Management of Climatic Extreme Events in Lakes and Reservoirs for the Protection of Ecosystem Services

Ecosystem services 1. Overview and integration in management

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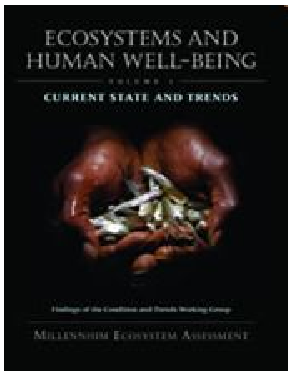
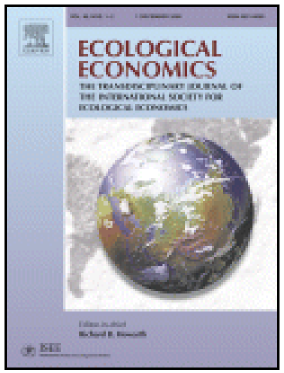
Ecosystem services are:

1. the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al. 1997).
2. the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005).
3. the ecological components directly consumed or enjoyed to produce human well-being (Boyd and Banzhaf 2007).
4. the aspects of ecosystems utilized (actively or passively) to produce human well-being (Fisher et al. 2009).

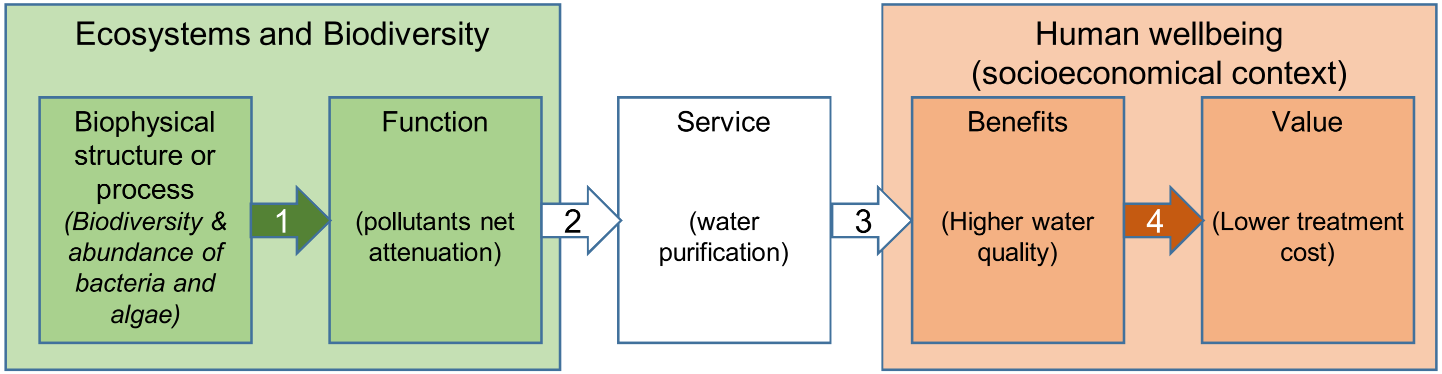




WHAT A SERVICE IS?

	Main service types
	PROVISIONING SERVICES
1	**Food** (e.g. fish, game, fruit)
2	**Water** (e.g. for drinking, irrigation, cooling)
3	**Raw Materials** (e.g. fiber, timber, fuel wood, fodder, fertilizer)
4	**Genetic resources** (e.g. for crop-improvement and medicinal purposes)
5	**Medicinal resources** (e.g. biochemical products, models & test-organisms)
6	**Ornamental resources** (e.g. artisan work, décorative plants, pet animals, fashion)
	REGULATING SERVICES
7	**Air quality regulation** (e.g. capturing (fine)dust, chemicals, etc)
8	**Climate regulation** (incl. C-sequestration, influence of vegetation on rainfall, etc.)
9	**Moderation of extreme events** (eg. storm protection and flood prevention)
10	**Regulation of water flows** (e.g. natural drainage, irrigation and drought prevention)
11	**Waste treatment** (especially water purification)
12	**Erosion prevention**
13	**Maintenance of soil fertility** (incl. soil formation)
14	**Pollination**
15	**Biological control** (e.g. seed dispersal, pest and disease control)
	HABITAT SERVICES
16	**Maintenance of life cycles of migratory species** (incl. nursery service)
17	**Maintenance of genetic diversity** (especially in gene pool protection)
	CULTURAL & AMENITY SERVICES
18	**Aesthetic information**
19	**Opportunities for recreation & tourism**
20	**Inspiration for culture, art and design**
21	**Spiritual experience**
22	**Information for cognitive development**

Pathway from ecosystem structure and processes to human wellbeing

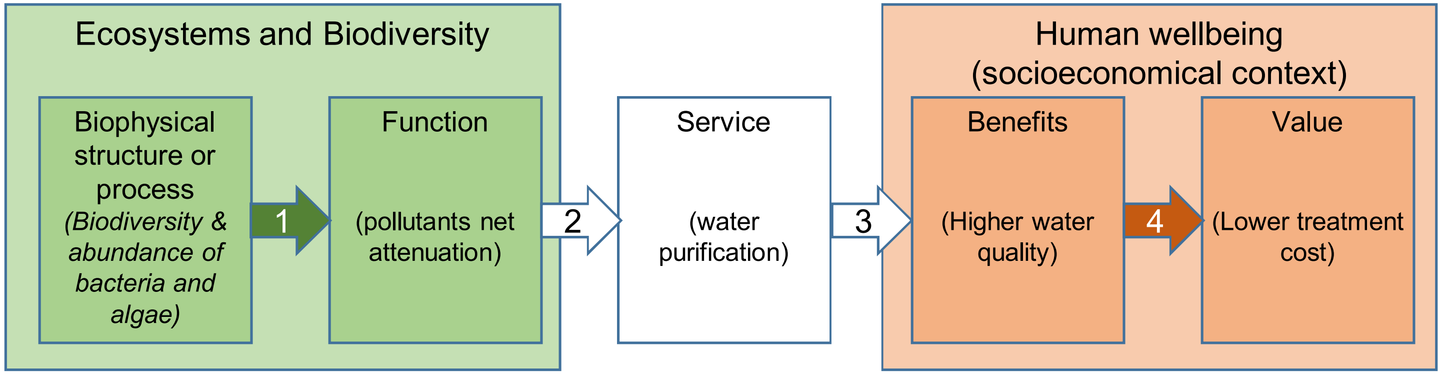


Eco functions are subset of the interactions between structure and process that underpin capacity of ecosystem to provide goods and services.

Building blocks of eco functions may be physical, chemical or biological.

Services are conceptualizations of the useful things ecosystems do for people.

Pathway from ecosystem structure and processes to human wellbeing



There are 4 steps from biophysical structure or process to value!

- **From diversity to function**
- **From function to service**
- **From service to benefit**
- **From benefit to value**

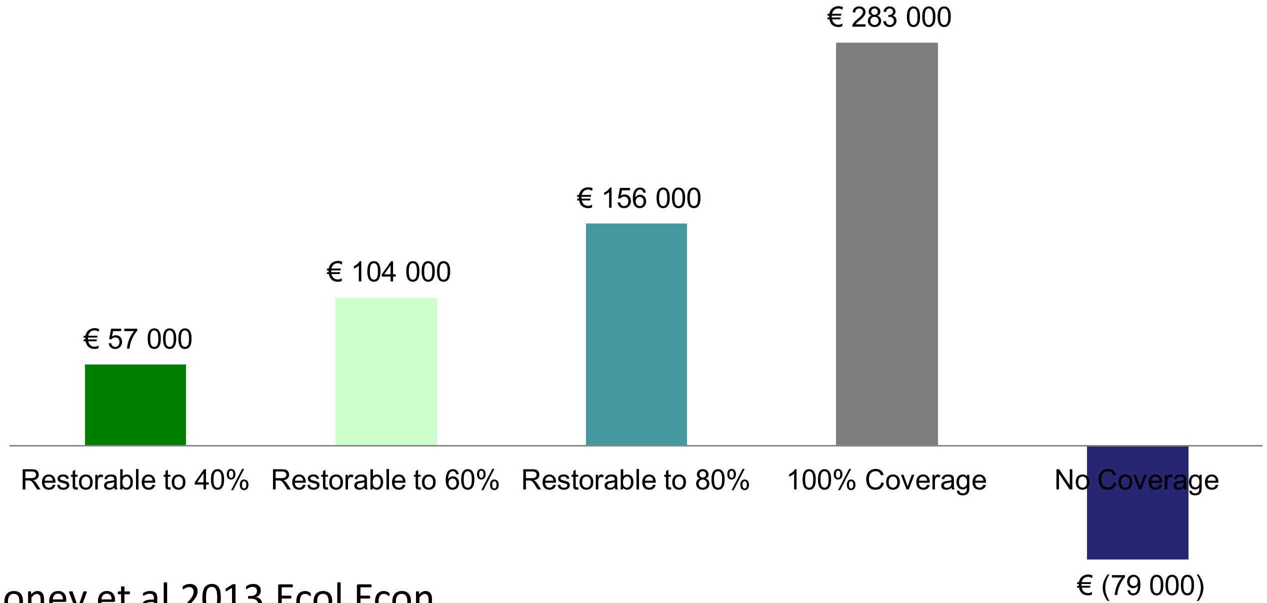
Societal preferences, which determine demand for ecosystem services are the most important factor, although the most influential and often unconsidered factors altering the biodiversity – services relationships are:

- **valuation strategy**
- **spatial and temporal dimensions**
- **services use and demand**
- **individual revealed and stated preferences.**

- *Valuation strategy*

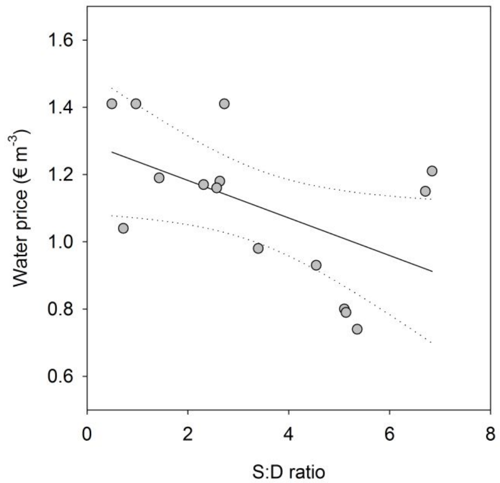
1. Ecosystem service	2. Benefit			3. Valuation metric selection
		Endpoints	Beneficiaries	
Water provisioning	Water for drinking purpose	Surface water	Household water consumers	WP1. Market price: value of water for drinking purpose
	Water for irrigation purpose	Surface water	Farmers	WP2. Production based approach: value of water for irrigation purpose
		Surface water	Farmers	WP3. MAUT based simulation: value of water for irrigation purpose
	Hydropower production	Surface water	Energy producers and tax payers	WP4. Market price: value of water for hydropower production
Water treatment	Higher surface water quality	Drinking water	Treatment facilities and tax payers	WT1. Avoided cost: cost of water treatment for drinking purpose (contaminant removal)
		Drinking water	Treatment facilities and tax payers	WT2. Avoided cost: cost of water treatment for drinking purpose (contaminant removal)
		Drinking water	Consumers	WT3. Avoided cost: cost of health care linked to poor water quality
		Rivers and lakes	Users and non-users	WT4. Avoided cost: cost of ecosystem damages
	Enjoyment of recreational areas	Rivers and lakes	Recreationists	WT5. Contingent valuation: willingness to pay for clean water bathing areas
Erosion protection	Higher surface water quality	Drinking water	Treatment facilities and tax payers	EP1. Avoided cost: cost of water treatment for drinking purpose (suspended sediment filtering)
	Avoided soil losses	Land	Land owners	EP2. Replacement cost: cost of soil restoration
		Land	Land owners	EP3. Market price: loss of income from productivity loss
	Extension of water management infrastructures lifetime	Reservoirs	Reservoirs managers and taxpayers	EP4. Avoided cost: cost of dredging dam reservoirs
		Reservoirs	Reservoirs managers and taxpayers	EP5. Avoided cost: cost of dredging dam reservoirs
	Soil carbon storage	Land	Users and non-users	EP6. Market price: value of soil carbon storage
	Enjoyment of recreational areas	Rivers and lakes	Recreationists	EP7. Contingent valuation: willingness to pay for clear water bathing areas

