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Ecohydrology

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Definition of Ecohydrology

Ecohydrology is a scientific concept applied to environmental problem-solving. It quantifies and explains the relationships between hydrological processes and biotic dynamics at a catchment scale.

The concept is based upon the assumption that sustainable development of water resources is dependent on the ability to restore and maintain evolutionarily established processes of water and nutrient circulation and energy flows at the basin scale.

Definition of Ecohydrology

This depends on an in-depth understanding of a whole range of processes involved that have a two-dimensional character:

1. **temporal:** spanning a time frame from the past to the present with due consideration of future global change scenarios; and
2. **spatial:** understanding the dynamic role of aquatic and terrestrial biota over a range of scales from the molecular- to the basin-scale.

Both dimensions should serve as a reference system for enhancing the buffering capacity of ecosystems against human impacts by using ecosystem properties as a management tool. This, in turn, depends on the development, dissemination, and implementation of interdisciplinary principles and knowledge based on recent advances in environmental science.

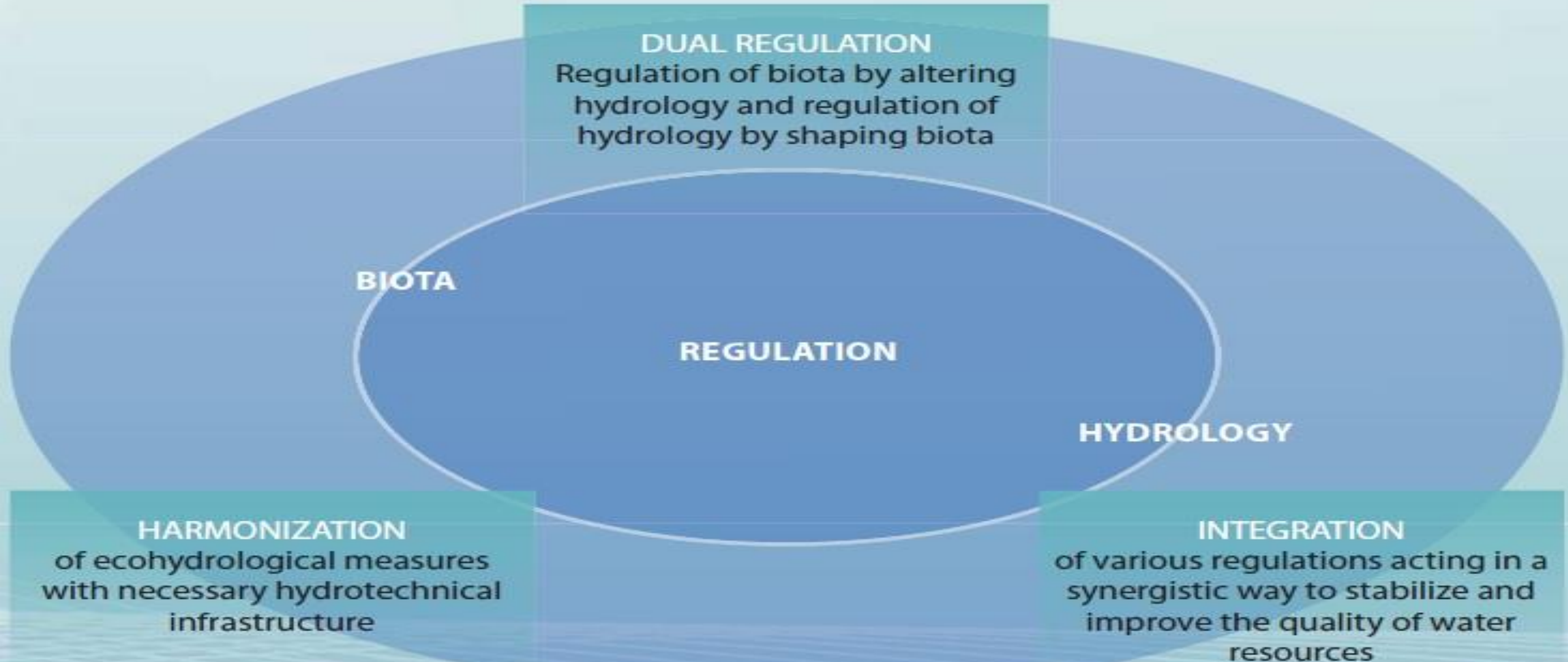
Ecohydrology Assumptions

The ecohydrology paradigm, which is based on functional relationships between hydrology and biota can be expressed in three key assumptions:

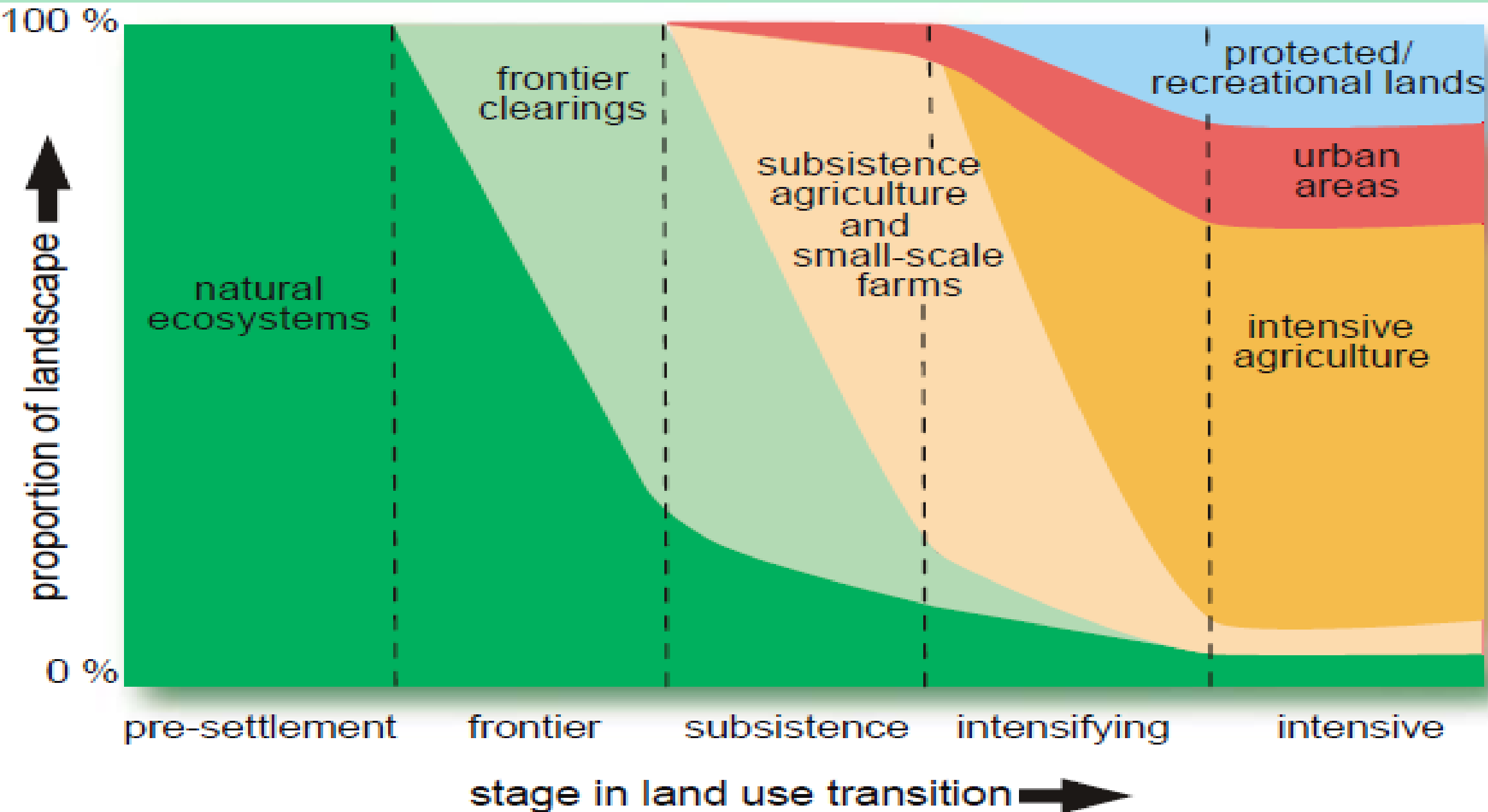
- 1. REGULATION** of hydrology by shaping biota and, vice versa, regulation of biota by altering hydrology.
- 2. INTEGRATION** - at the basin scale various types of regulations act in a synergistic way to improve and stabilize the quality of water resources.
- 3. HARMONIZATION** of ecohydrological measures with necessary hydrotechnical solutions (e.g., dams, sewage treatment plants, levees at urbanized areas, etc.)

