream, over and over again. Ideally, one can imagine a system of sequential reuse all the way down the river valley, hindered only by excessive pollution or increasing salinity. The consumptive water use, on the other hand, is represented by the water returned to the atmosphere after diversion and use for irrigation. This flow (plus, of course, any out-of-basin transfers) represents a loss from the side of the catchment where it is reflected in a corresponding river depletion. Clear illustrations are the cases of the Aral Sea and the Colorado River in North America. From the side of biomass production this “loss” evidently represents a productive use, however.

Summarizing water’s multiple functions for human life, in society and landscape, water is an extremely complex resource: for humans it has a health function both in the sense that it is necessary for sheer survival, and that it plays a crucial role in transfering diseases to human settlements; a habitat function for aquatic biota; production functions both in terms of biomass production (food, fodder, fiber, fuelwood and timber) and socioeconomic production (industrial production, energy). But besides these societally-linked functions, it creates problems by its carrier functions of water-soluble pollutants and of silt. Finally, it has fundamental psychological and religious functions related to human well-being, and as a component of religious ceremonies. In all the main religions, water in fact appears in crucial roles in the stories of the original creation of mankind.

Human ingenuity is ever-more challenged as survival problems increase with unabated population growth, increasing erosion of the life support base, and a continuously “willful neglect” of the escalating pollution. But before we look more closely at this dilemma, let us direct our attention to the main interactions between society and the phenomena in the landscape that provide the life support, and to some key challenges involved. We will also look more closely at fundamental water-related differences between different climatic zones, and at food production difficulties in dry climates.

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Biographical Sketch

Malin Falkenmark, Professor Emerita of Applied and International Hydrology at the Natural Science Research Council, is tied to the Dept of Systems Ecology at Stockholm University, and to the Stockholm International Water Institute (SIWI) where she is in charge of the scientific programme of the annual Stockholm Water Symposia. She is also a member of the Technical Advisory Committee of the Global Water Partnership and member of the UN Committee on Energy and Natural Resources for Development. Her particular interests are interdisciplinary, with a focus on similarities and differences between different regions, especially linkages between land/water and their policy implications. In the 1970s, she became interested in the "temperate zone bias" in addressing water problems of developing countries and explaining the widespread "water blindness" in international debate. In the 1980s, her research was directed towards growing water scarcity, and she came to realize that a fundamental predicament of the hunger crescent in sub-Saharan Africa is a fourfold water scarcity, complicating both plant production and societal water use, which is difficult to cope with, especially under rapid population growth. In the 1990s, she became increasingly clear about the crucial role of the global water cycle as the bloodstream of the biosphere, deeply involved not only in human life support but also in generating environmental side effects from human efforts to harvest water, energy, and biomass from the natural landscape. Professor Falkenmark is a Global 500 Laureate and has been awarded the Swedish KTH Great Prize, the International Hydrology Prize and the prestigious Volvo Environment Prize.