- *Temporal component - Technological change*



Honey et al 2013 Ecol Econ

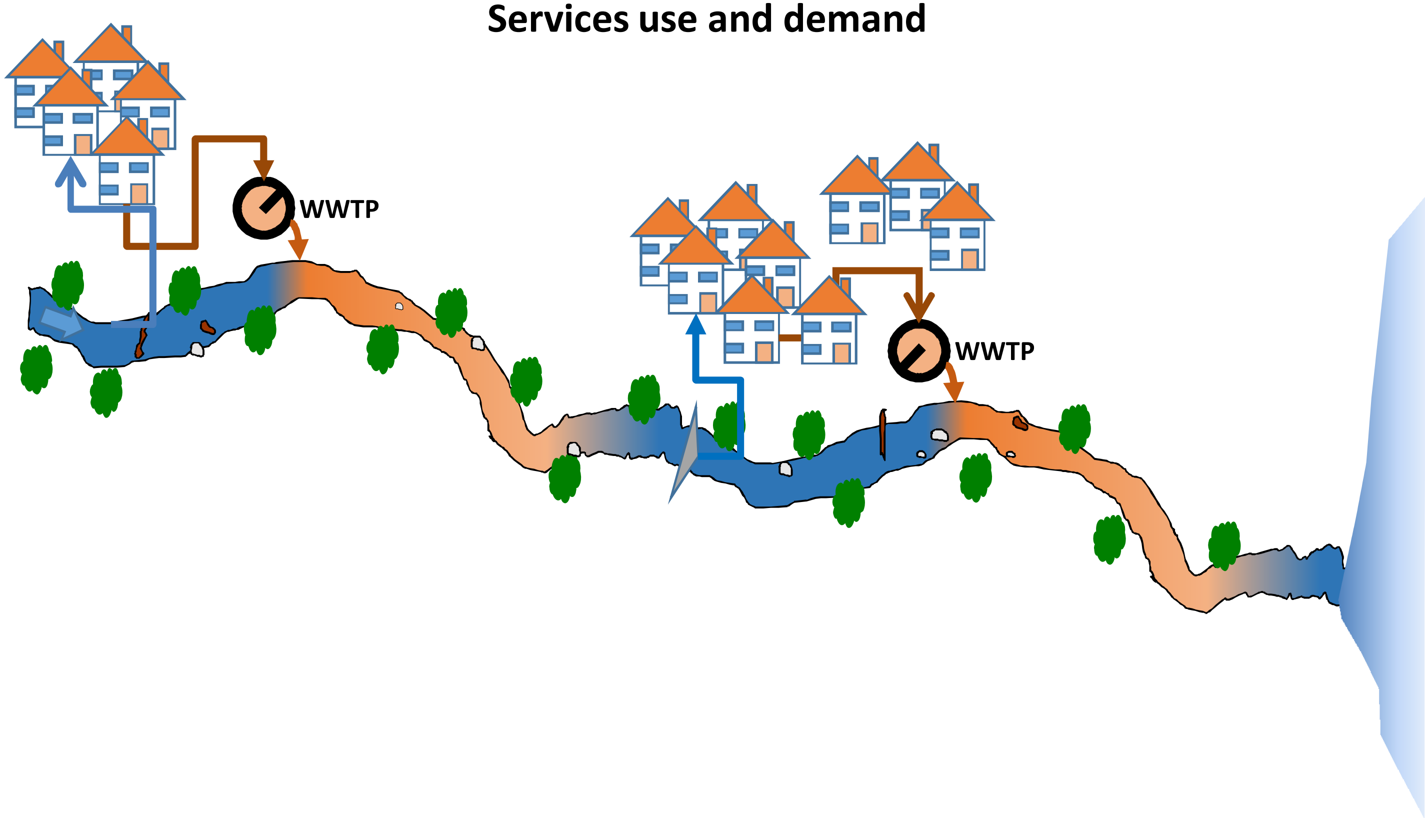
Services use and demand



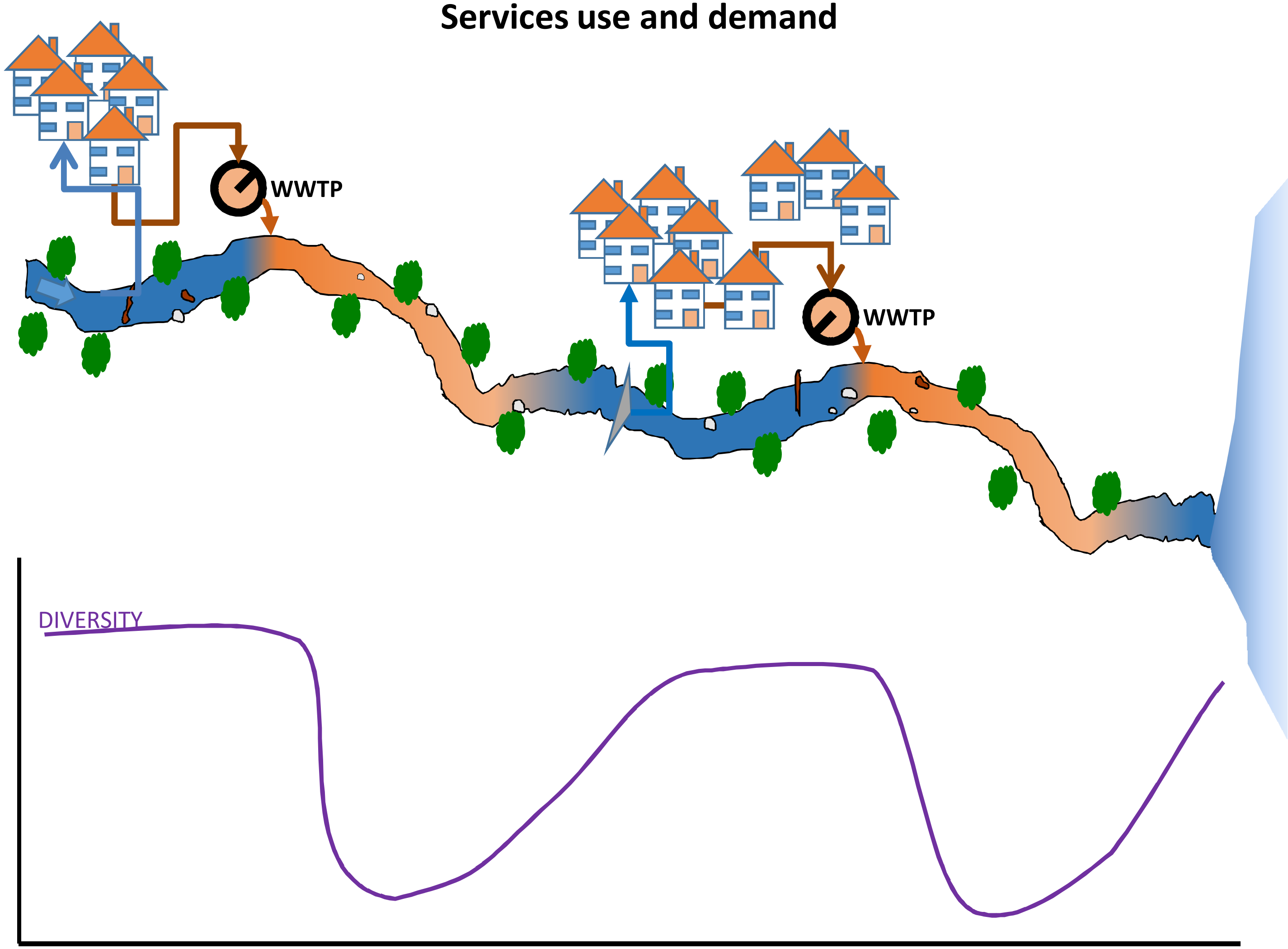
Ratio between provisioning of service, and demand for service influences the value, so that scarcity implies high value.