Ecohydrology Principles

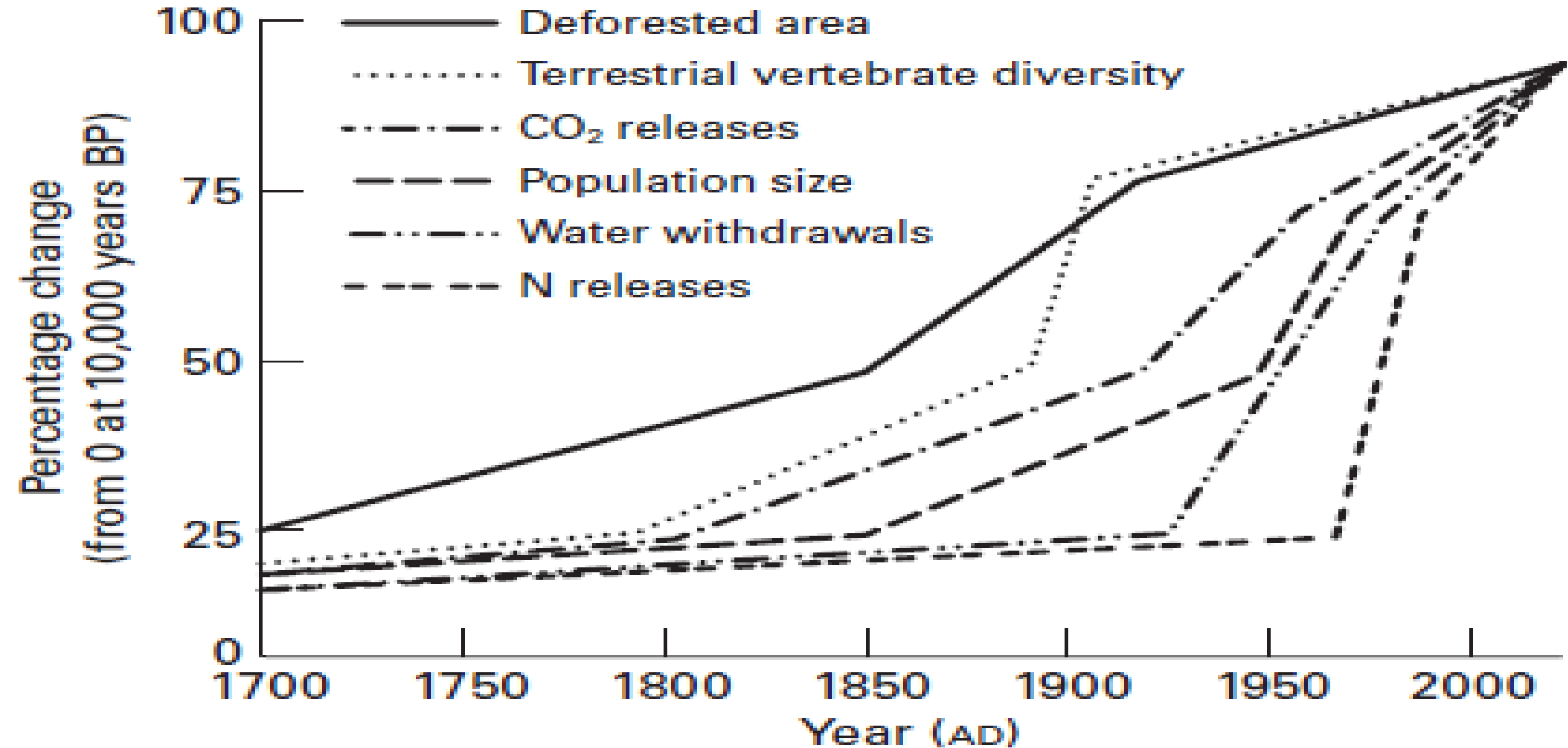
Key principles of ecohydrology



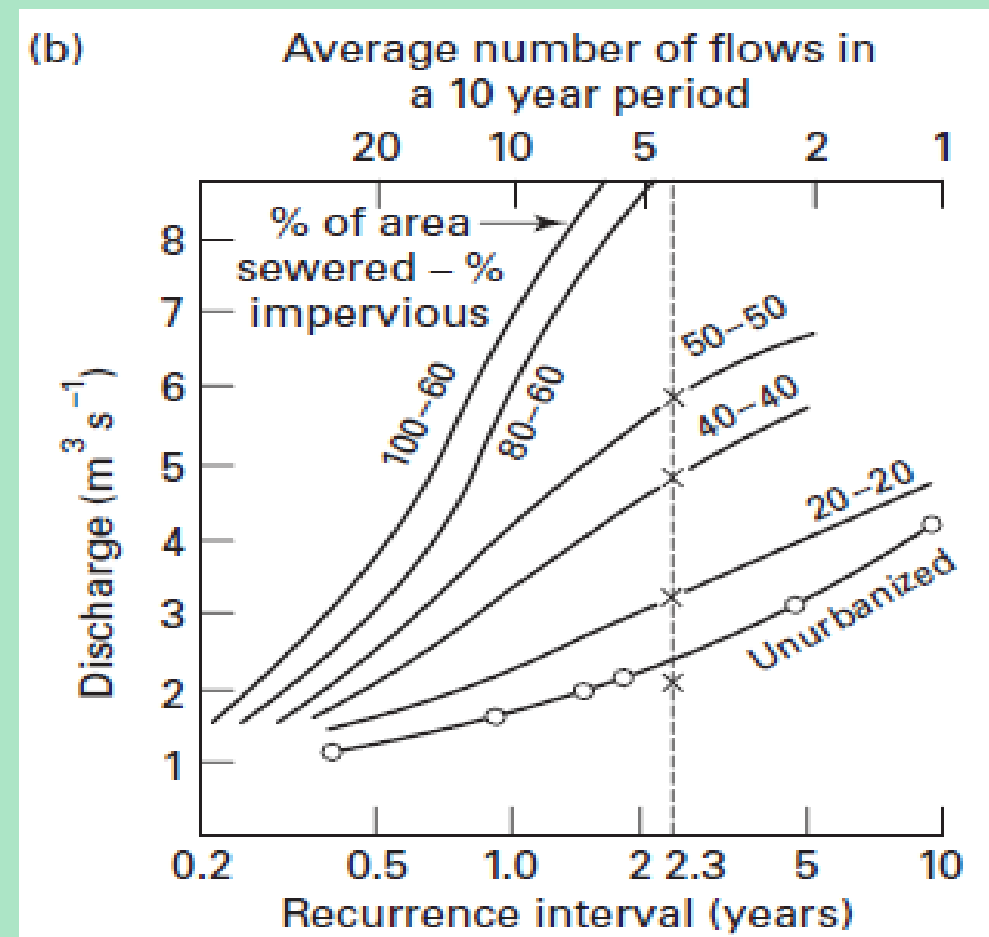
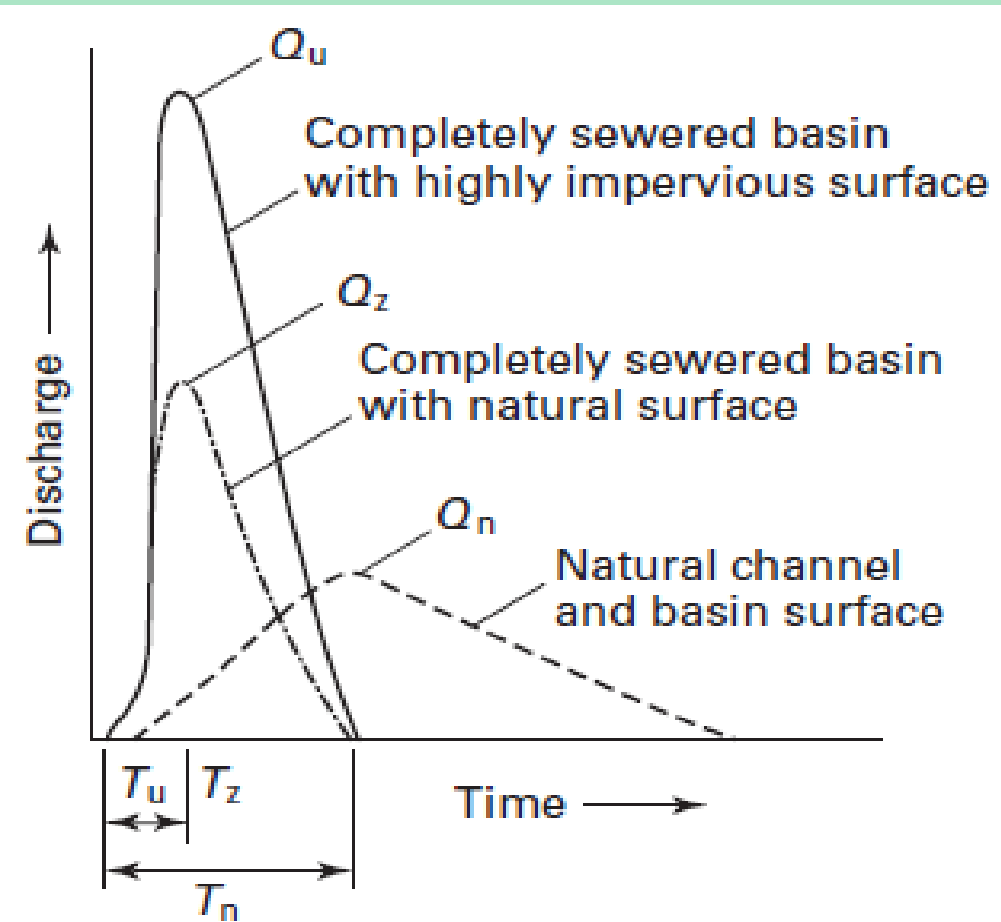
Human Impacts on nature



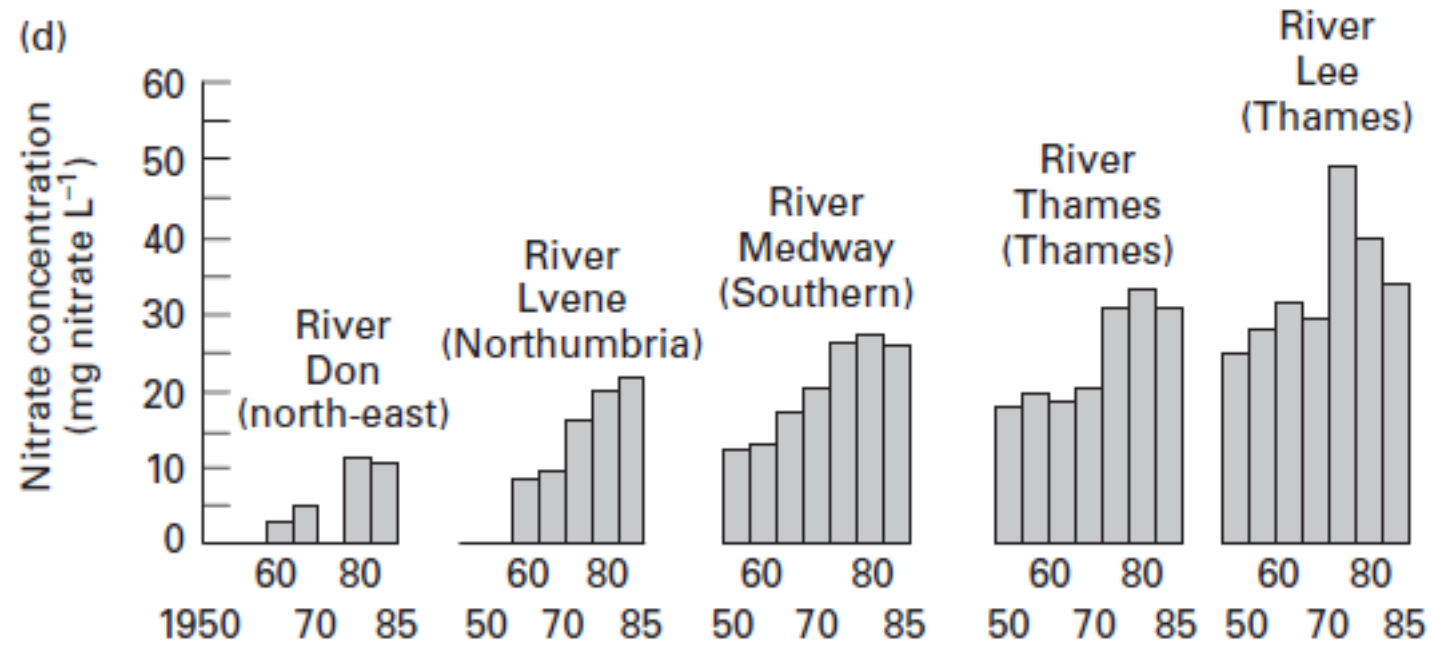
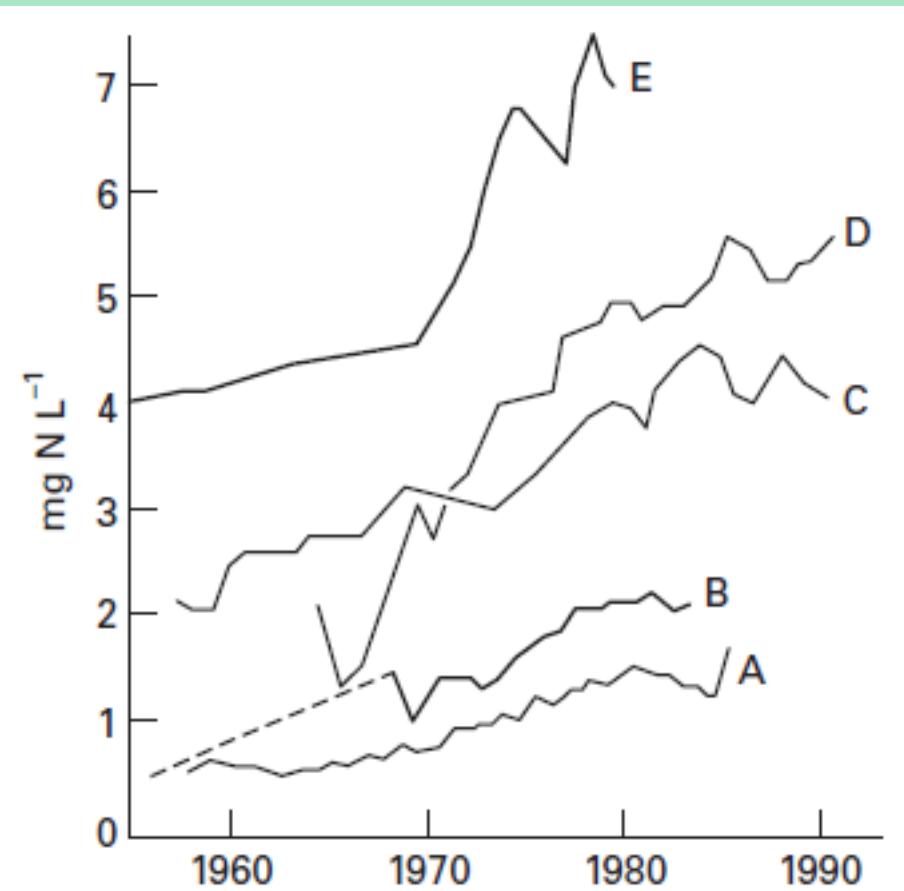
Human Impact on Nature



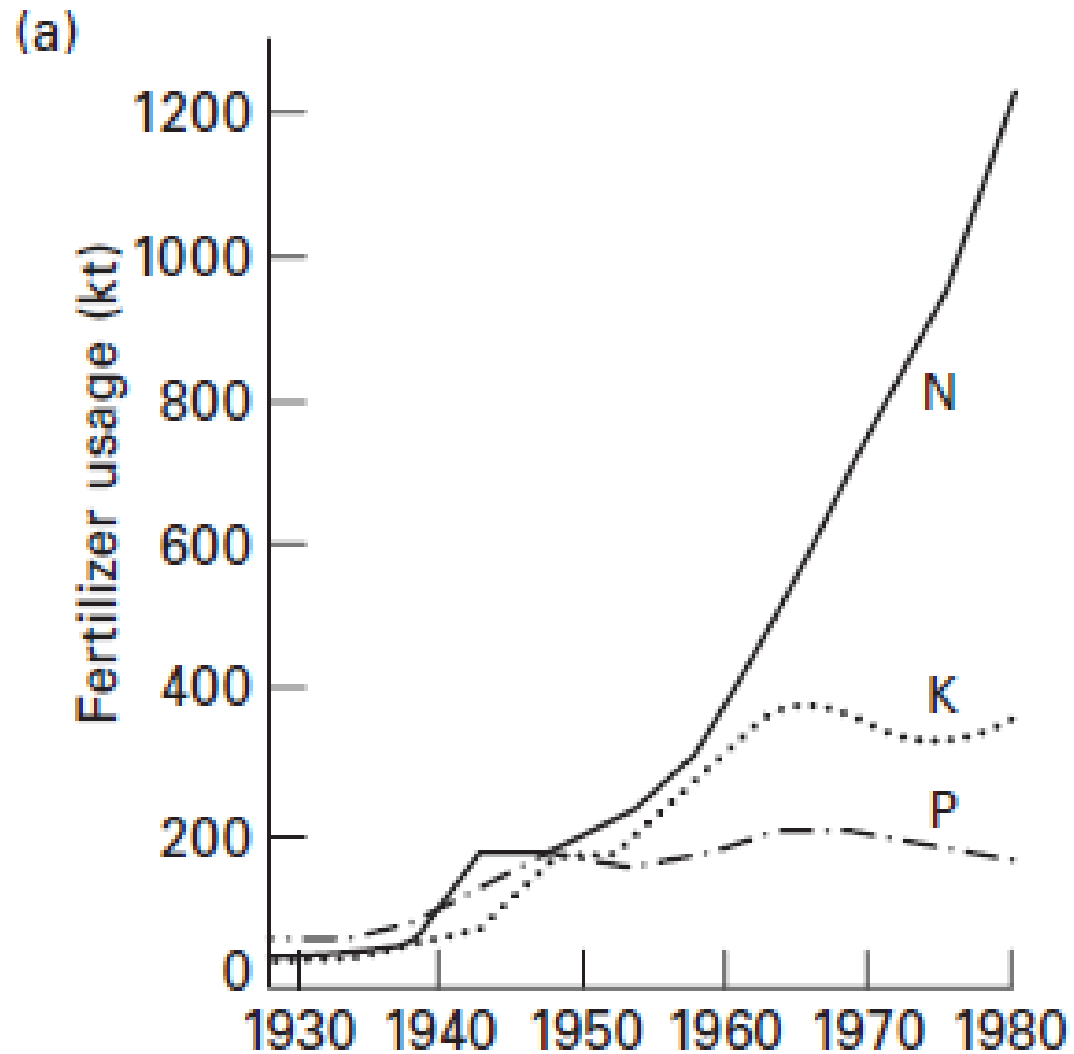
Human Impact on Nature



Human Impact on Nature



Human Impact on Nature



Ecohydrology Principles

Following these assumptions (Regulation, Integration, Harmonization), the concept of ecohydrology is based on three principles:

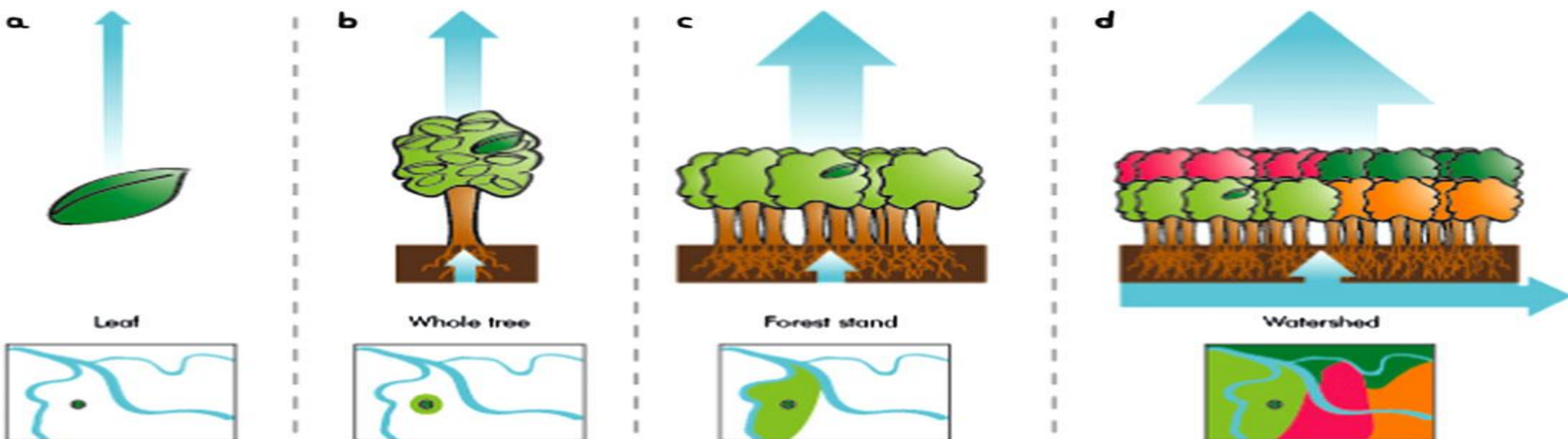
1. FRAMEWORK - Integration of the catchment, water and its biota into one entity, including:

a) Scale - the mesoscale cycle of water circulation within a basin is a template for the quantification of ecological processes;

b) Dynamics - water and temperature are the driving forces for both terrestrial and freshwater ecosystems;

c) Hierarchy of factors - abiotic (e.g., hydrological) processes are dominant in regulating ecosystem functioning. Biotic interactions may manifest themselves when abiotic factors are stable and predictable.

SCALING ECOHYDROLOGICAL PROCESSES FROM LEAVES TO WATERSHEDS



Leaf

Whole tree

Forest stand

Watershed

Ecological constraints

- leaf size
- stomatal conductance/sensitivity
- microclimate (temp, light, VPD)
- water use efficiency
- leaf boundary layer

Hydrological constraints

- atmospheric moisture

Ecological constraints

- sapwood variation
- canopy roughness
- crown architecture
- canopy boundary layer
- rooting depth
- depth of plant water uptake
- foliar deposition of fog, dew

Hydrological constraints

- soil moisture availability
- soil physical properties (texture, porosity, depth, etc.)
- soil hydraulic conductivity
- groundwater depth

Ecological constraints

- variation in plant species and vegetative cover types
- edge dynamics (advection, fog/dew inputs)
- canopy interception
- diel coupling transpiration-streamflow

Hydrological constraints

- hydrologic flowpaths
- hydrologic connectivity
- deep drainage
- soil moisture storage capacity
- geohydrologic properties

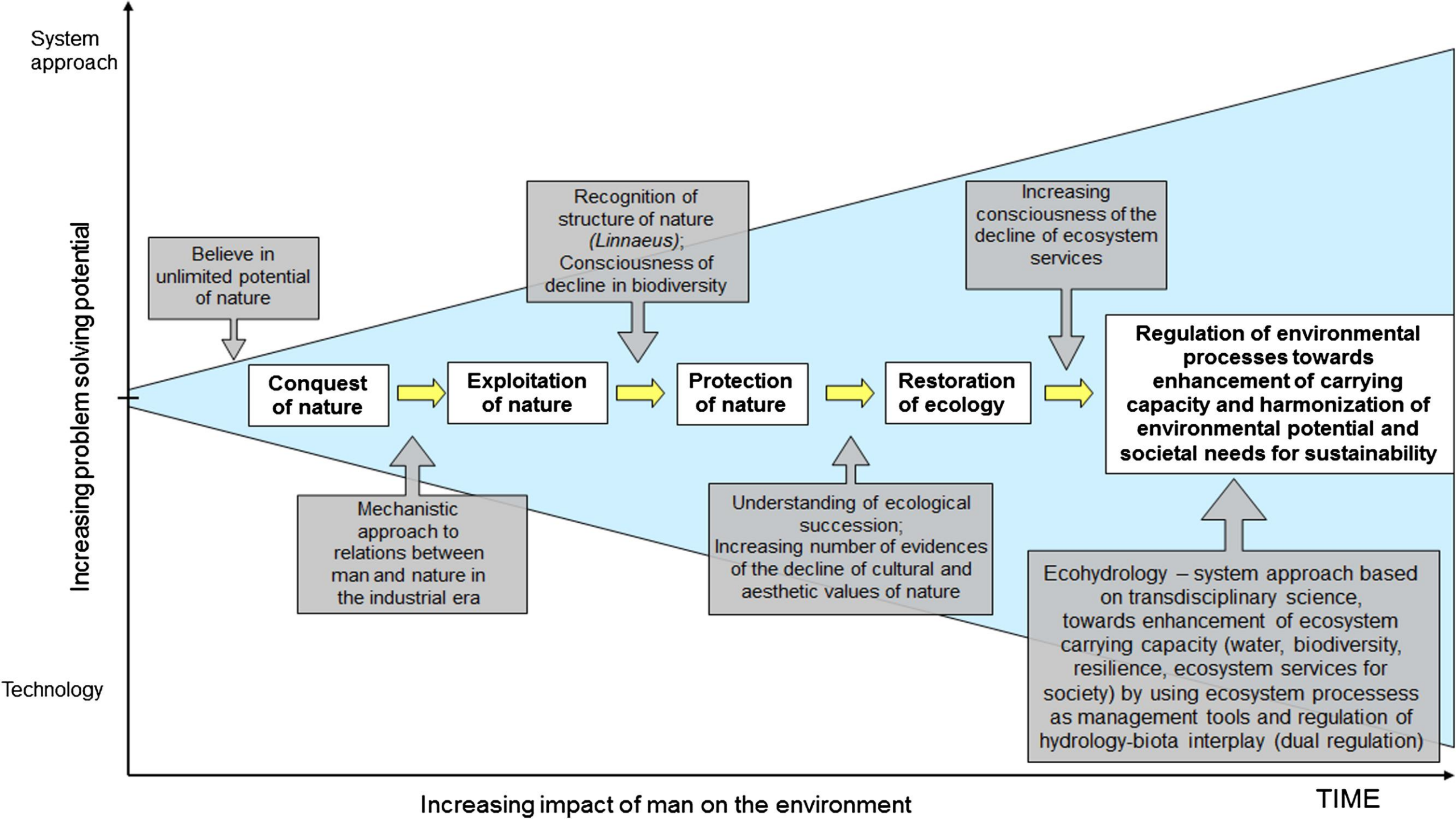
Ecohydrology Principles

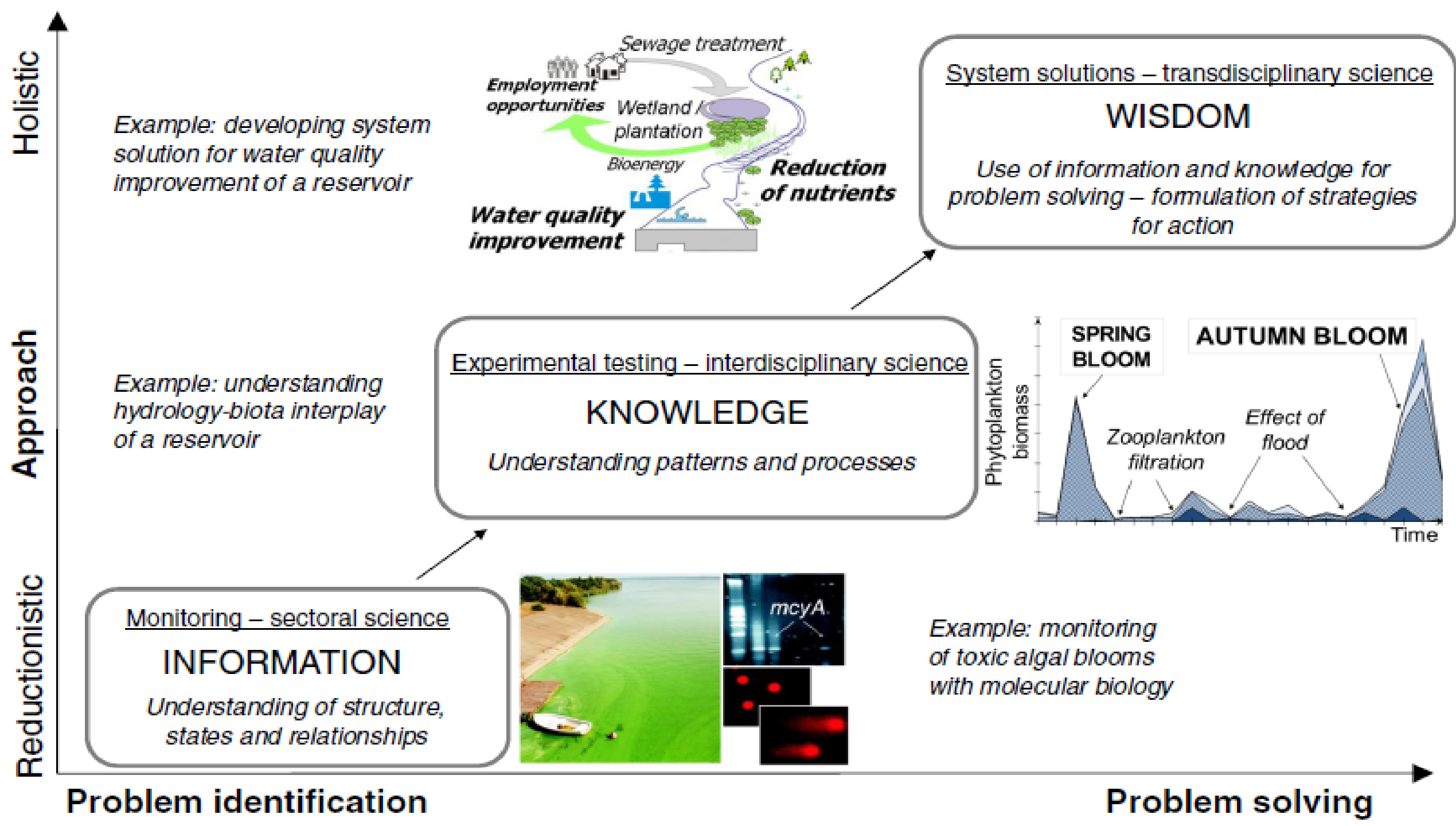
2. TARGET - Understanding evolutionarily established ecohydrological processes is crucial for a proactive approach to the sustainable management of freshwater resources.

It assumes that it is not enough to simply protect ecosystems but, in the face of increasing global changes (such as increasing population, energy consumption, global climate change), it is necessary to increase the carrying capacity of ecosystems, and their resistance and resilience, to absorb human-induced impacts.

Ecohydrology Principles

3. METHODOLOGY - ecohydrology uses ecosystem properties as a management tool. It is applied by using biota to control hydrological processes and, vice versa, by using hydrology to regulate biota. Scientific basis for the methodological aspect of using biota for water quality improvement has been seriously advanced by ecological engineering.





Ecohydrology Applications

TABLE 4.4
Role of various structures in a landscape

STRUCTURE TYPE	FUNCTION IN A LANDSCAPE
built-up areas	create impermeable surfaces in the catchment and act as a pollution source, and a place for humans to expand
agricultural lands	are sources of non-point pollutants and the cause of biodiversity loss
linear anthropogenic structures	source of pollution and also participate in landscape fragmentation
meadows	are buffers of medium effectiveness against pollutants
woods and forests	efficient structures regulating rate and mode of flow of water and chemicals through a landscape
land / water transition zones	regulate the exchange ratio of water and nutrients between water and terrestrial systems
water bodies	act as both a recipient of pollutants and as a tool for reduction of nutrient content in ground water