Boithias et al 2014 STOTEN

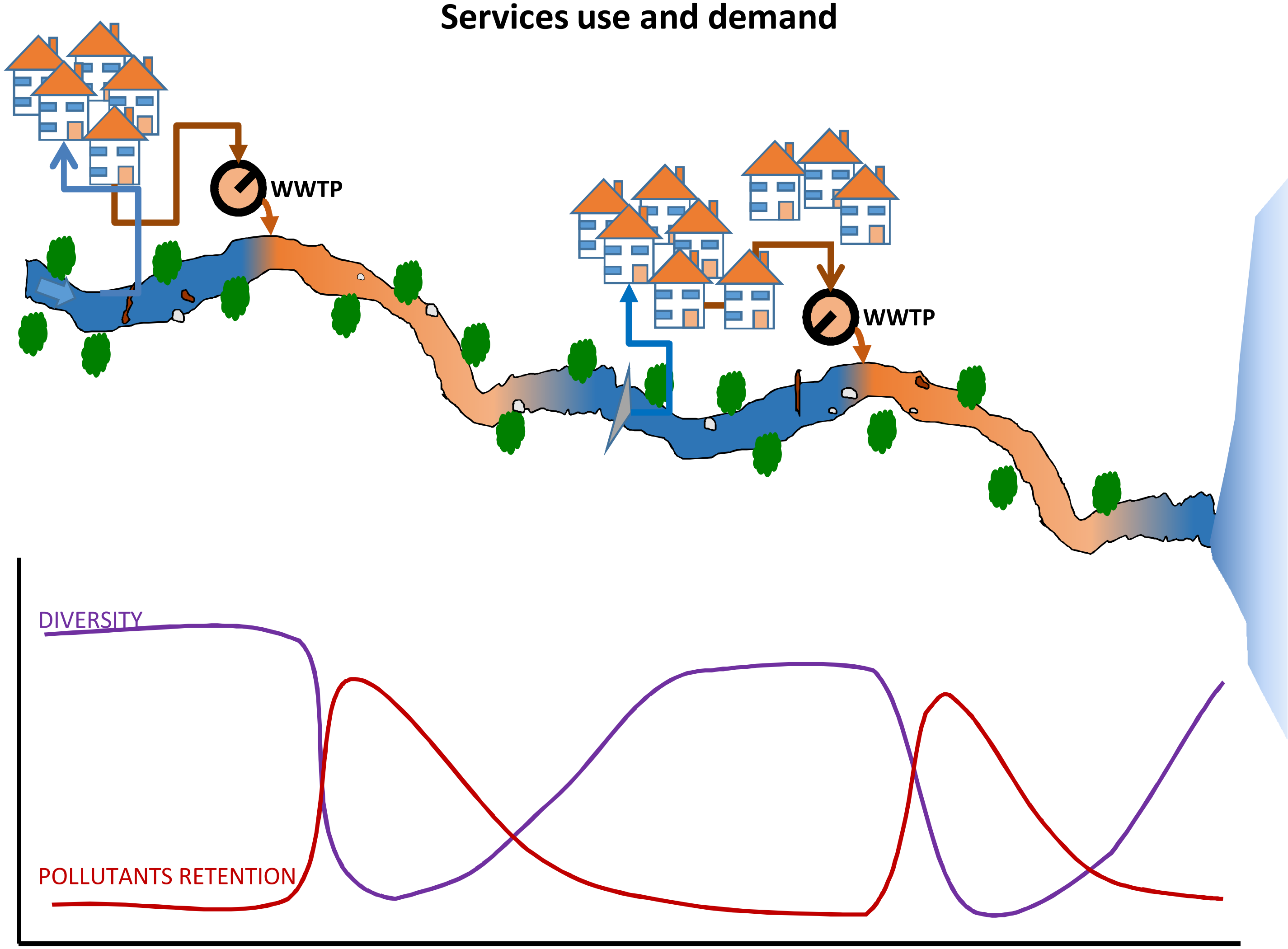
Services use and demand



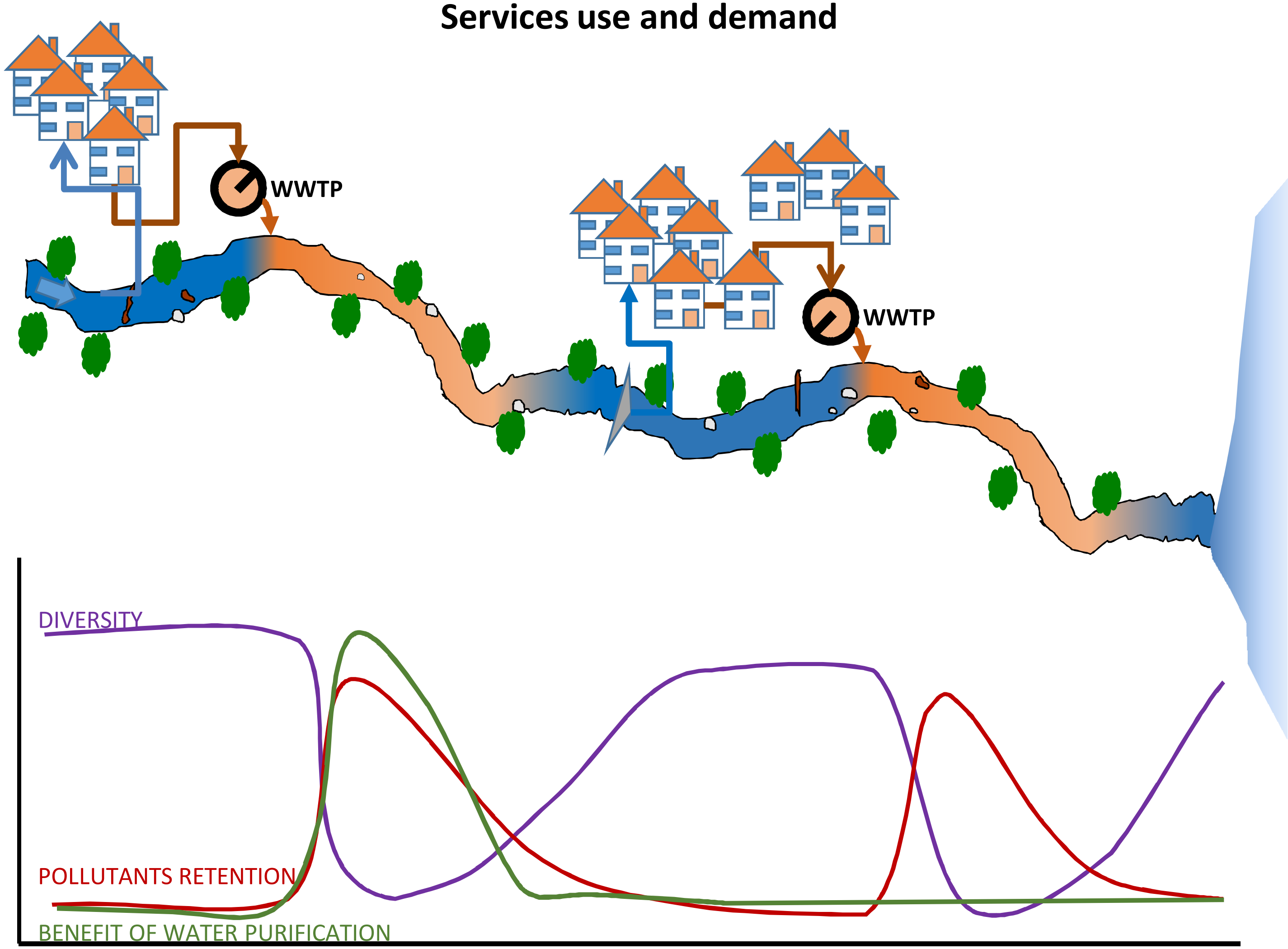
Services use and demand

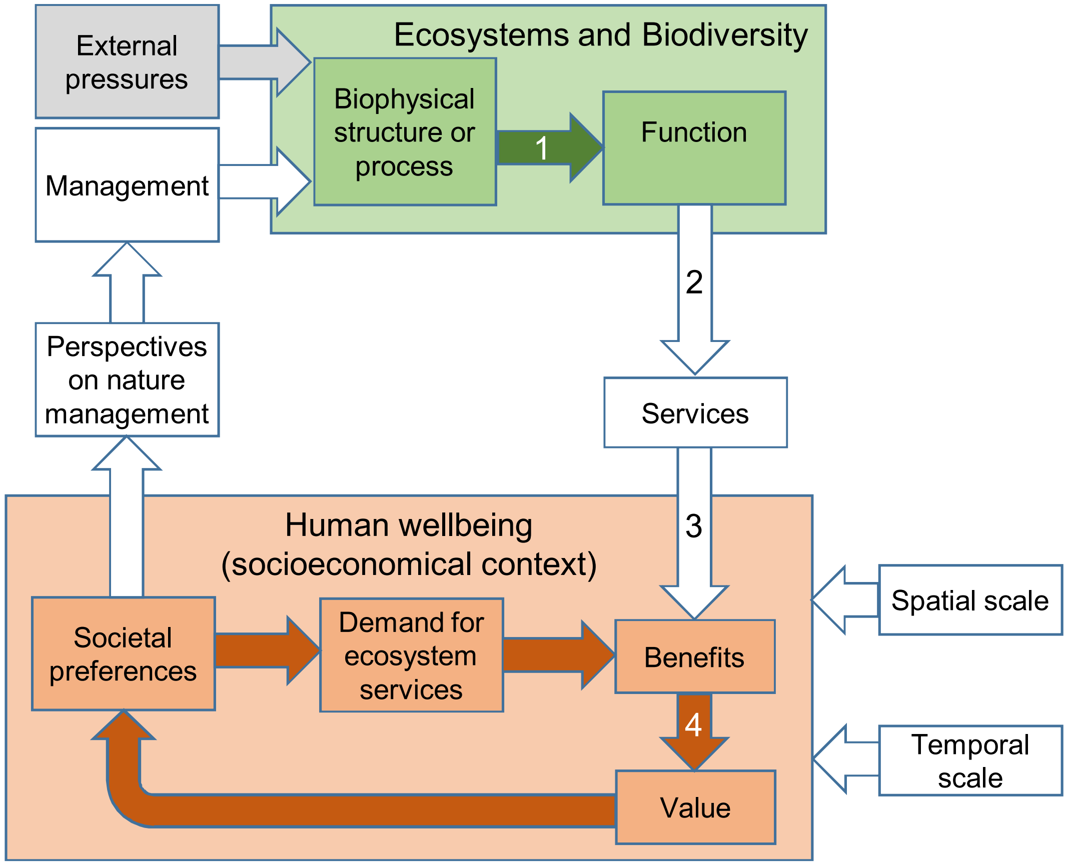


Services use and demand



Services use and demand




External pressures
Ecosystems and Biodiversity
Biophysical structure or process
1
Function
Management
2
Perspectives on nature management
Services
3
Human wellbeing (socioeconomical context)
Societal preferences
Demand for ecosystem services
Benefits
4
Value
Spatial scale
Temporal scale

How and why to integrate ecosystem services in management

For any management action, we should:

1. **Determine the net benefits of interventions that alter ecosystem conditions.**

   Would the benefits of a given investment justify its costs?

2. **Examine how the costs and benefits of the intervention are distributed.**

   Who pays and who benefits? where and when?

We should consider ecosystem services because the markets do not reflect the full social costs or benefits of a management action. Common market failures:

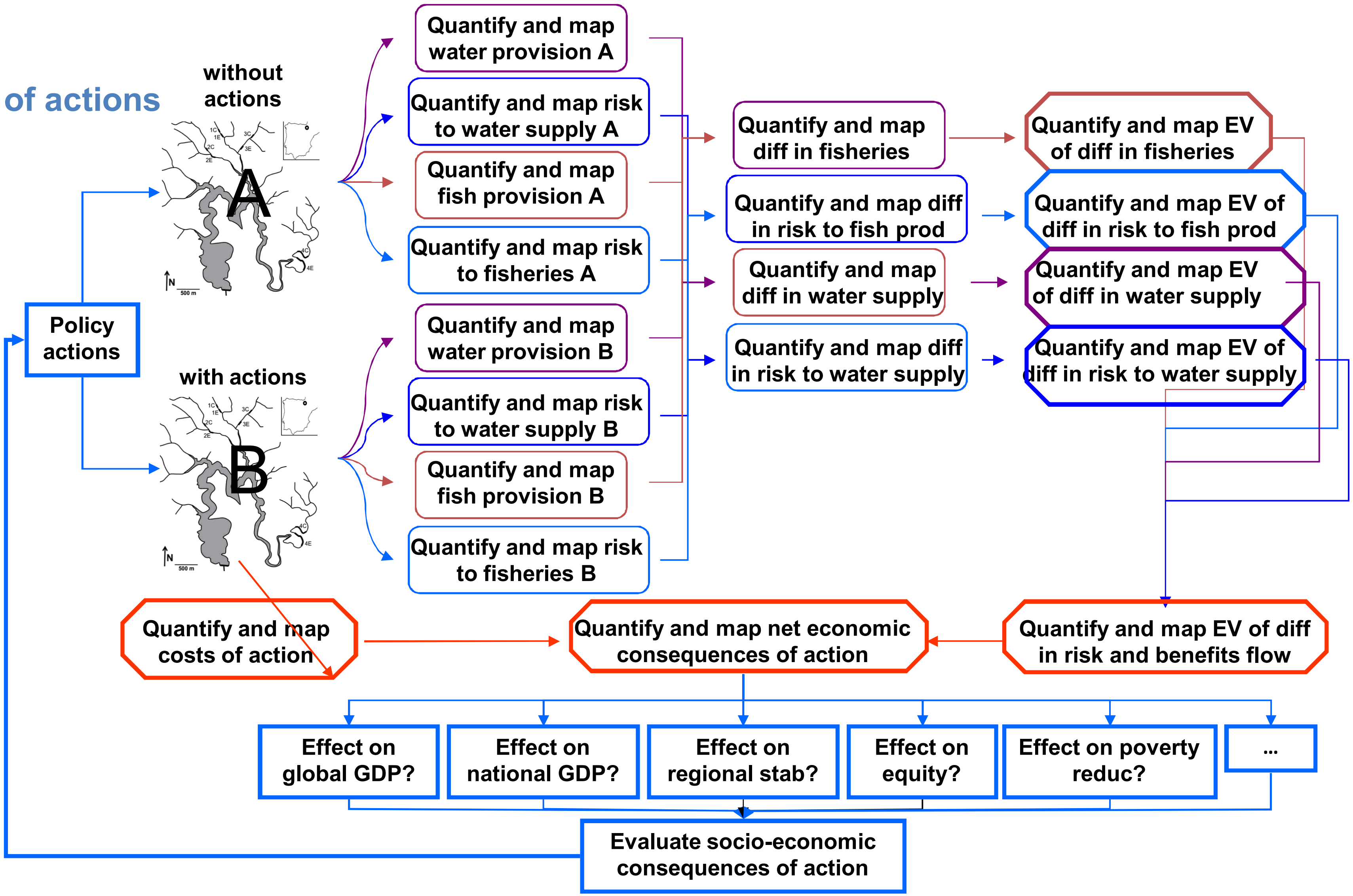
i) many ecosystems provide services that are public goods (ex. aesthetic view, recreational area);

ii) property rights related to ecosystems and their services are often not clearly defined (ex. fish, water);

iii) many ecosystem services are considered externalities, or uncompensated side effects of management actions.