Ecohydrology Applications

Box 2.2

Application of Ecohydrology in problem solving

**BIOGEOCHEMICAL CYCLES
CLIMATE CHANGE & BIOENERGY**

**BIODIVERSITY
& FISHERIES**

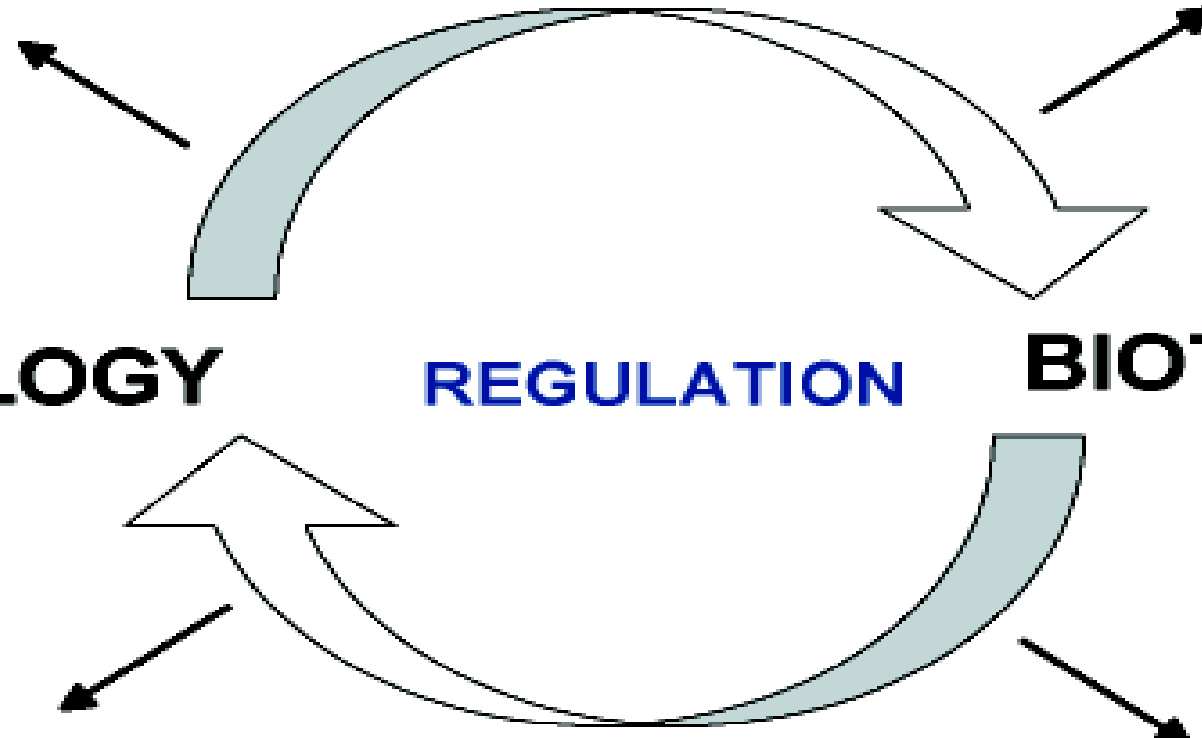
HYDROLOGY

REGULATION

BIOTA

**EUTROPHICATION
& HUMAN HELTH**

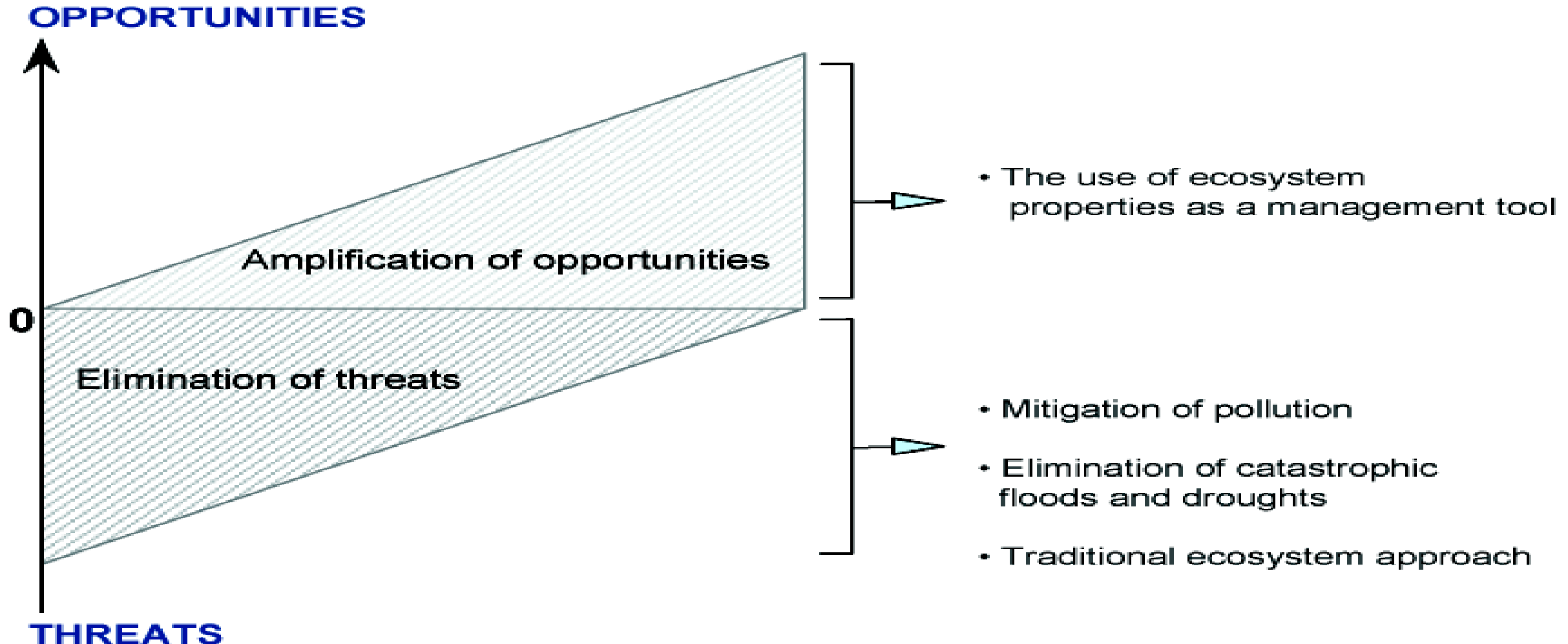
FOOD PRODUCTION



Ecohydrology Applications

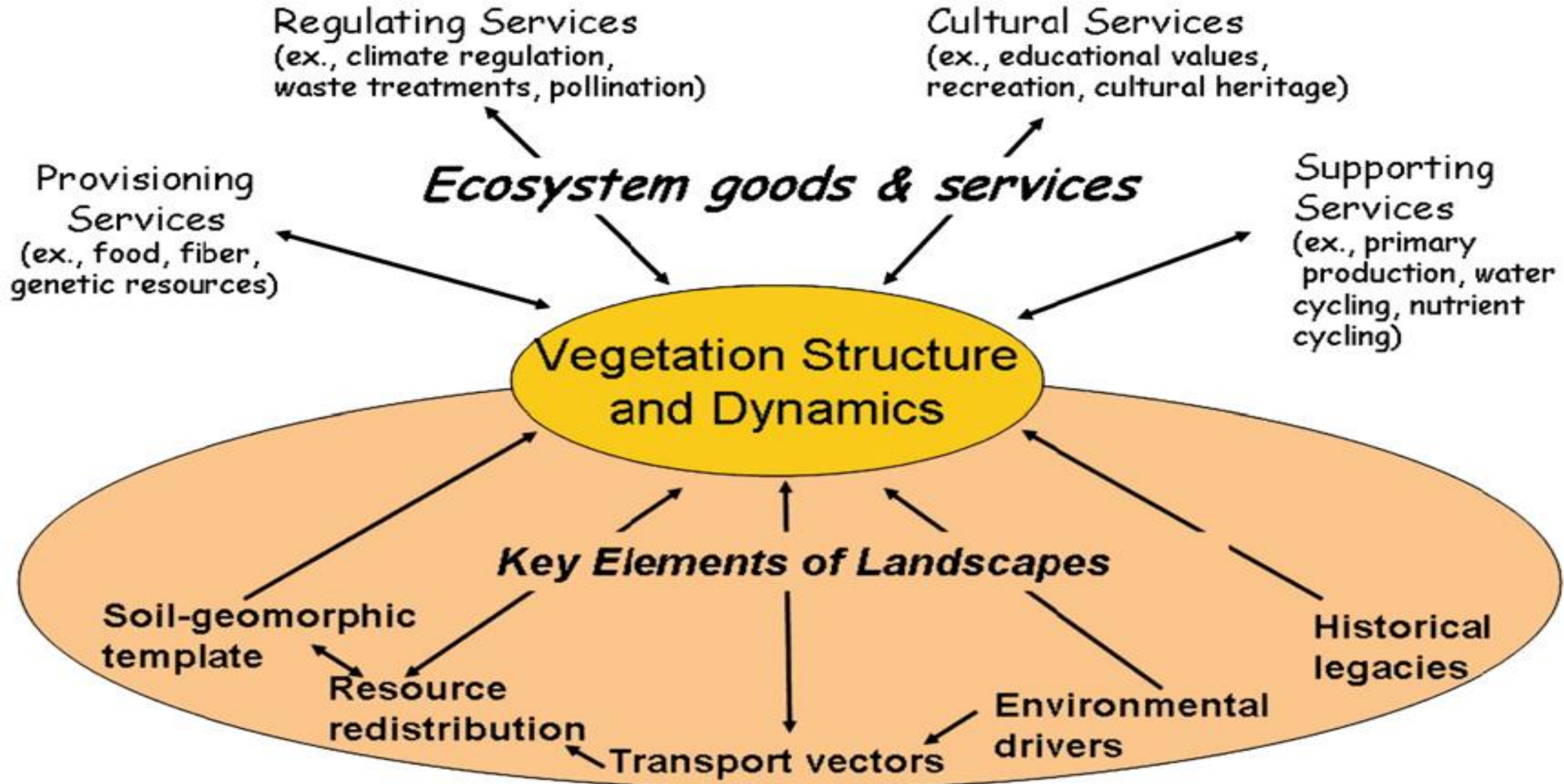
BOX 2.1

Application of Ecohydrology as a Factor Maximizing Opportunities
in a Successful Strategic Scenario of Sustainable Freshwater Management



(modified from Zalewski, 2002)

Ecohydrology Applications



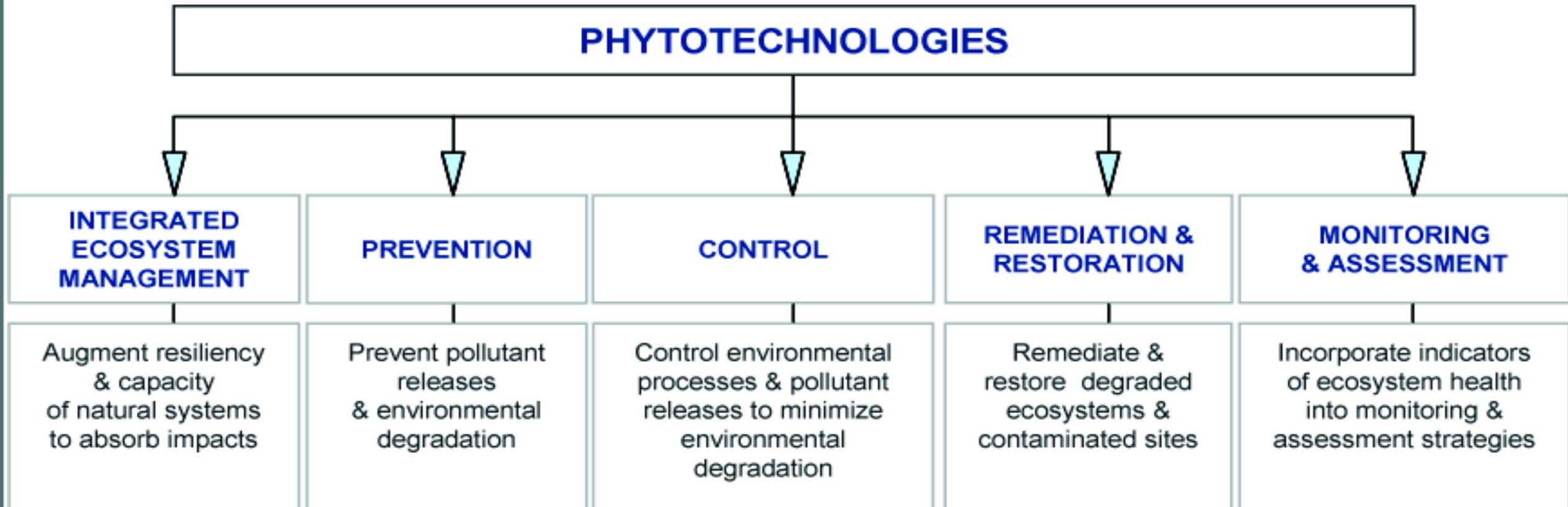
Phytotechnology

In general, the term phytotechnology describes the application of science and engineering to examine problems and provide solutions involving plants. The term itself is helpful in promoting a broader understanding of the importance of plants and their beneficial role within both societal and natural systems. A central component of this concept is the use of plants as living environmentally sound technologies (ESTs) that provide services in addressing environmental issues.

Ecohydrology Applications

BOX 2.3

Environmentally beneficial applications of phytotechnology

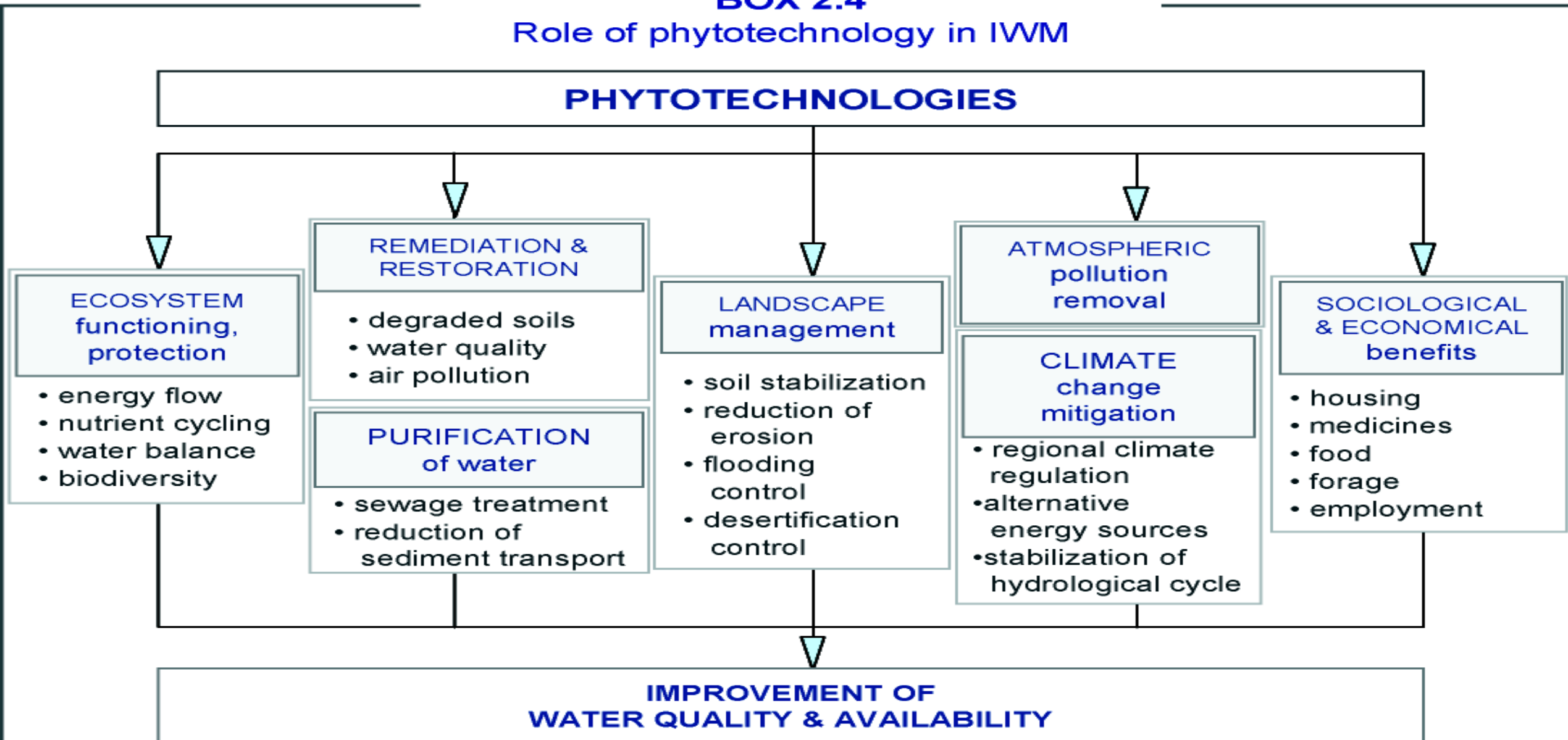


(modified from UNEP, 2003)