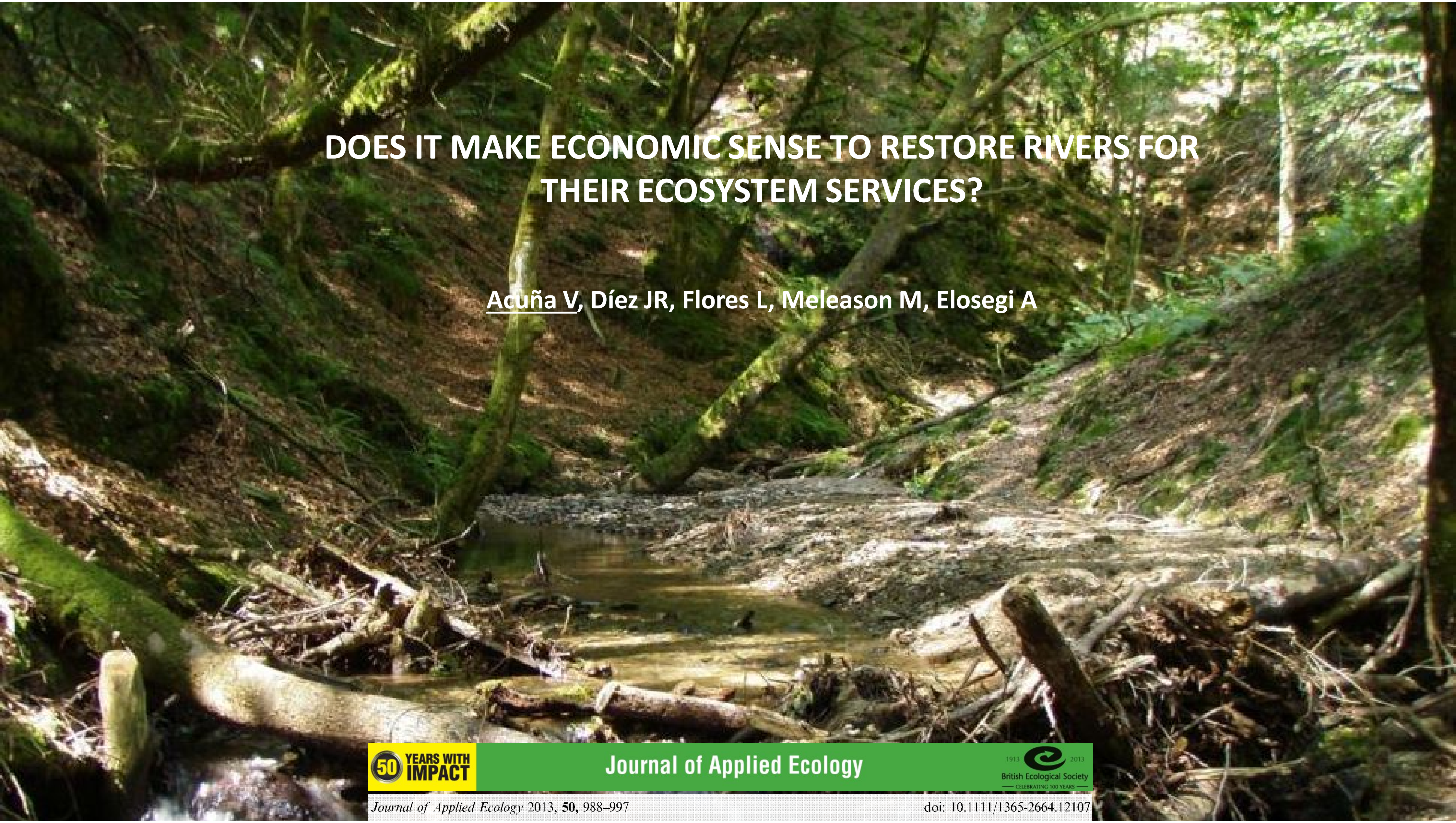
Integration of ecosystem services in management allows resource managers to account for all costs and benefits related with the different possible management actions.

Net benefit of actions



Examples on implementation of ecosystem services in management

1. **The Añarbe.** ***Acuña et al 2013. J Applied Ecol***
    1. ***Ex-post cost-benefit analysis***
    2. ***What should we do to avoid reservoir excessive sedimentation?***
    3. ***Instream habitat restoration by wood addition.***
2. **The Yarqon.** ***García-Acosta et al 2016. Env. Science and Policy***
    1. ***Ex-post cost-benefit analysis.***
    2. ***Was it economically worth to restore the Yarqon River?***
3. ***The Llobregat RBMP. Terrado et al 2016. J Applied Ecology***
    1. ***Incorporing ES as management goals!***
    2. ***Combination of CEA and CBA.***



DOES IT MAKE ECONOMIC SENSE TO RESTORE RIVERS FOR THEIR ECOSYSTEM SERVICES?

Acuña V, Díez JR, Flores L, Meleason M, Elosegi A

50 YEARS WITH IMPACT
Journal of Applied Ecology
1913 2013 British Ecological Society — CELEBRATING 100 YEARS —
Journal of Applied Ecology 2013, **50**, 988–997 doi: 10.1111/1365-2664.12107

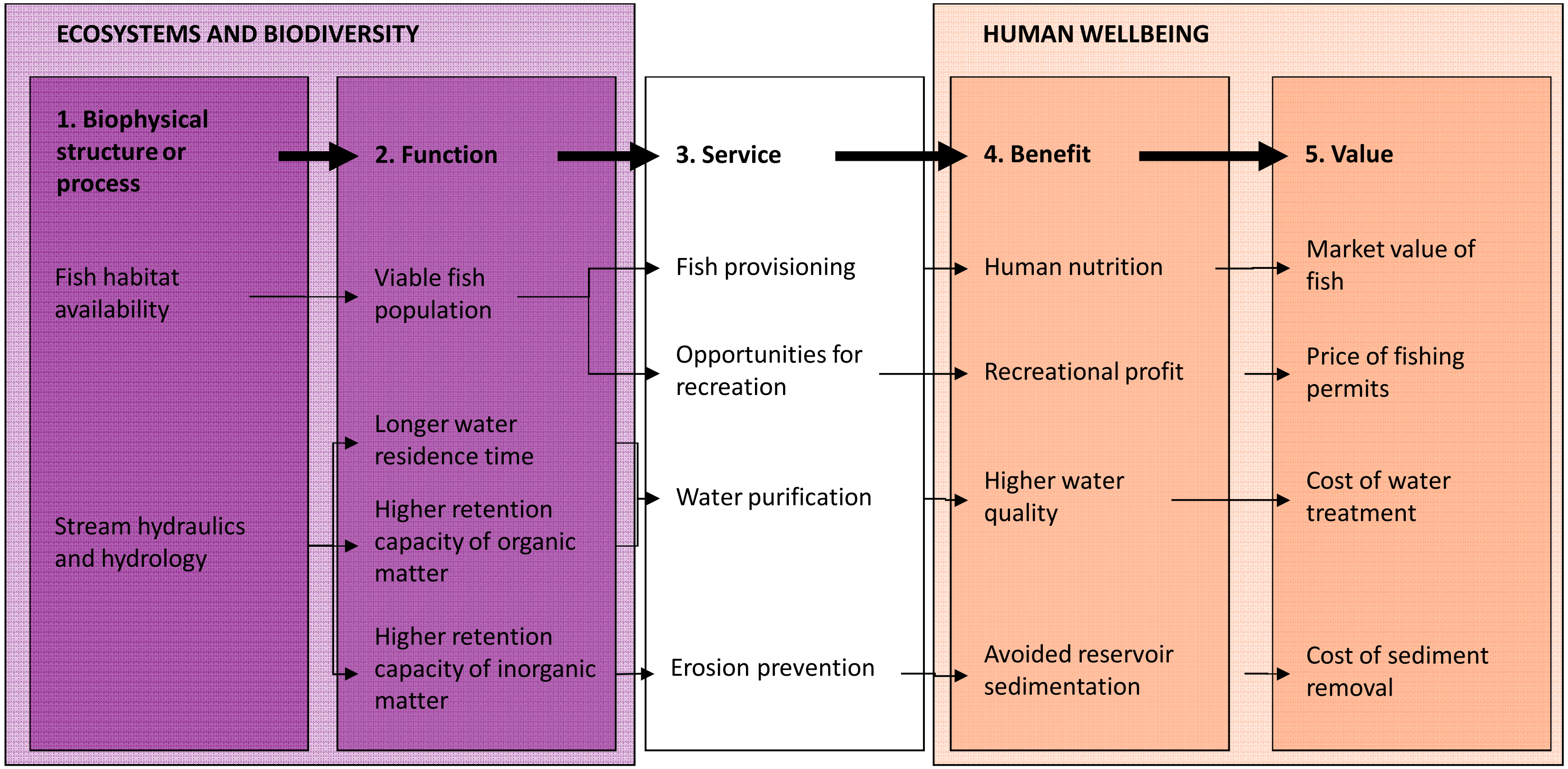
Background and Management problem

The reservoir of Añarbe stores and supplies water for the city of Donosti, but litter and sediment inputs from the associated basin are relatively high and reduce the reservoir storage capacity by 2% every year.

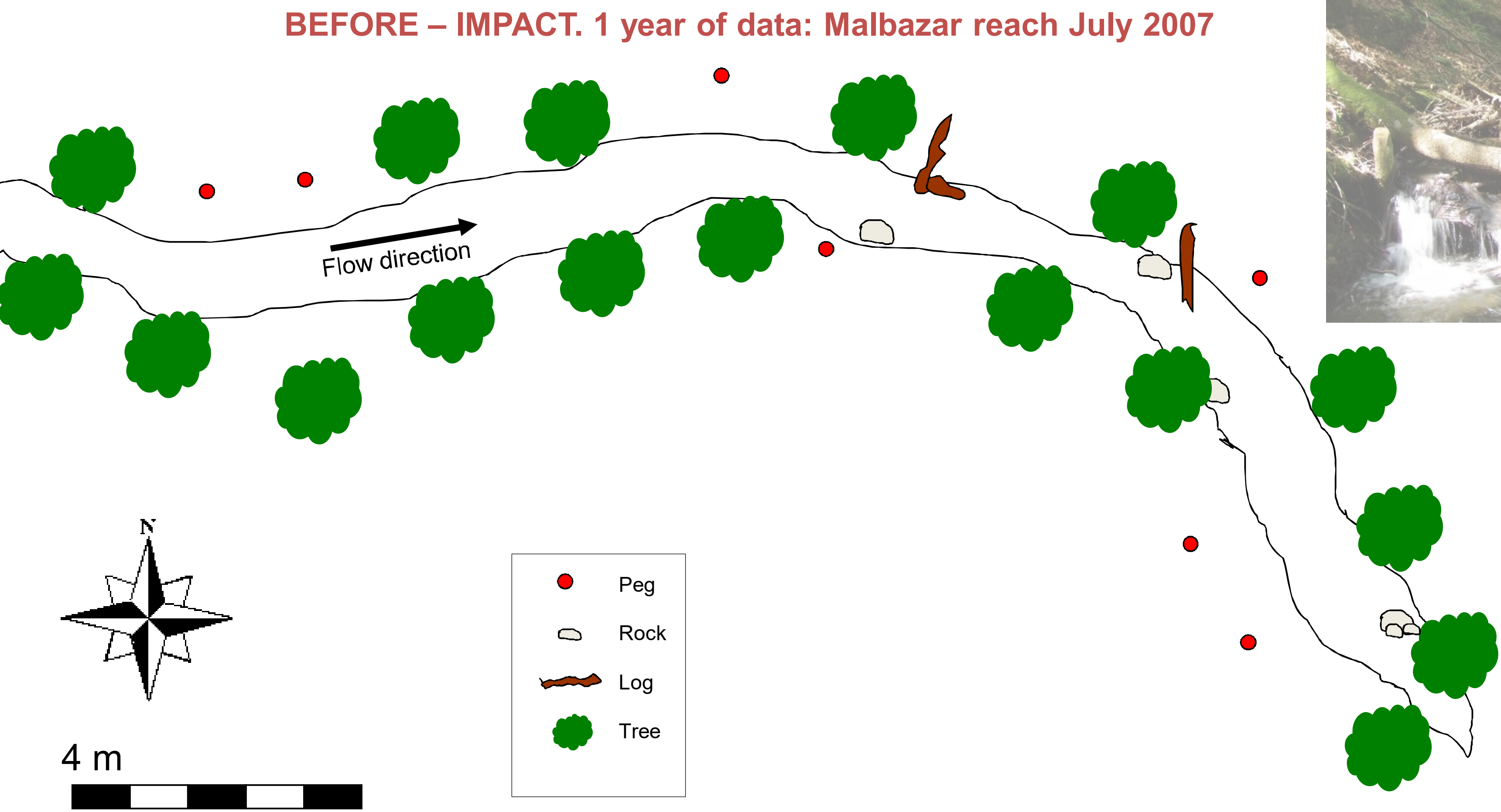
We aim to comprehend the causes behind the input of sediment and litter to the reservoir and design restoration measures that can decrease this input and thus reduce dredging costs.

We identify current logging practices as the cause behind the litter and sediment inputs, and design a restoration action to increase the retentiveness of the river network: wood addition.

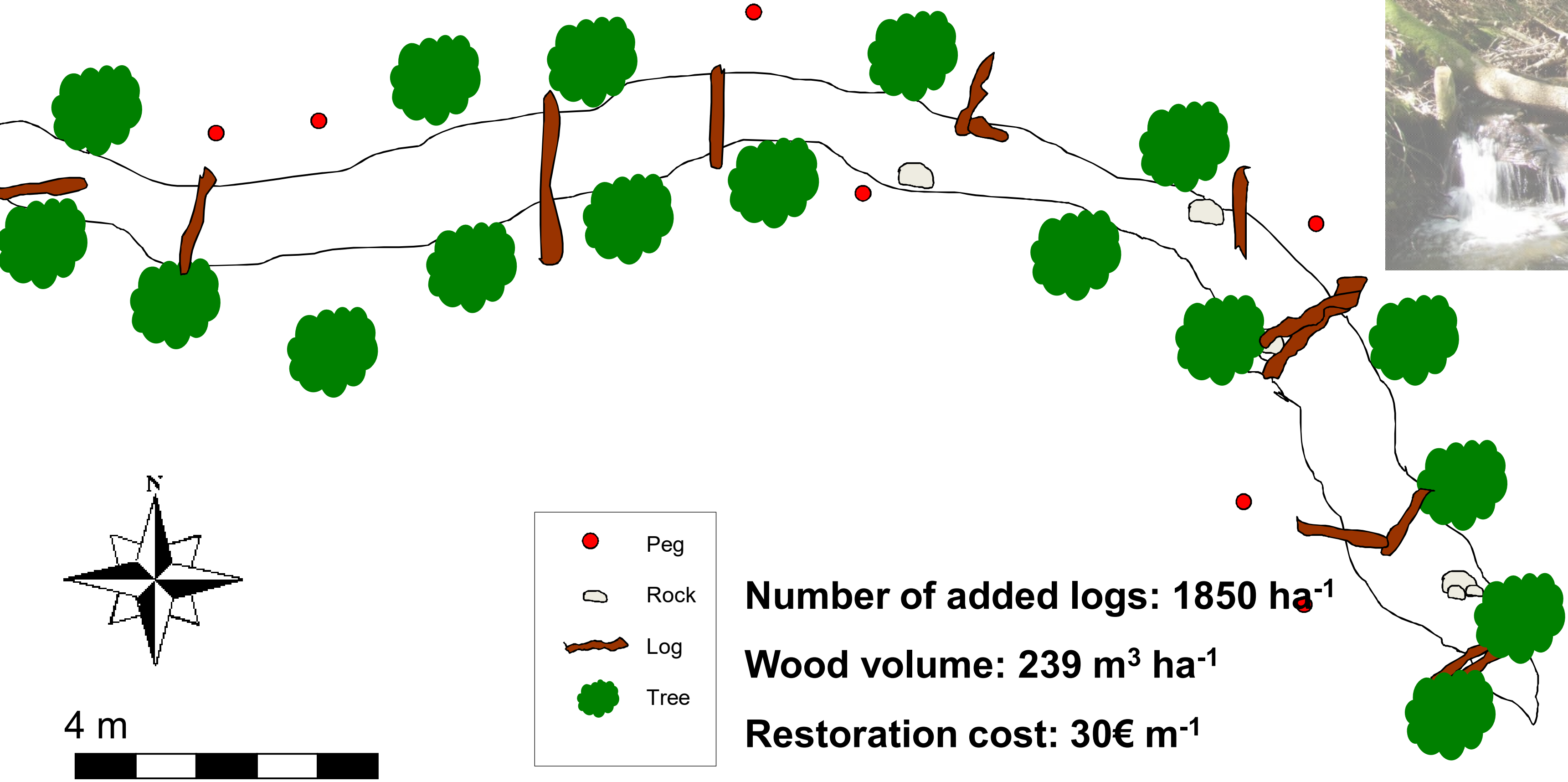
Restoration at the reach scale performed to assess effects, following a BACI (Before-After, Control-Impact) design, including 4 pairs of reaches (upstream control and downstream impacted).



(adapted from de Groot et al. 2010)


BEFORE – IMPACT. 1 year of data: Malbazar reach July 2007
Flow direction
N
4 m
Peg
Rock
Log
Tree

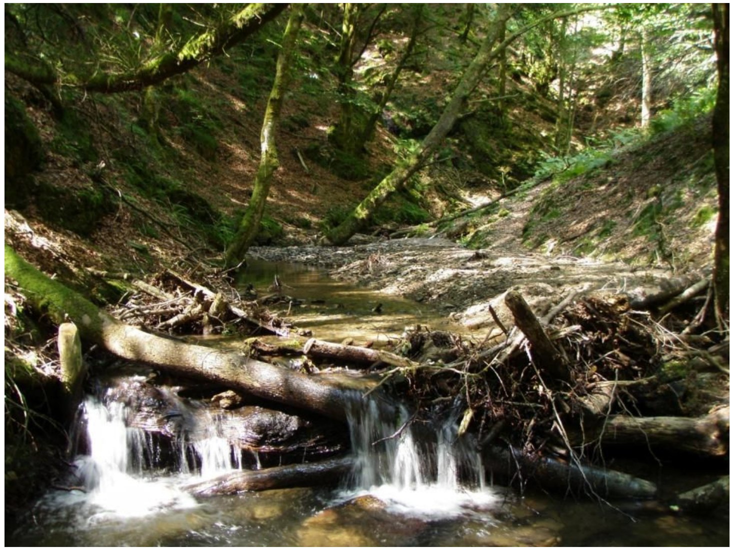
IMPACT!! Malbazar experimental February 2008