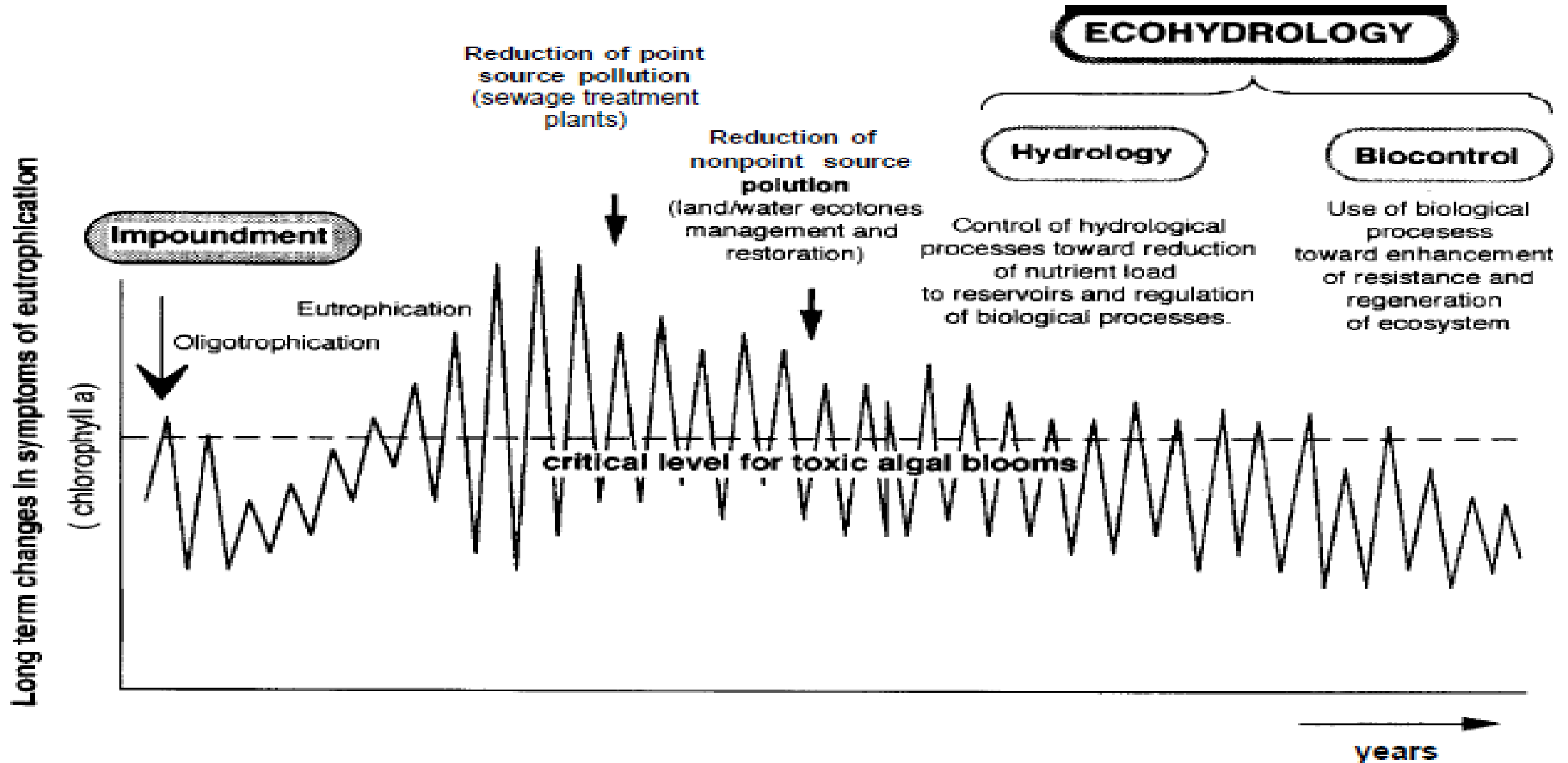
Ecohydrology Applications

BOX 2.4

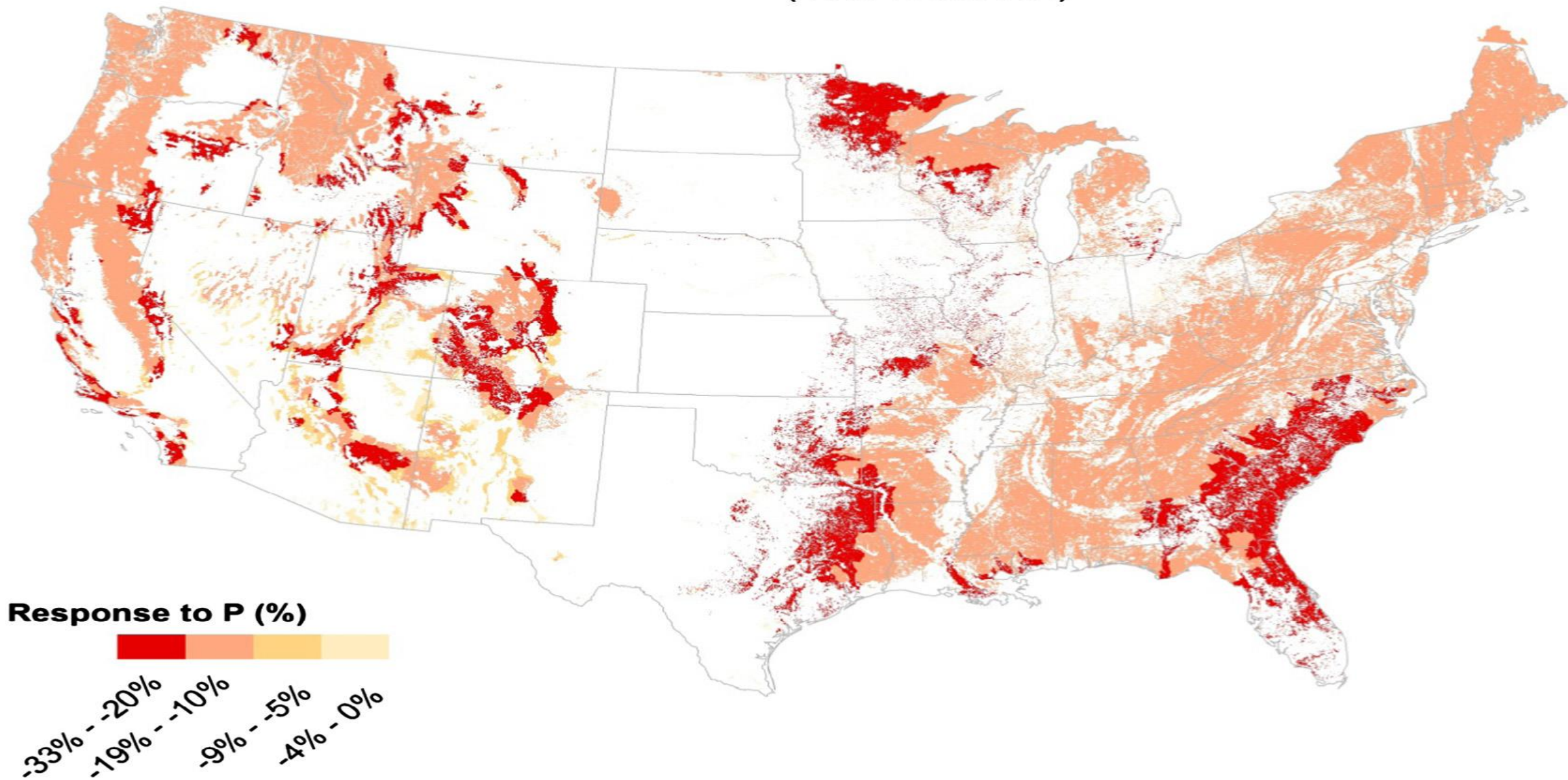
Role of phytotechnology in IWM



BOX 5. Hypothetical scenario of the application of ecohydrology to the restoration of eutrophic Sulejów Reservoir (Zalewski 1996).



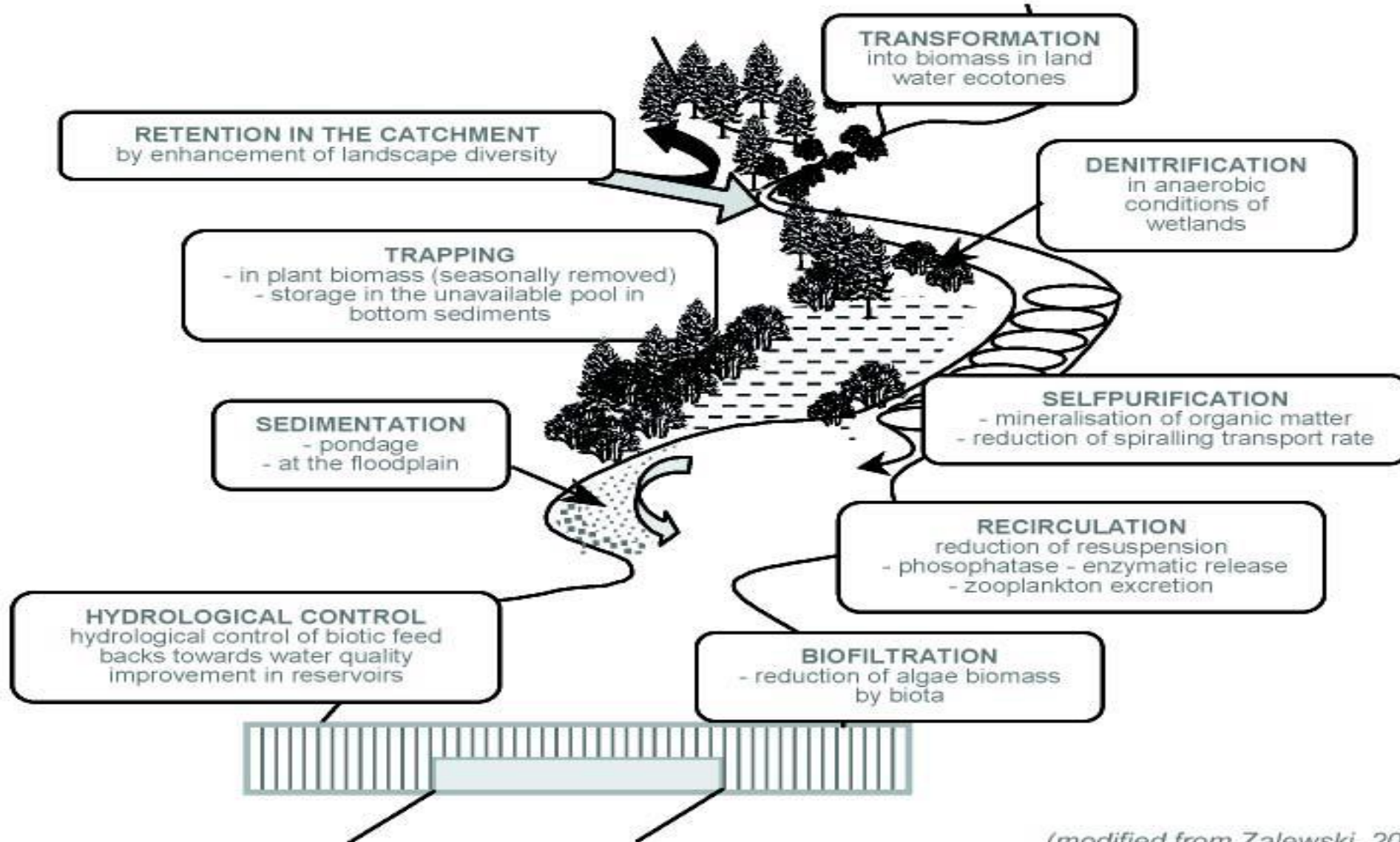
Response of Forest Water Yield to Change in Precipitation (10% reduction)



Ecohydrology Applications

BOX 1.2

Ecohydrology and phytotechnologies as a tool in IWM

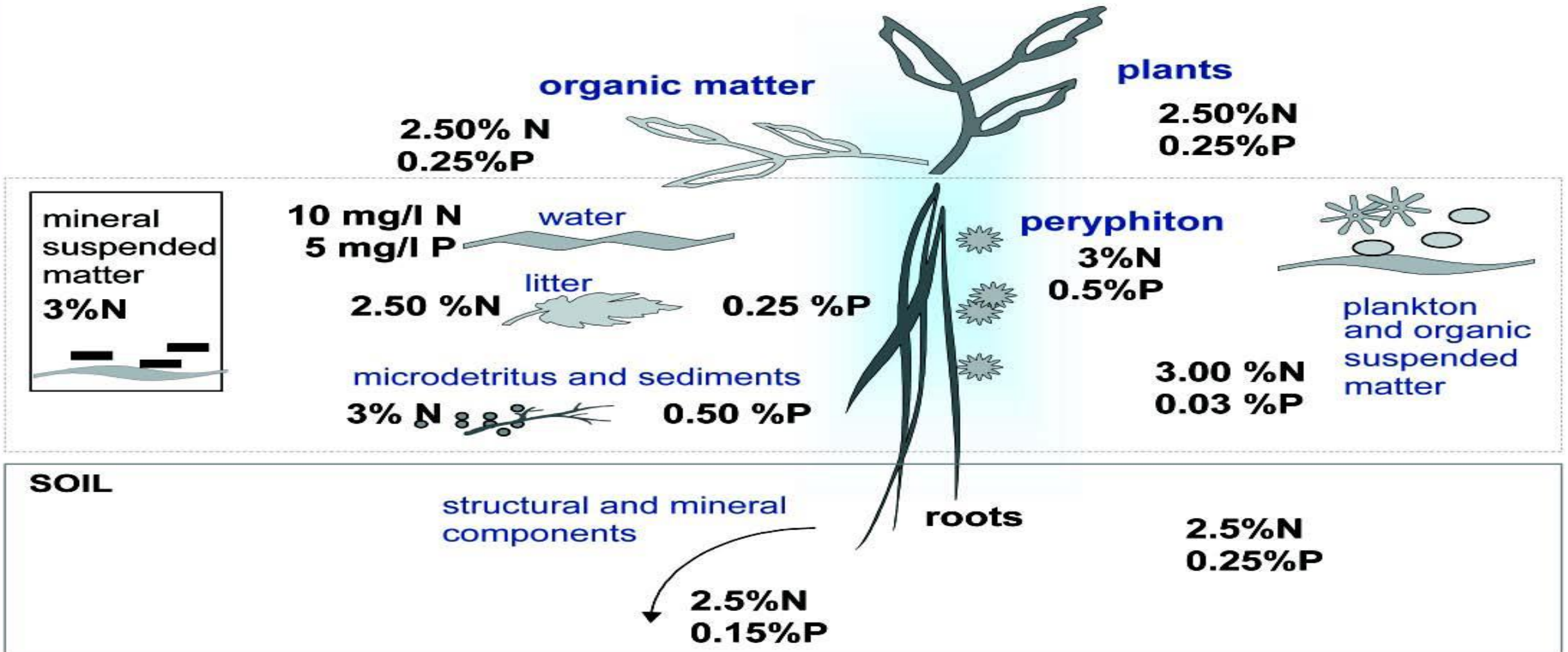


(modified from Zalewski, 2000)

Ecohydrology Applications

BOX 5.11

Mechanisms and elements involved in nutrient retention in buffering zones covered with reeds (*Phragmites australis*)



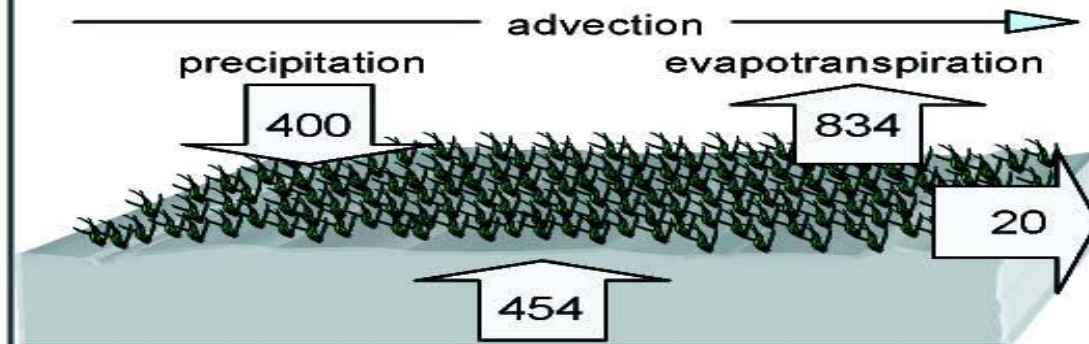
(modified from Kadlec & Knight, 1996)

Ecohydrology Applications

BOX 9.6

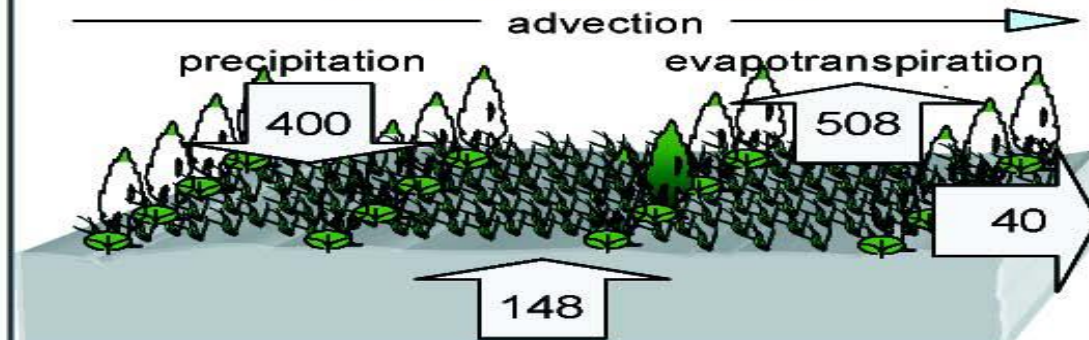
Impact of shelterbelts on alfalfa field water balance under advection