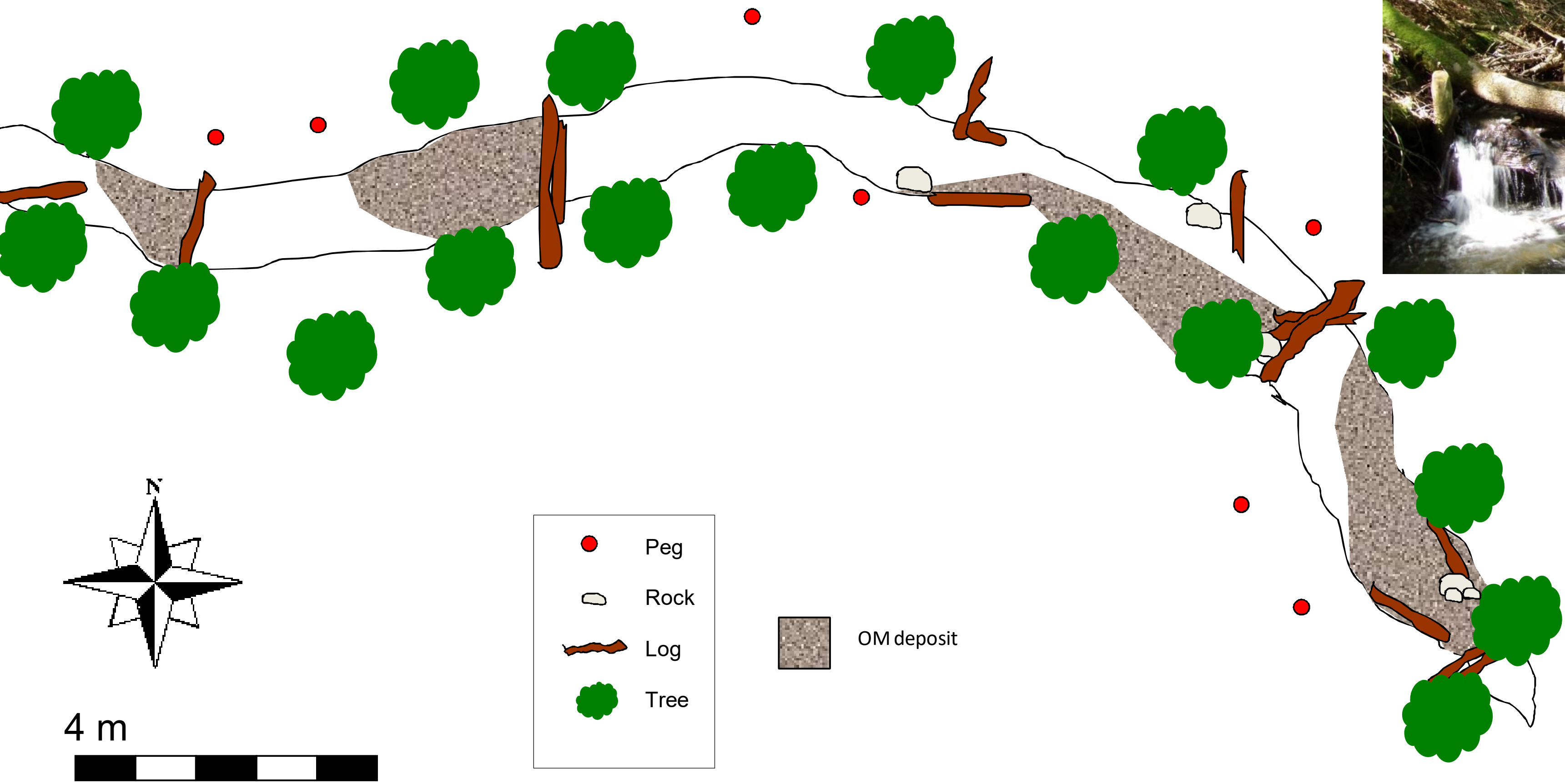
Number of added logs: 1850 ha^{-1}

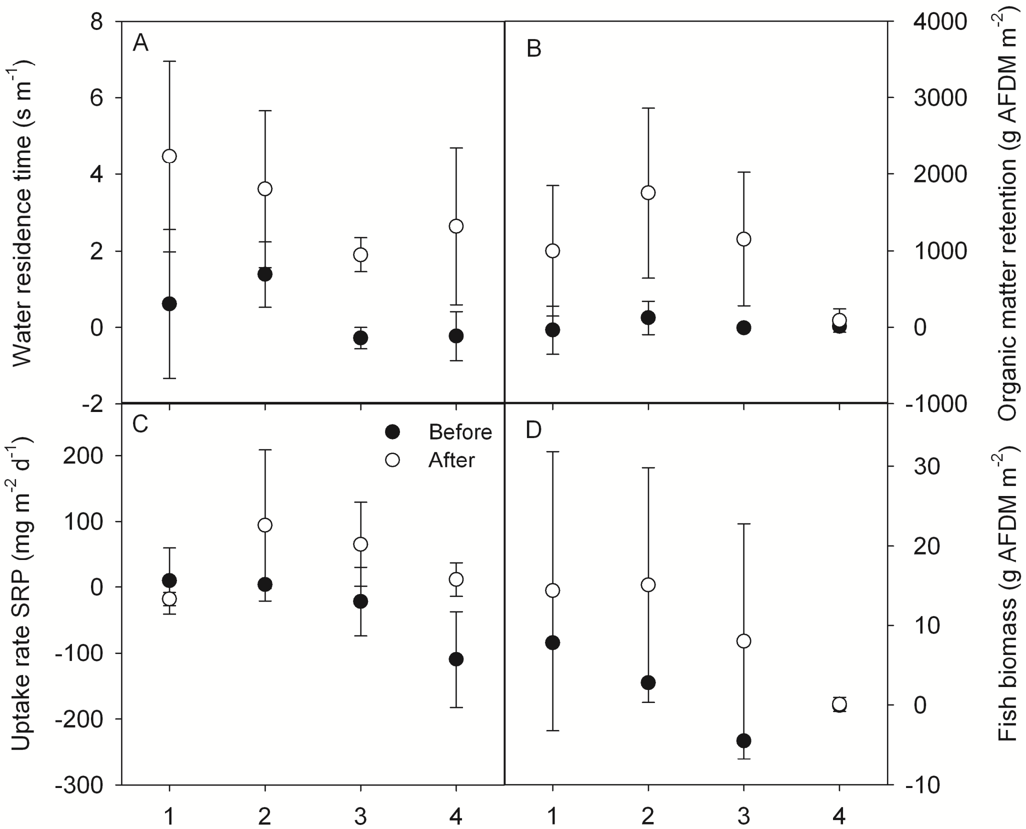
Wood volume: 239 m^{3} ha^{-1}

Restoration cost: 30€ m^{-1}



AFTER – IMPACT. 2 years of data. Malbazar reach July 2009





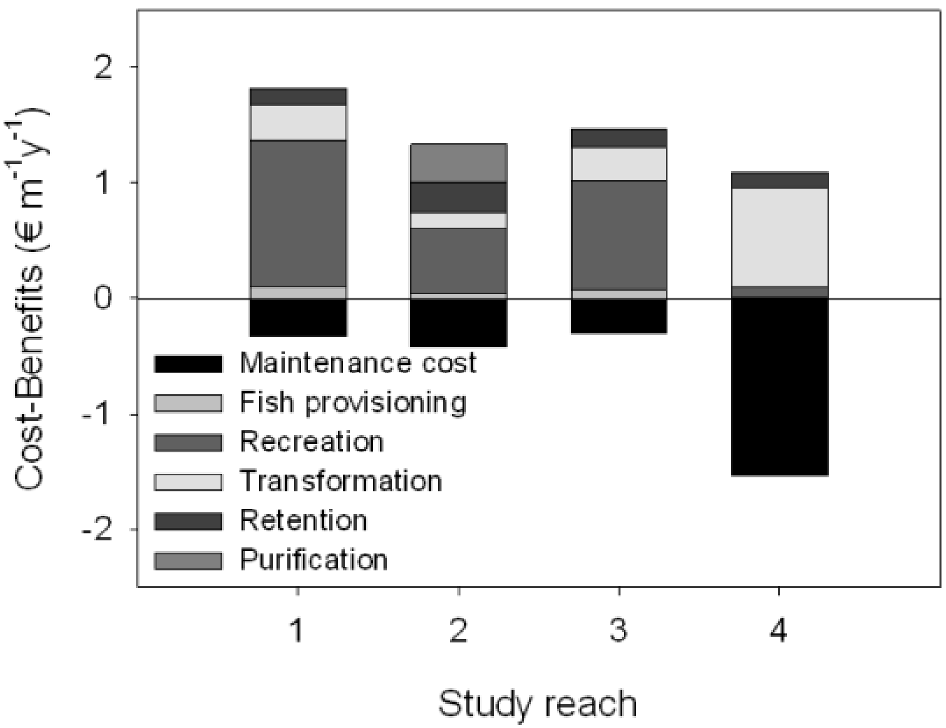
Water residence time doubled.

Retention capacity of particulate materials increased many folds in reaches 1, 2 and 3.

Uptake rate of SRP increased in reaches 2, 3 and 4.

Fish biomass doubled.

Differences between experimental and control reaches before and after the dead wood addition, for water residence time (a), organic matter retention (b), uptake rate of SRP (c) and fish biomass (d). Note that mean and standard deviation values were calculated with the differences between experimental and control reaches at each survey, meaning 6 surveys before and 5–6 surveys after the restoration action.



Benefits 1.08 – 1.81 € m^{-1} y^{-1}

Contribution to TEV: opportunities for recreation > fish provisioning

Active restoration cost and maintenance costs vary among streams

Net benefit of active rest. maximum at low order streams, with ROI > 1 by 2025-2030 in reaches 1-3.

Distributional cost/benefit analysis allows compensations among users (recreation > forestry)

Benefits and maintenance costs of the active restoration activity at the reach scale. Note that the active restoration costs are not shown in the figure, but only the maintenance costs in any given year, and that all values correspond to autumn 2008.

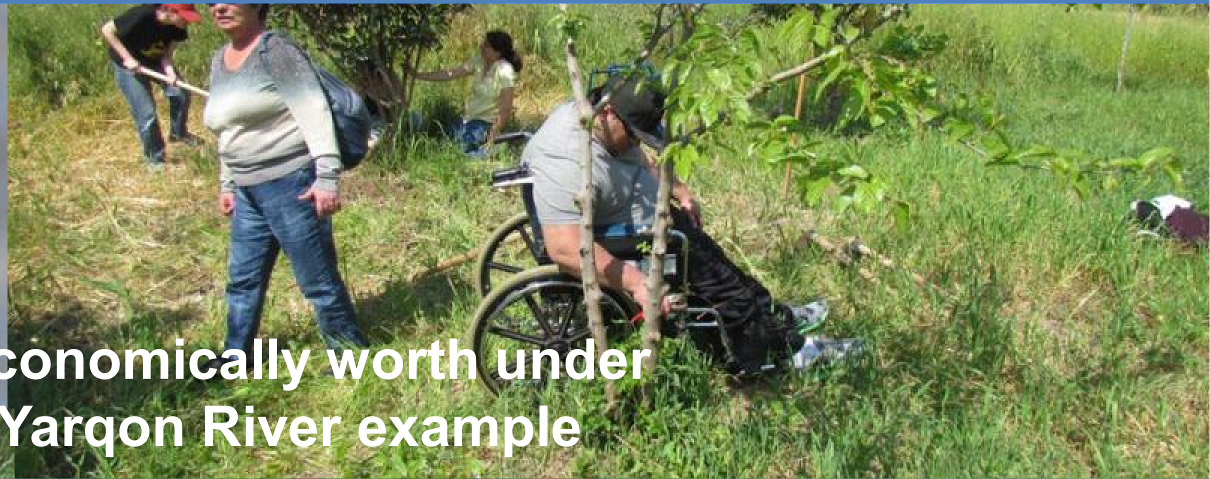
Take-home messages

Results indicate that the lack of dead wood in streams has an important economic cost because of the effects on fish provisioning, opportunities for recreation and tourism, water purification and erosion control.

Active reach-scale restoration resulted in a 10- to 100-fold increase in the monetary benefits provided by streams, accounting as much as 1.8 € per meter of restored river length each year.

Results of the reach-scale cost–benefit analyses estimated that the time required to recover the active restoration investment ranged from 15 to 20 years in low- to middle-order streams.

Inclusion of other ecosystem services such as conservation of biodiversity might make restoration more economically profitable.



Is river rehabilitation economically worth under water scarcity? The Yarqon River example

Garcia-Acosta X., Corominas L., Pargament D., Acuña V.

Environmental Science & Policy 61 (2016) 154–164

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Contents lists available at ScienceDirect

Environmental Science & Policy

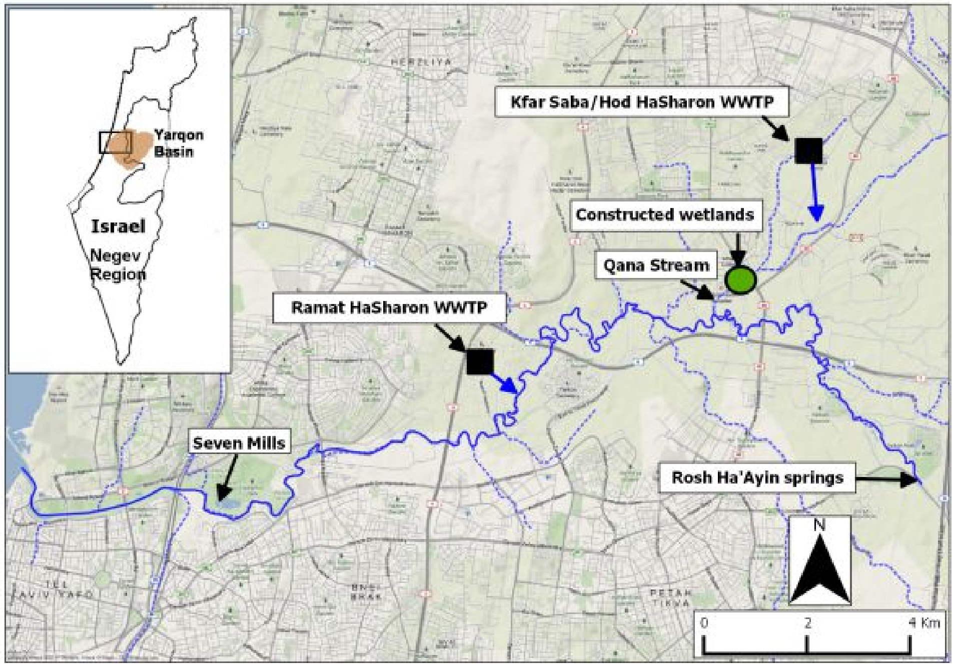
journal homepage: www.elsevier.com/locate/envsci

Background

River rehabilitations have proven to enhance the provision of many valuable ecosystem services, but water resource authorities have seemed reluctant to implement them in water scarce regions because they might suppose a reallocation of the available water resources from consumptive uses such as irrigation agriculture to non-consumptive uses such as environmental flows. A cost-benefit analysis integrating marketed and non-marketed benefits was applied in this study to assess the feasibility, in economical terms, of the Yarqon River Rehabilitation project (Israel).