WATER BALANCE OF A ALFALFA FIELD
WITHOUT SHELTERBELTS



$$P + ETR + H + R = 0$$
$$400 - 834 - 40 + 454 = 0$$

WATER BALANCE OF A ALFALFA FIELD
WITH SHELTERBELTS

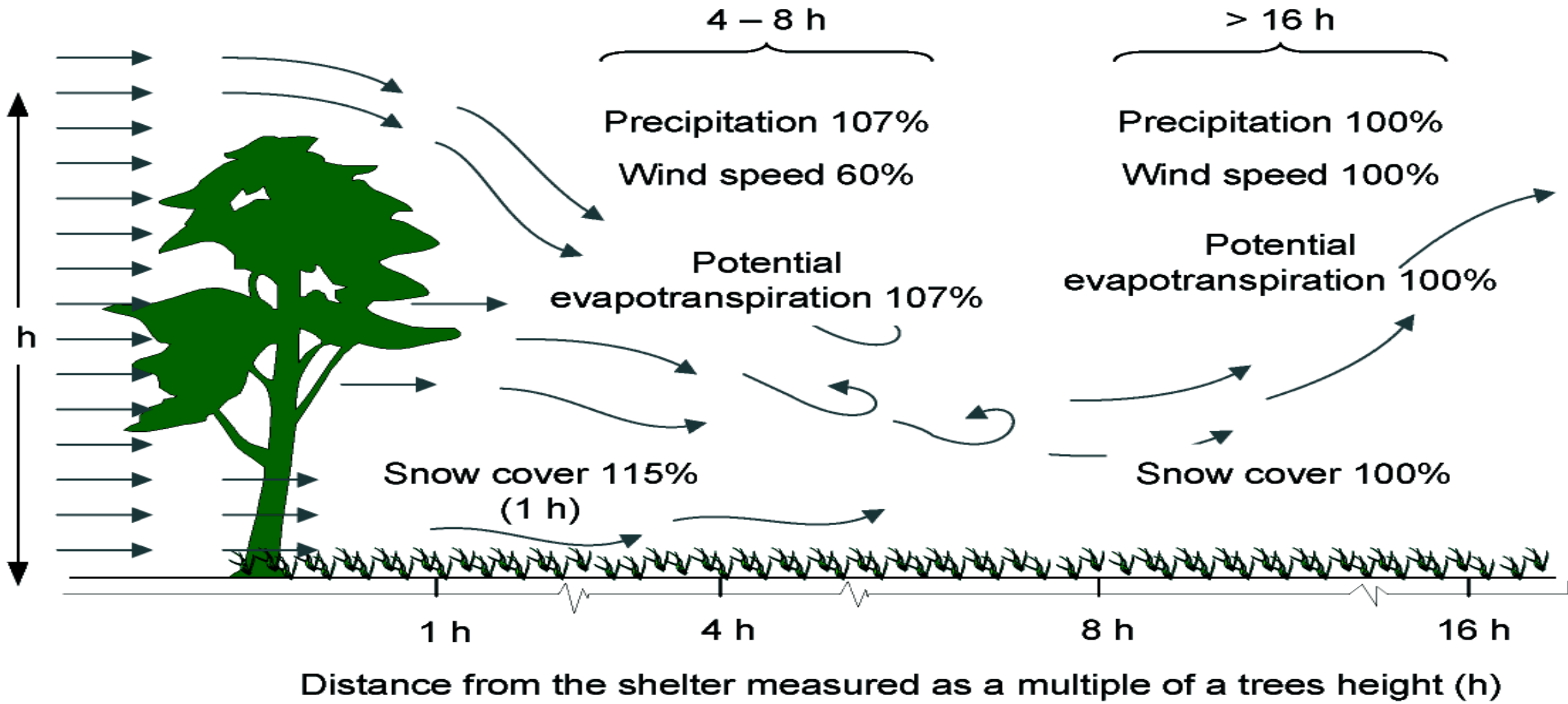


$$P + ETR + H + R = 0$$
$$400 - 508 - 40 + 148 = 0$$

Ecohydrology Applications

BOX 9.8

Impact of shelterbelt on microclimat of adjoining fields

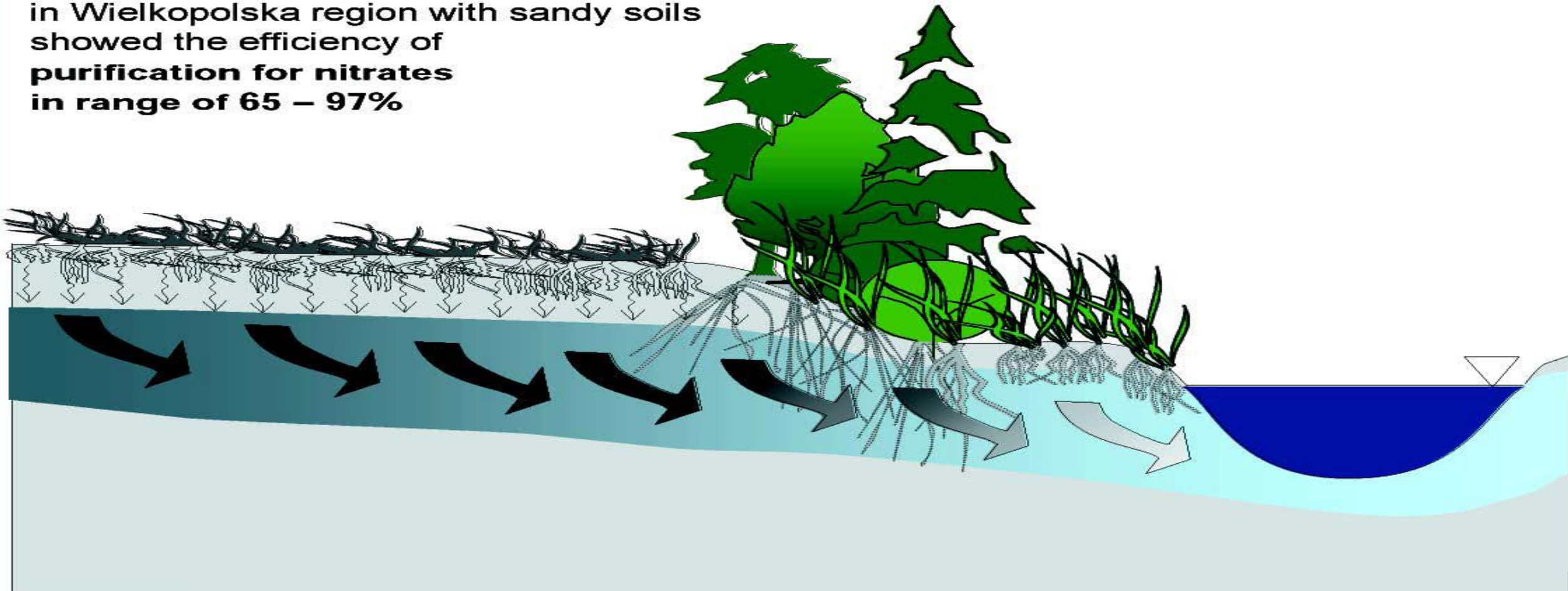


Ecohydrology Applications

BOX 9.9

Function of shelterbelts in purification of groundwater pollution

The studies carried out in Wielkopolska region with sandy soils showed the efficiency of **purification for nitrates in range of 65 – 97%**



gradient of concentration of chemical compounds dissolved in ground water

Ecohydrology Applications

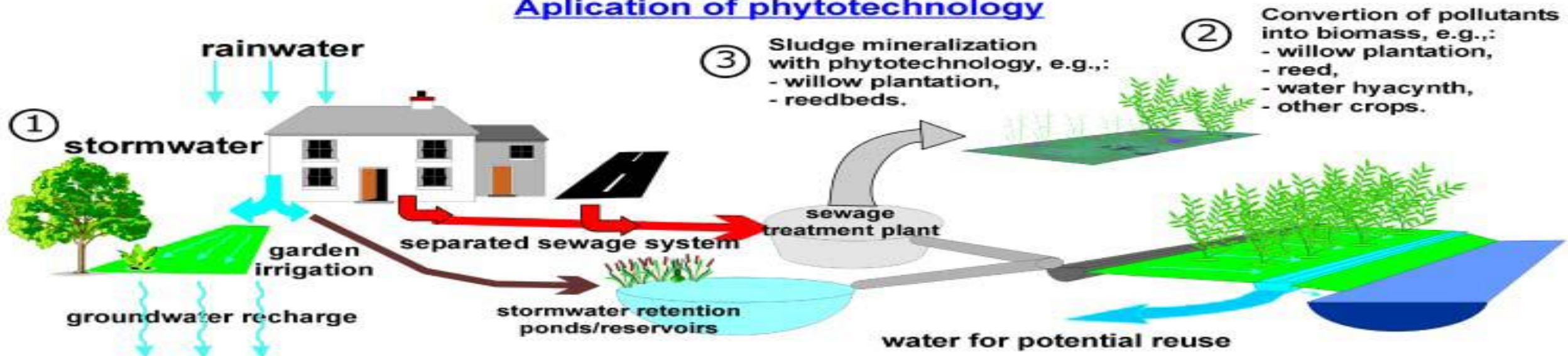
BOX 10.2

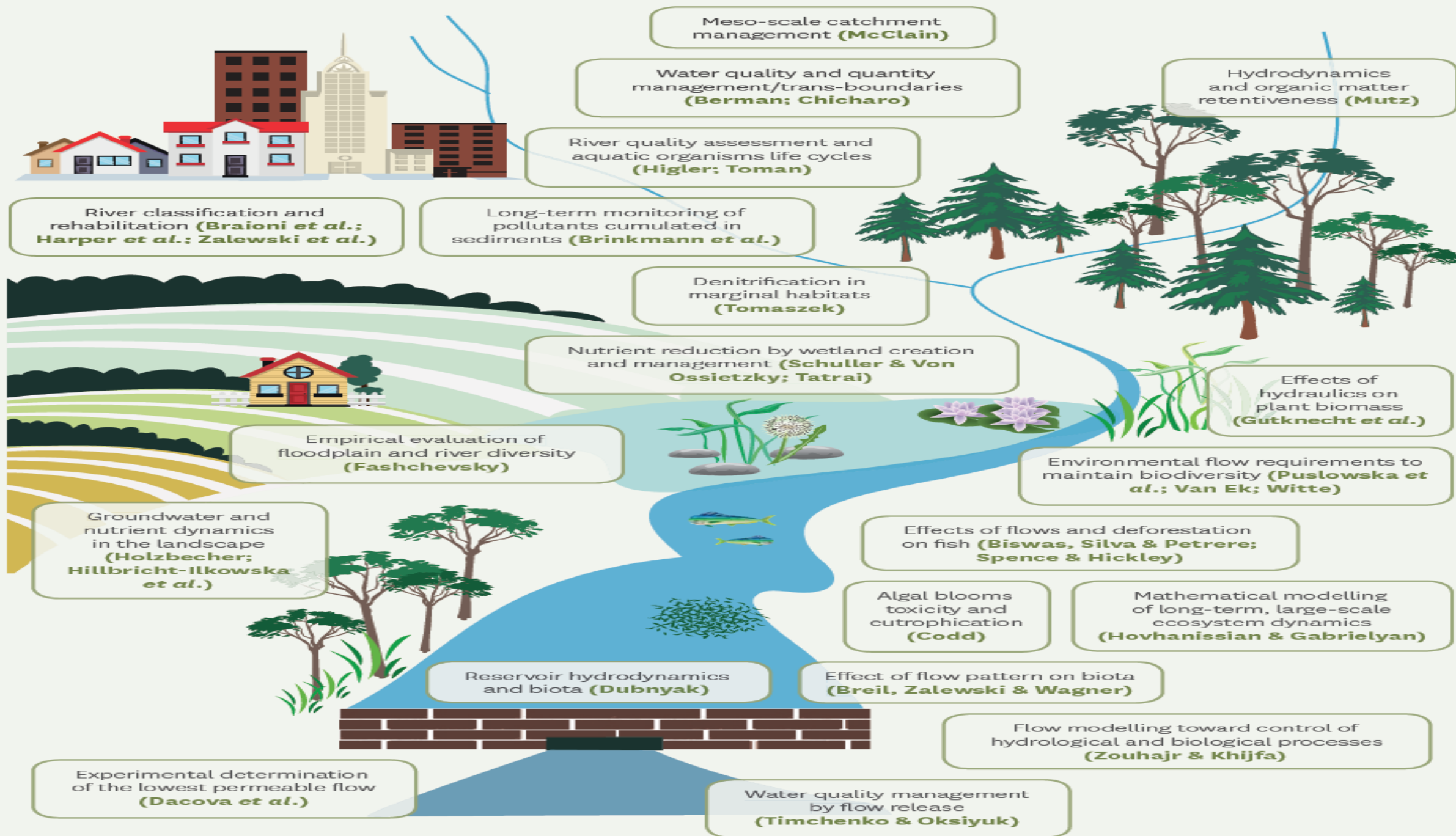
Application of phytotechnology in sewage purification systems

Conventional system



Application of phytotechnology





Ecohydrology Applications

PAST

1. Hydrology focused on control of catastrophic events and water supply
2. Descriptive ecology
3. Restrictive conservation aquatic ecosystem

Generation of sustainability concept

PRESENT

ECOHYDROLOGY

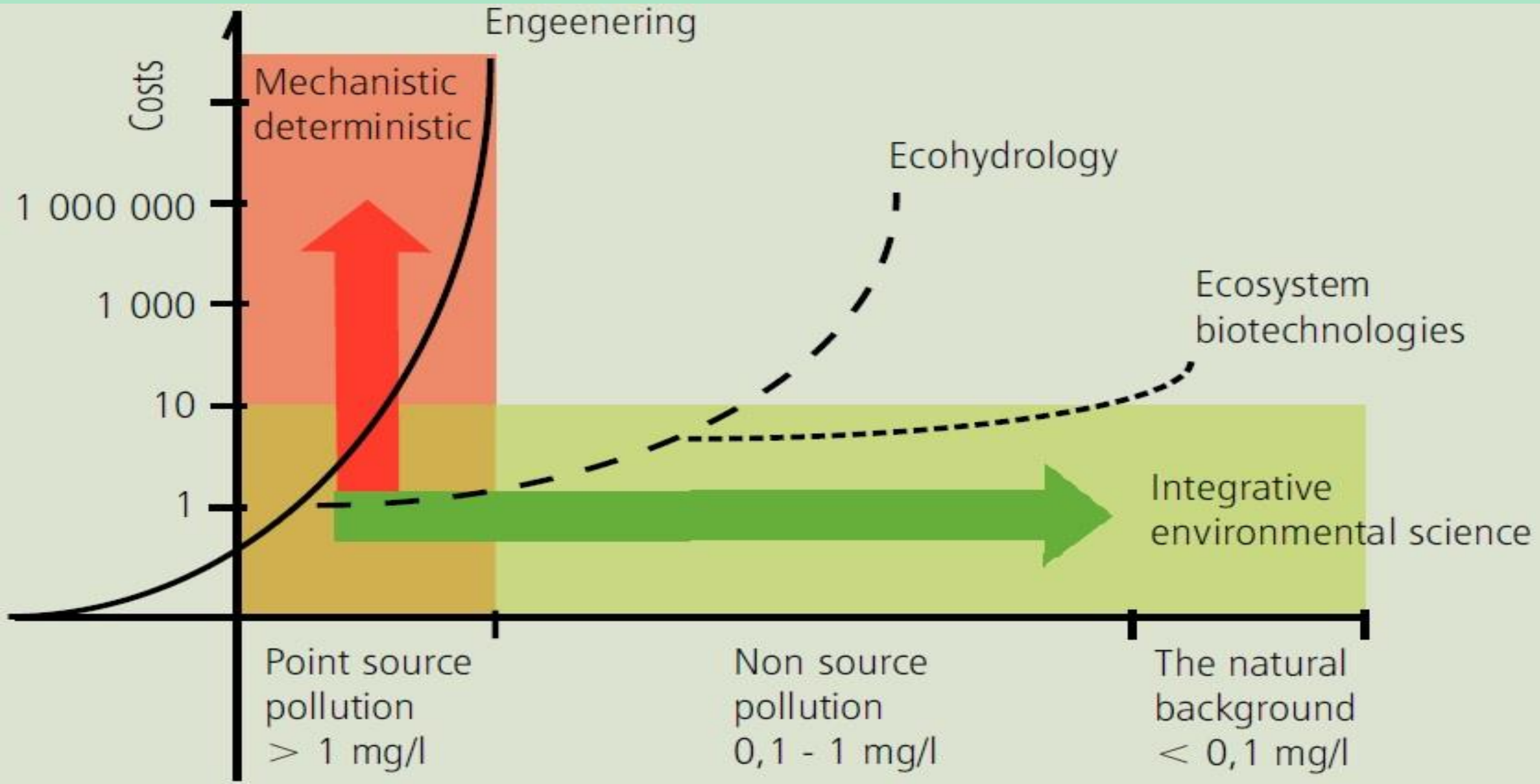
Integration of Ecology + Hydrology
Improvement of predictive abilities of large scale, long term processes as a background of sustainable management