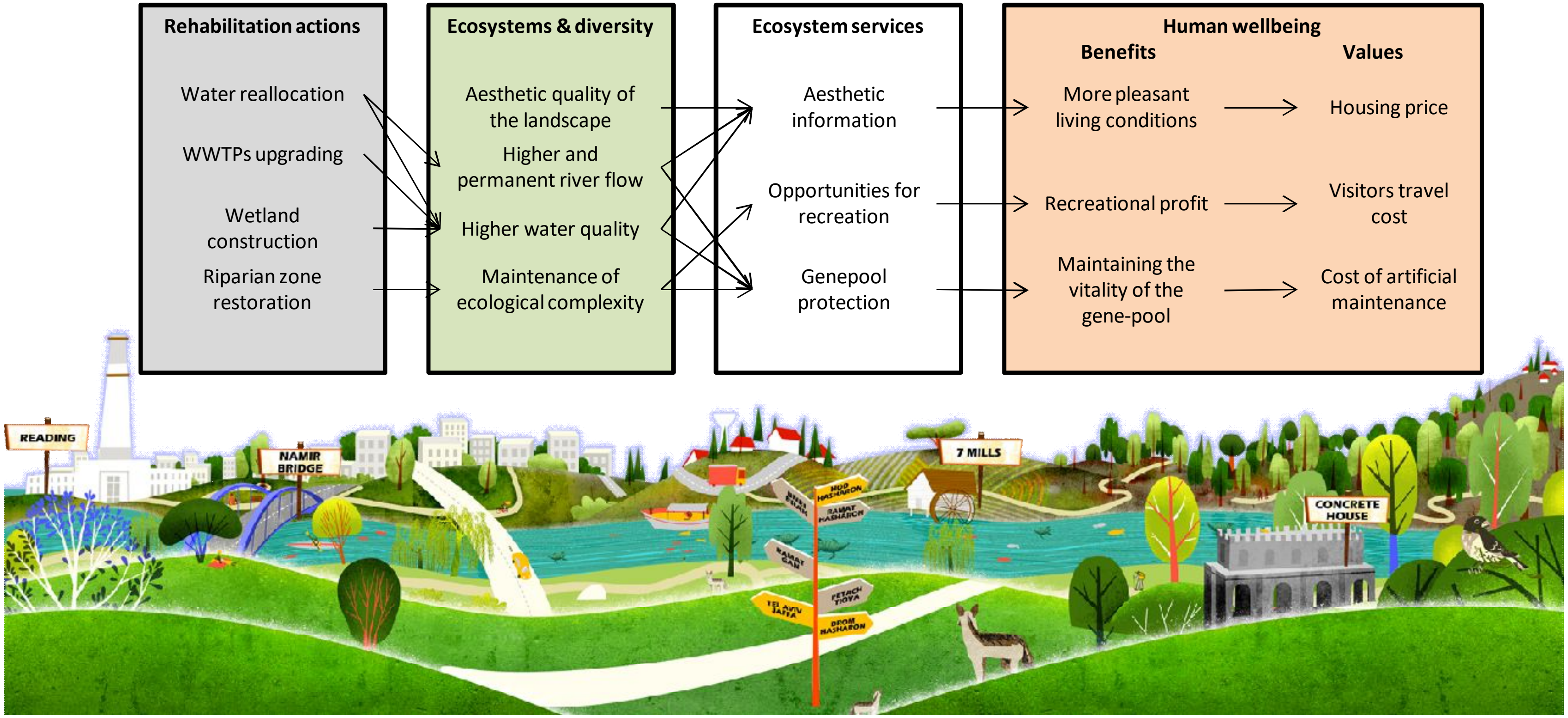
Rehabilitation actions

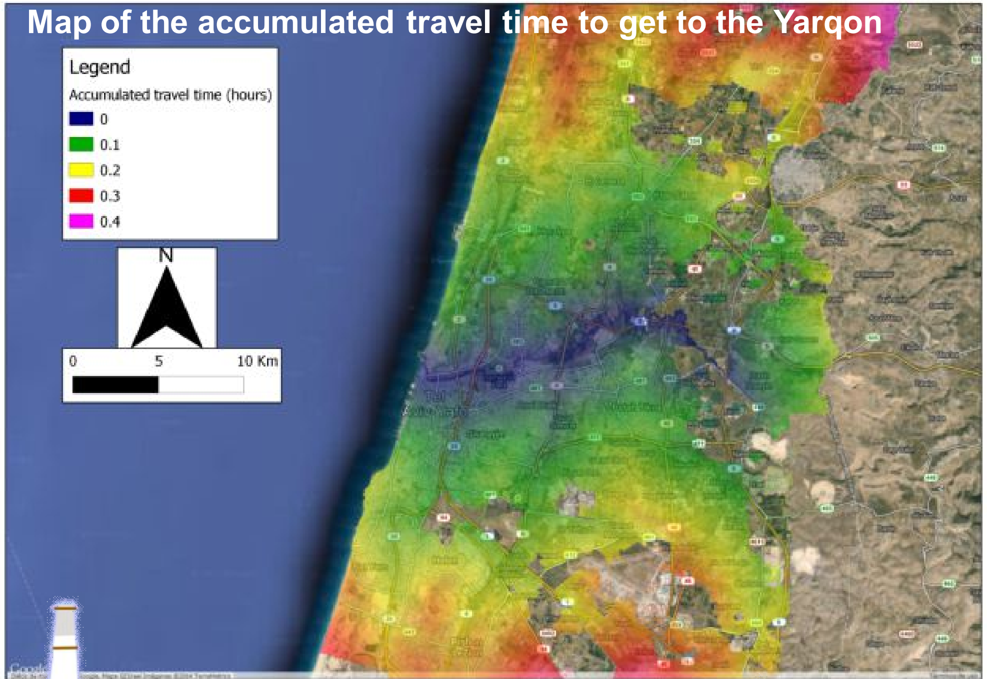
- Water reallocation
- WWTPs upgrading
- Wetland construction
- Riparian zone restoration



Approach

Considered benefits were aesthetic information (hedonic pricing), recreation and tourism (value function transfer), and gene-pool protection (replacement cost), whereas considered costs were implementation costs and opportunity costs of foregone users (water provisioning for agriculture).



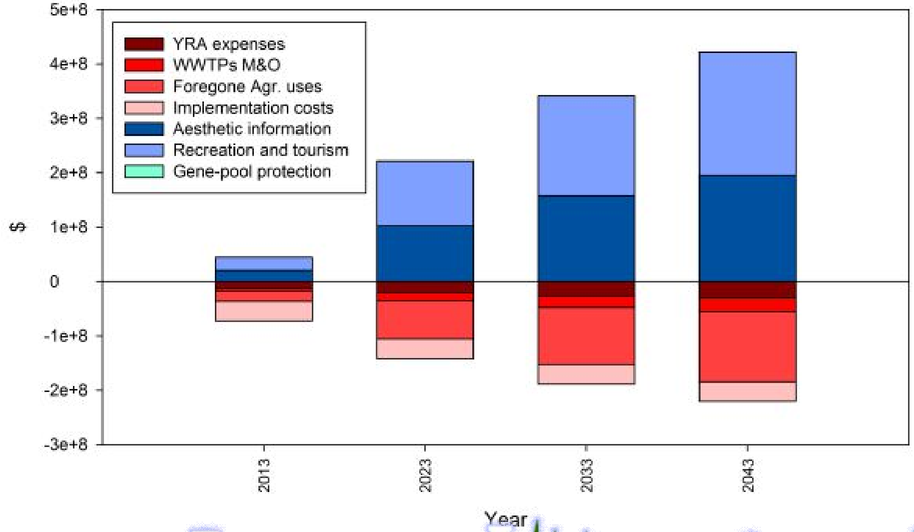


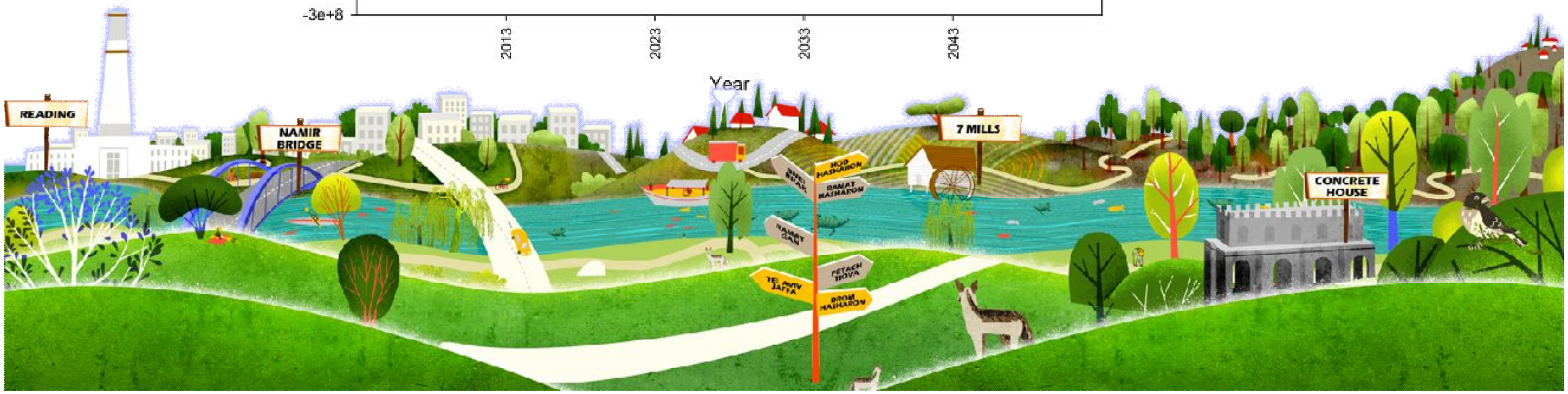
Value function transfer between policy and study sites.

Study site: Alezander-Zeimar River.

Contingent behavior travel cost demand model.

The rehabilitation of the Yarqon River provided positive net present values despite that the massive water reallocation involved high opportunity costs for foregone users.





A sensitivity analysis was also applied to identify the most influential input parameters applying Monte Carlo simulations and estimating the standardized regression coefficients.

The performed sensitivity analysis determined that the probability of obtaining a positive net present value was 91.75%.