FUTURE

1. Ecohydrology as a tool for sustainable use of aquatic resources
2. Analytical/functional ecology
3. Integrated and creative conservation of freshwater resources

Operational stage of sustainable management of freshwater resources

Ecohydrology Applications



Ecohydrology Applications

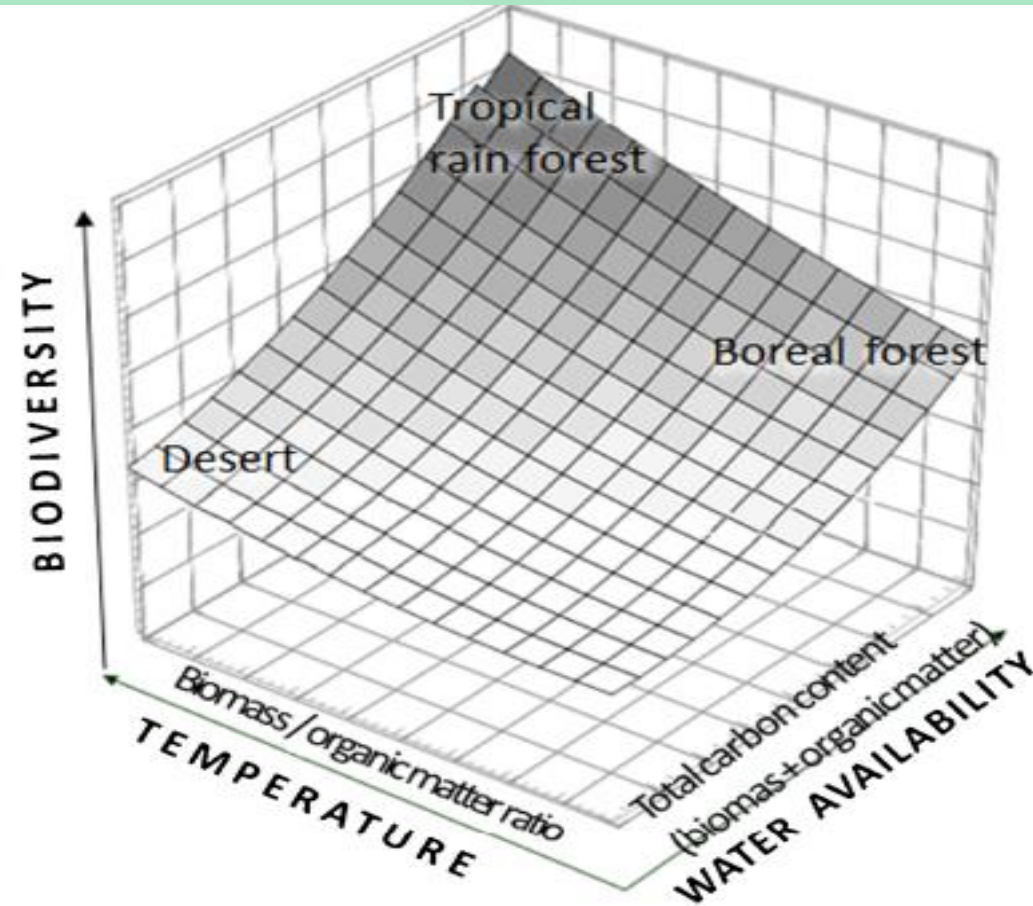
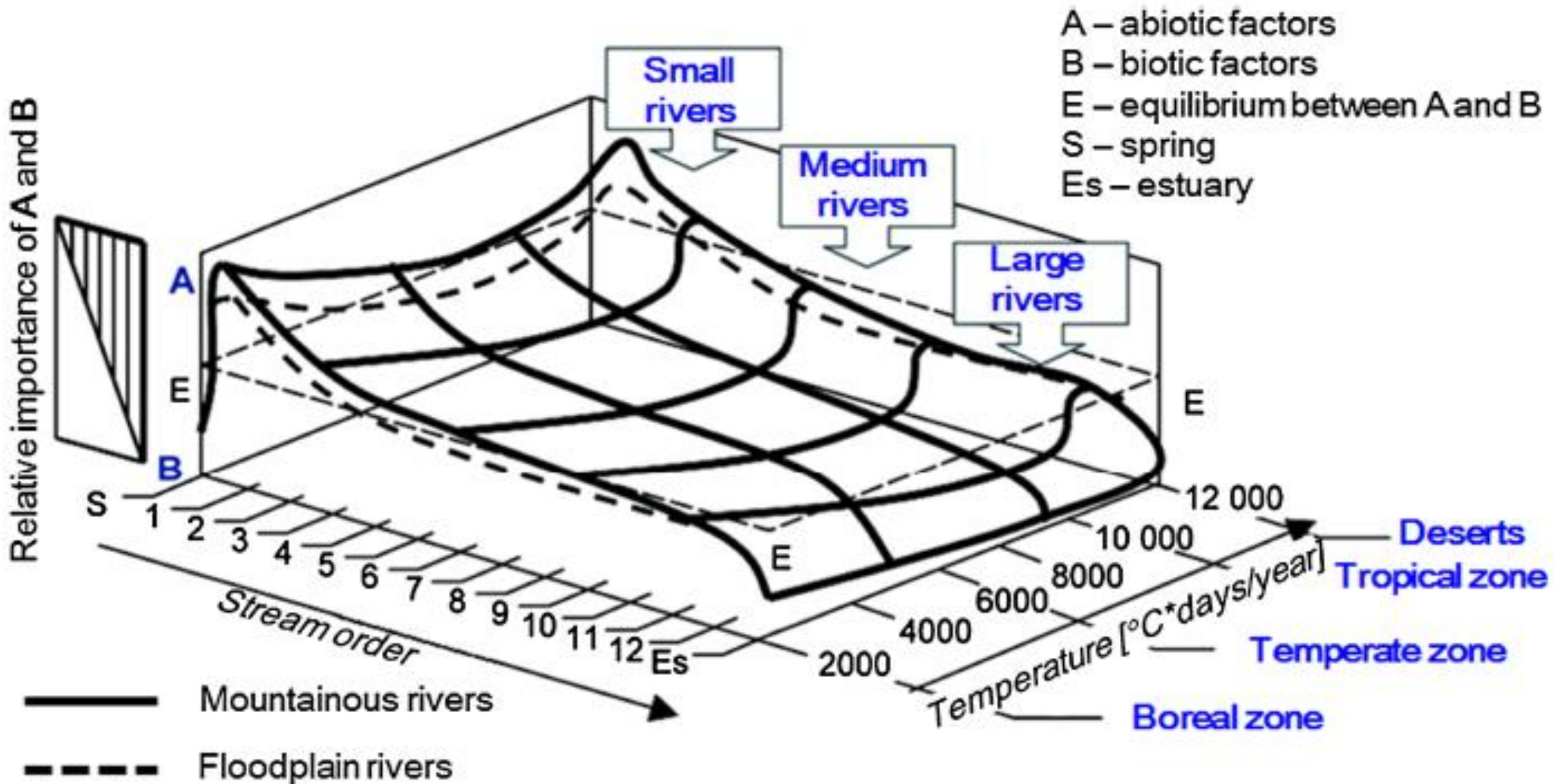
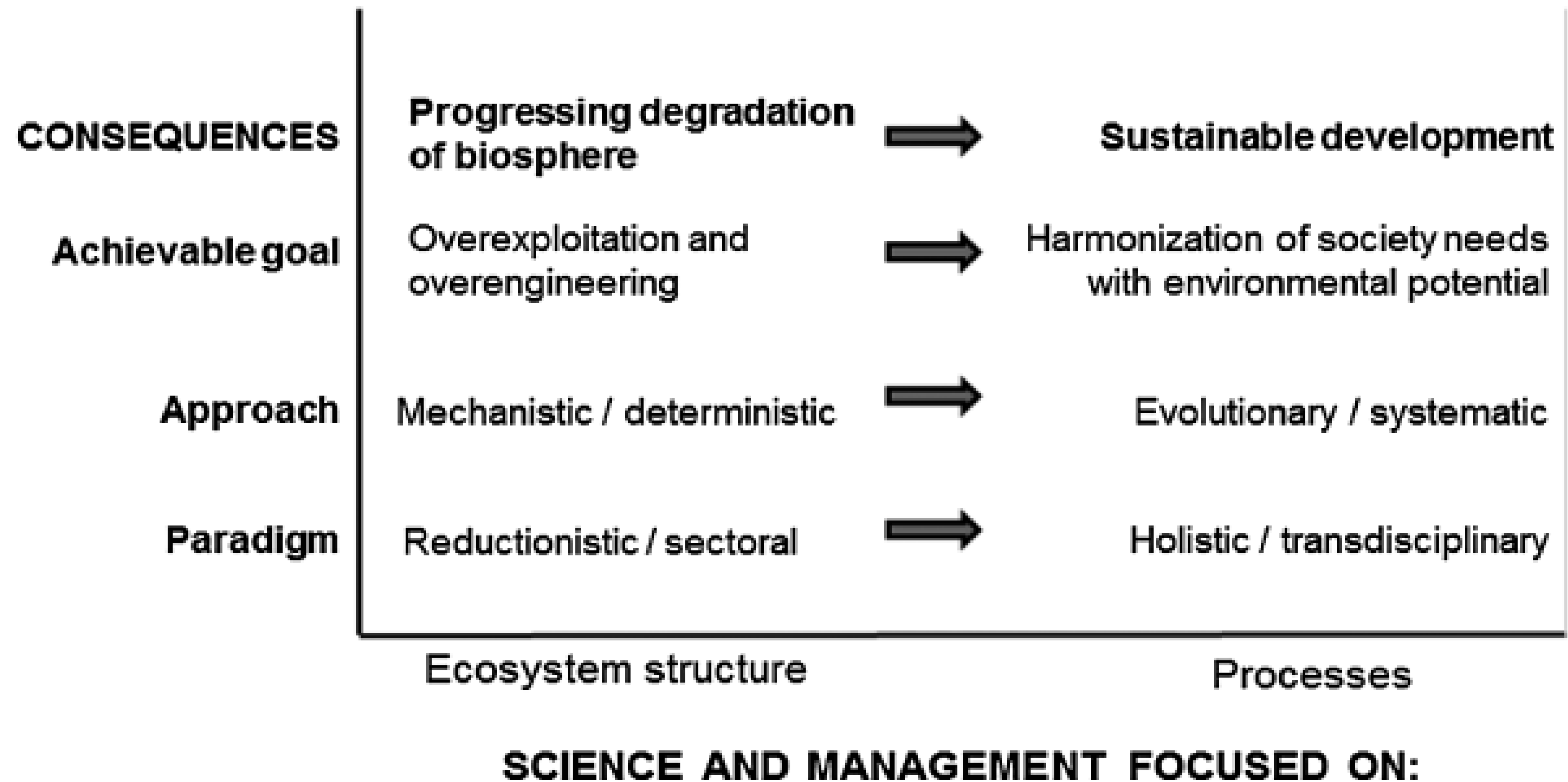


Fig. 2. Deductive background of ecohydrology theory, terrestrial phase, drivers of biodiversity; the amount of water determines the amount of carbon accumulated in an ecosystem while temperature determines the carbon allocation between biomass and soil organic matter; the maximum biodiversity and bioproductivity is achieved at highest water availability and highest temperatures (Zalewski 2002a, with permission from Taylor and Francis Ltd., <http://www.tandfonline.com>)

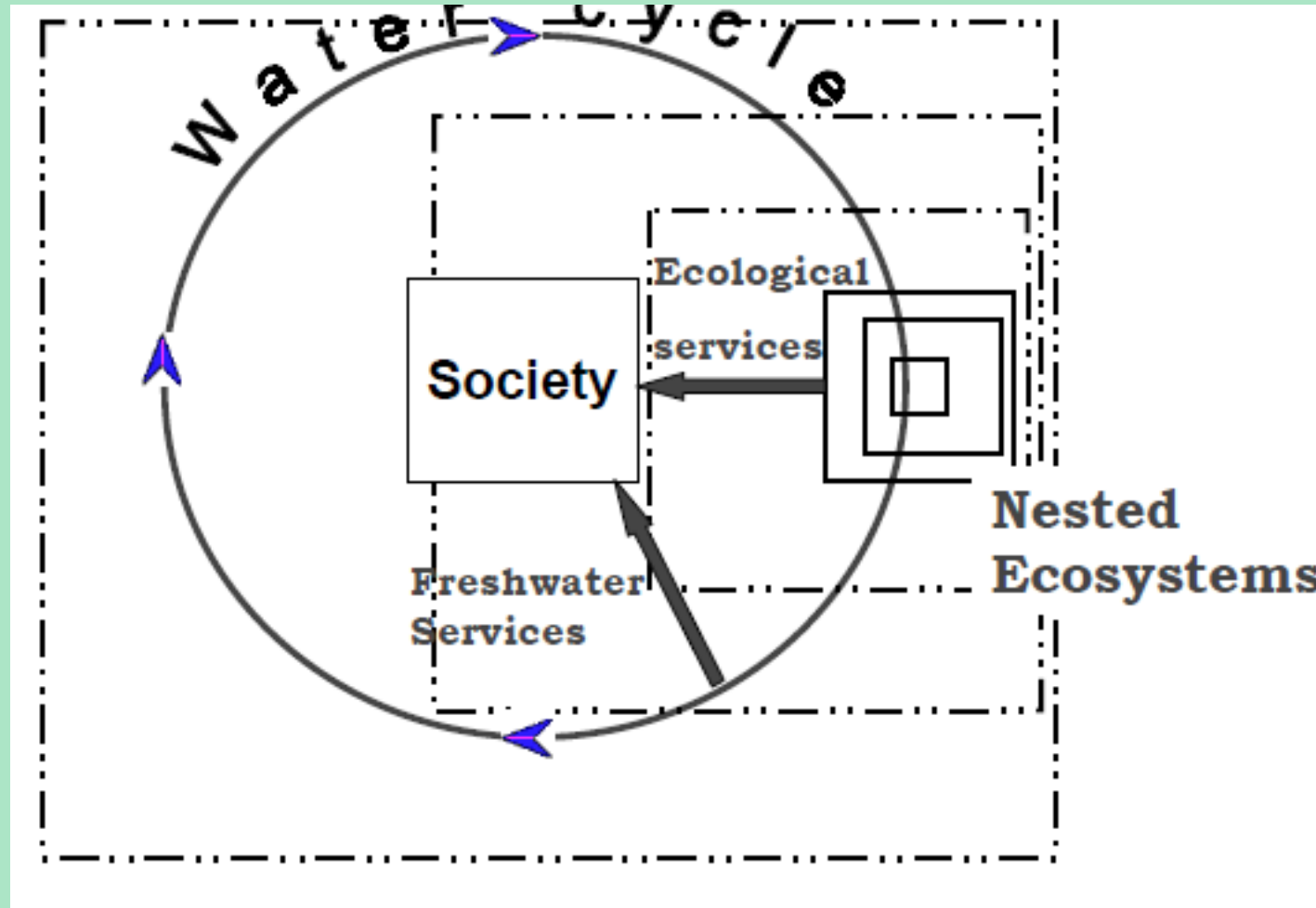
Ecohydrology Applications



Ecohydrology Applications



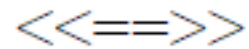
Social Ecohydrology



Social Ecohydrology

THE HUMAN-ENVIRONMENTAL RELATIONSHIP

Human social and
cultural beliefs
and practices



Material environment
Ecosystems
Hydrological systems

Social Ecohydrology

SOCIAL AND CULTURAL SYSTEMS

- Religious and secular beliefs and values.
- Social and spatial organisation.
- Economic organisation and forms of production.
- Political organisation, governance.
- Legal and moral systems.