Journal of Applied Ecology

British Ecological Society

Journal of Applied Ecology 2016, **53**, 865–875 doi: 10.1111/1365-2664.12613

Integrating ecosystem services in river basin management plans

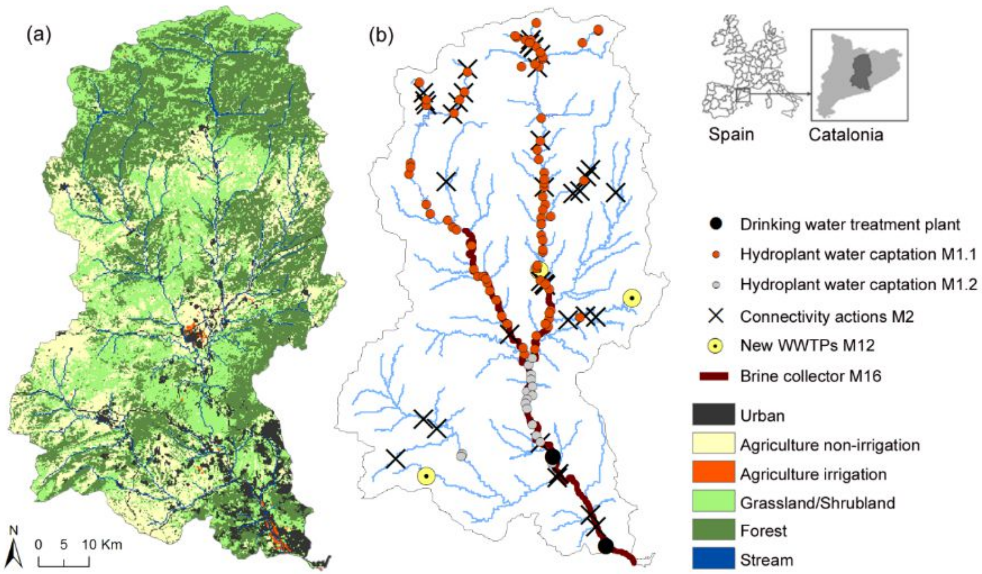
Marta Terrado[1]*, Andrea Momblanch[2], Mònica Bardina[3], Laurie Boithias[1], Antoni Munné[3], Sergi Sabater[1,4], Abel Solera[2] and Vicenç Acuña[1]

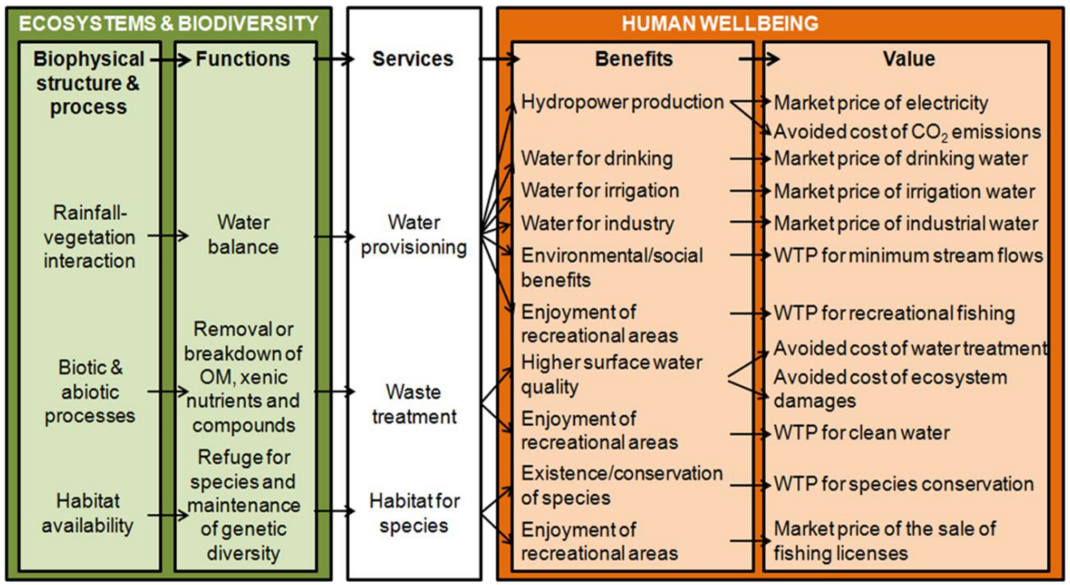
Context:

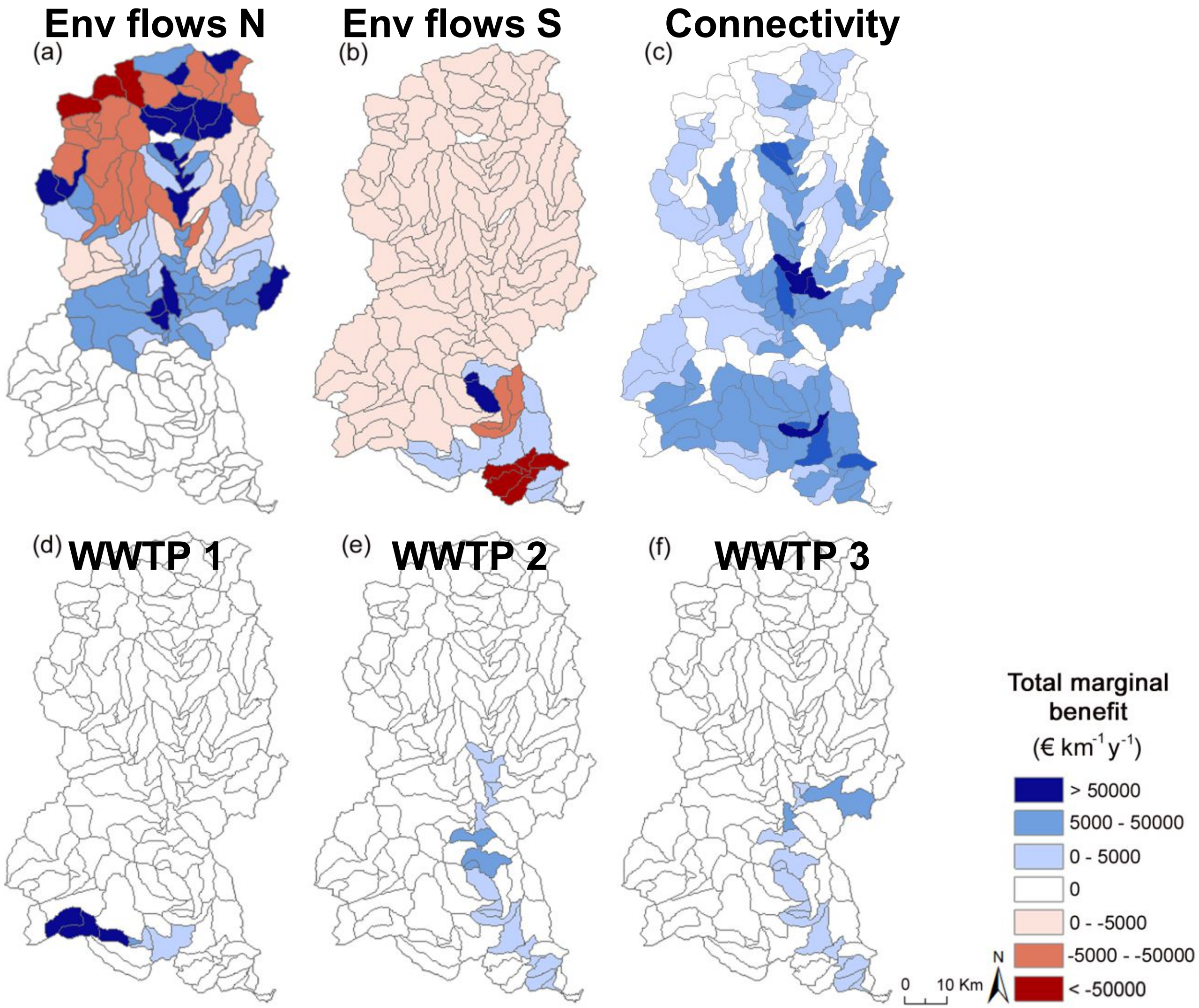
- **WFD, RBMP, PoM including management actions for the achievement of good ecological status in all water bodies.**
- **Design and later prioritization of these management actions through cost-effectiveness analysis (CEA), which compares management action costs with expected improvements in ecosystem status. It does not consider the effects of management actions on human well-being resulting from changes in the provision of ecosystem services.**

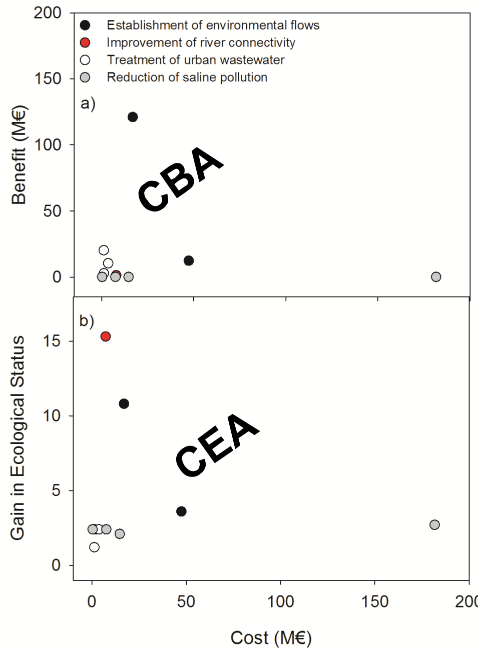
Goal:

- **We propose to complement the current CEA approach with a cost-benefit analysis (CBA) integrating the effects of management actions on the provision of ecosystem services, therefore moving from a single-objective to a multi-objective approach.**
- **Real case-study at Llobregat River basin.**
- **Considered management actions: establishment of environmental flows, improvement of river connectivity, treatment of urban wastewater, and reduction of saline pollution.**


(a)
(b)
N
0 5 10 Km
Spain
Catalonia
Drinking water treatment plant
Hydroplant water captation M1.1
Hydroplant water captation M1.2
Connectivity actions M2
New WWTPs M12
Brine collector M16
Urban
Agriculture non-irrigation
Agriculture irrigation
Grassland/Shrubland
Forest
Stream


ECOSYSTEMS & BIODIVERSITY
HUMAN WELLBEING
Biophysical structure & process
Functions
Services
Benefits
Value
Rainfall-vegetation interaction
Biotic & abiotic processes
Habitat availability
Water balance
Removal or breakdown of OM, xenic nutrients and compounds
Refuge for species and maintenance of genetic diversity
Water provisioning
Waste treatment
Habitat for species
Hydropower production
Water for drinking
Water for irrigation
Water for industry
Environmental/social benefits
Enjoyment of recreational areas
Higher surface water quality
Enjoyment of recreational areas
Existence/conservation of species
Enjoyment of recreational areas
Market price of electricity
Avoided cost of CO_2 emissions
Market price of drinking water
Market price of irrigation water
Market price of industrial water
WTP for minimum stream flows
WTP for recreational fishing
Avoided cost of water treatment
Avoided cost of ecosystem damages
WTP for clean water
WTP for species conservation
Market price of the sale of fishing licenses


Env flows N
(a)
Env flows S
(b)
Connectivity
(c)
(d) WWTP 1
(e) WWTP 2
(f) WWTP 3
0 10 Km
N
Total marginal benefit
(€ km^{-1} y^{-1})
> 50000
5000 - 50000
0 - 5000
0
0 - -5000
-5000 - -50000
< -50000


Establishment of environmental flows
Improvement of river connectivity
Treatment of urban wastewater
Reduction of saline pollution
a)
CBA
Benefit (M€)
b)
CEA
Gain in Ecological Status
Cost (M€)

Take home messages:

- **Management actions designed to improve ecosystem status do not necessarily improve human well-being through changes in the provision of ecosystem services.**
- **The implementation of the CEA and CBA allowed the identification of management actions providing the best trade-offs between improvements of ecosystem status and human well-being.**


Thanks for your attention!!