Social Ecohydrology

MEANINGS ENCODED IN WATER

- Religious and secular meanings: water as a (re)generative substance of life and health for humans, animals and plants, and whole ecosystems.
- Social meanings: water as a collectively shared social ‘substance’, integral to identity and vulnerable to pollution.
- Economic meanings: water as a symbol of wealth and productivity.
- Political meanings: water as a source of power.
- Moral meanings: water as a human right, a common good.

Social Ecohydrology

PRINCIPLES OF SOCIAL ECOHYDROLOGY

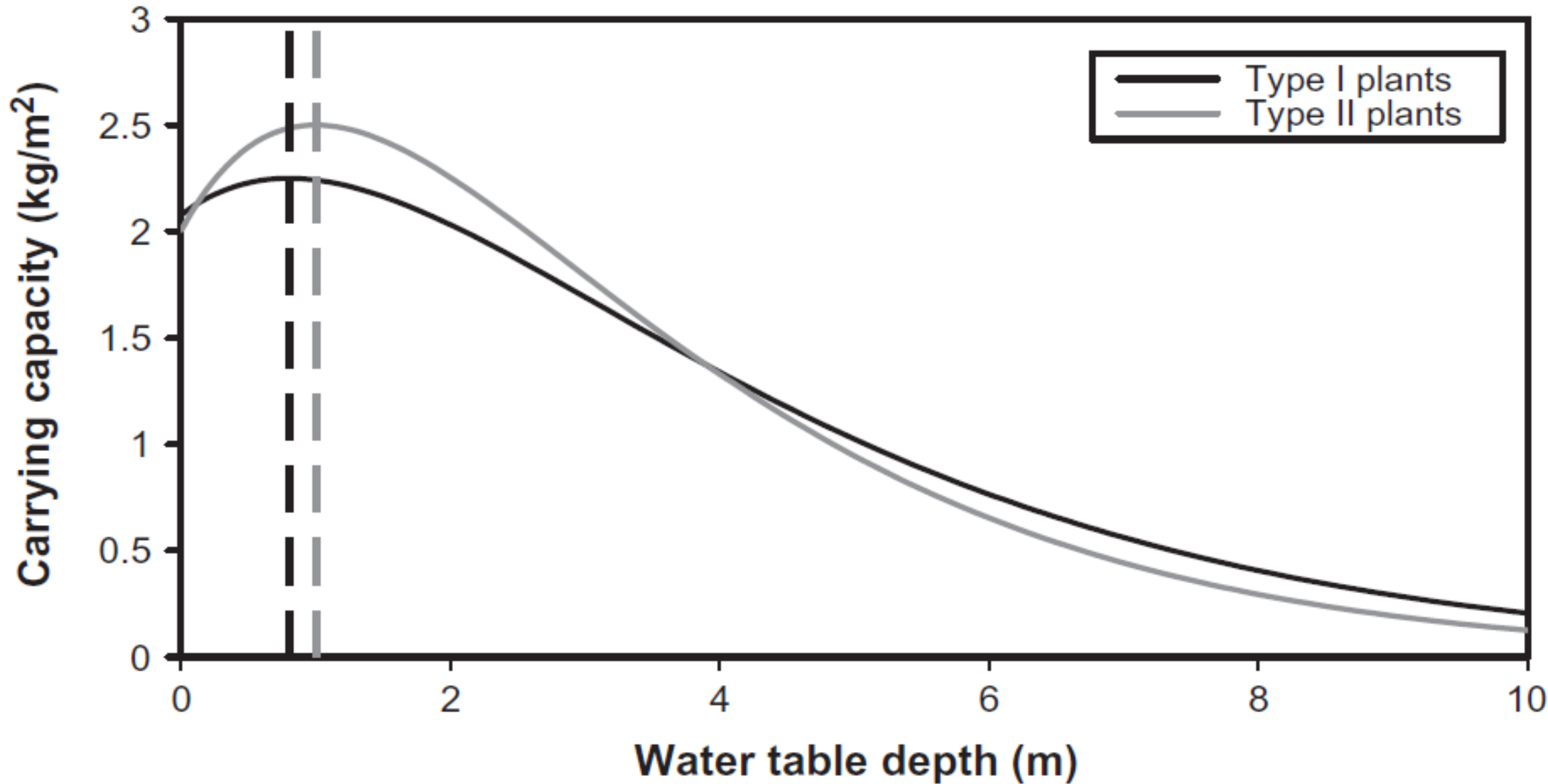
- It encompasses social, ecological and hydrological data.
- It recognises that social and natural science data represent two ‘halves’ of a whole human-environmental interaction, and treats them with equal weight.
- It allows for the inclusion of both qualitative and quantitative data.
- It organises data systematically.
- It is navigable, enabling analytic movement around the ‘landscape’ of data, and comparison between datasets.

Social Ecohydrology

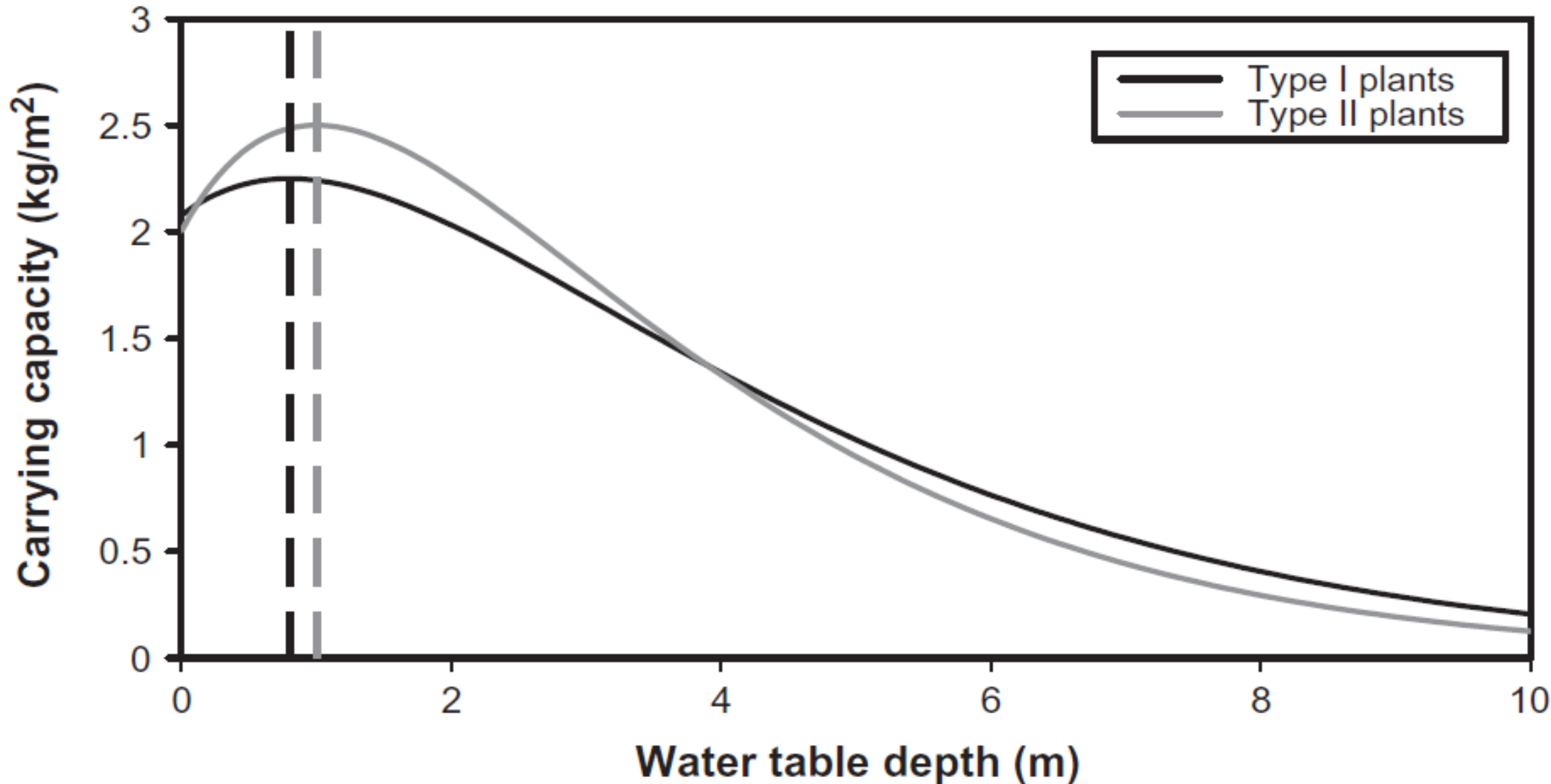
SOCIAL AND CULTURAL SYSTEMS

- Religious and secular beliefs and values.
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Groundwater and Plants



Groundwater and Plants



Watershed Setting

- 1. physical template:** This section covers the physical processes which are shaping forces of ecosystems. Climate, hydrology, and geomorphology provide the template upon which all life is ultimately based.
- 2. The biological setting:** This section discusses the terms and concepts associated with ecosystem science as it relates to living plant and animal communities.
- 3. Natural systems concept:** This section discusses how watersheds behave as natural systems and describes how different-sized watersheds operate on various spatial and temporal scales.

Watershed Functions

Category	Examples
Ecological Functions	<ul style="list-style-type: none">• Provision of sufficient water with a minimum required quality,• Provision of minimum water flow over time,• Provision of other goods and services from natural resources e.g. erosion control, soil fertility biodiversity, clean air, carbon sequestration.
Economic Functions	<ul style="list-style-type: none">• Provision of sufficient natural resource products (food, fuel wood, timber, water, fish, (hydraulic) energy required for basic needs of the local population,• Provision of income generating opportunities.• Sustain livelihoods
Social and Cultural Functions	<ul style="list-style-type: none">• Maintenance of social structures,• Protection and development of knowledge and lifestyle arrangements,• Maintenance and revitalization of cultural identity and values,• Recreational facilities

Watershed Functions

- 1. The Collection Function:** How runoff is collected within the watershed depends upon storm position and size relative to basin size, storm proximity to runoff source areas within the watershed, and precipitation type and intensity. Ultimately, these are critical issues of relative scales of the watershed and the runoff-producing event. Two of these issues are particularly relevant. The first is whether the event completely covers the watershed, and the second is where on the watershed the storm is located if it is smaller than the watershed.
- 2. The Storage Function:** The type, amount, and distribution of storage are the primary watershed characteristics that affect the storage function. As the function that is intermediate between the collection and discharge functions, some storage characteristics play an intervening, complex, and interacting role among all three functions.

Watershed Functions

3. The Discharge Function: The ultimate fate of runoff waters within a watershed is to be output from the basin, as depicted in the hydrograph, the record of the discharge function. Discharge takes place as the functions of collection and storage are played out over time scales varying from that of a runoff-causing event to a hydrologic year. Clearly, factors that affect the collection and storage functions also affect the discharge function, and are represented in both the storm and annual hydrographs.

4. The Chemical Function: Water is the principal medium in which most chemical reactions occur; watersheds provide diverse aqueous sites in which those chemical reactions take place. Over time, these reactions have ranged from those preceding beginnings of life on Earth to those affecting the movement of pollutants and unwanted nutrients in the modern aquatic environment.

5. The Habitat Function: Life on Earth takes place in the presence of water. The fluids of living organisms are like that of the oceans. One popular theory is that the "higher" living organisms on Earth developed in an aqueous environment. The evolution of humans most likely occurred at diverse and protective seashore environments (as opposed to the rather hostile savannah). Wherever the human species evolved into its current form, other mammals thrived and made similar dramatic changes in appearance and behavior.

Watershed Functions

Location of Benefits	Economic Benefit	Watershed Service ⁶	Economic Valuation Study
Upstream	Reduced crop losses	Soil quality maintenance: Reduced soil erosion, and loss of soil depth and fertility	Morocco: Loukkos Watershed. Brooks et al (1982)
	Value of e.g. forest products	Land/Water Productivity: conservation strategies: e.g. afforestation, provide livelihoods	
	Improved livestock and produce	Land/Water Productivity: conservation strategies: e.g. pasture management, provide livelihoods	Nepal: Phewa Tal Watershed. Fleming, Hufschmidt et al (1986)
	Increased crop yields	Soil quality maintenance: ecological benefits: increased soil organic matter, moisture retention etc.	Mali: Bishop & Allen (1989)
Downstream	Improved Water Availability	Water Yield: inter-sectoral reallocation of surface water yield from surface water management or optimal control of groundwater coupled to surface water	USA, Colorado: Howe (2000)
	Irrigation Benefits	Water quality maintenance: Improved yields through water quality improvement and reservoir yield	Java: Repetto et al (1989)
	Hydropower generation	Water quality/sediment retention and water yield: Reduced siltation of storage dams, increased inflow	El Salvador: Acelhuate Catchment. Wiggins and Palma, (1980)
	Flood damage prevention	Water flow smoothing: Reduced runoff in high rainfall periods	USA: North Carolina. Freund & Tolley (1966)
	Drought Mitigation	Water storage: increased groundwater for drought years	Indonesia: Manggarai watersheds. Pattanayak & Kramer (2001)
	Fisheries Benefits	Water quality: Increased yields from improved water quality	Australia: New South Wales. Sinden (1990).
	Domestic and other Industrial	Water yield and quality: Improved water quality, reduced treatment costs, reduced siltation of storage dams, increased yield	Morocco: Loukkos Watershed. Brooks et al (1982)
	Amenity	Environmental/ecological: Recreation, tourism, ecological/habitat	Cyprus: Kouris Catchment. Swanson et al (2001)