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Environmental Effectiveness of Woodland Measures for Reducing Agricultural Diffuse Pollution to Water – Evidence, SWAT Modelling and Decision Support Tools

23 October 2018, Vairão, Porto, Portugal

COST Action CA15206 PESFOR-W Payments for Ecosystem Services Forests for Water

(1) Cost-effectiveness of woodland measures
(2) Water economics, schemes and decision-making tools

Paola Ovando Pol

The James Hutton Institute

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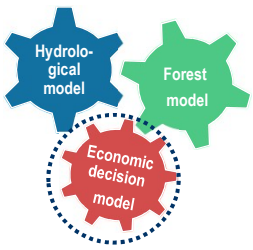
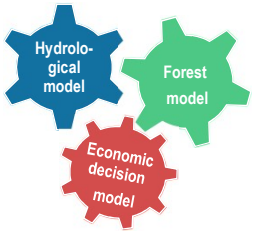
FOREST – WATER – ECONOMIC NEXUS

- Increased pressure on forest and water resources, due to land use changes and global warming
- Forest enhances the provision of diverse watershed services
- Complex interactions depending on diverse factors and drivers at different spatial and time scales
- **Still much to learn on how socioeconomic processes can be integrated within eco-hydrological ones**



FOREST – WATER – ECONOMIC NEXUS

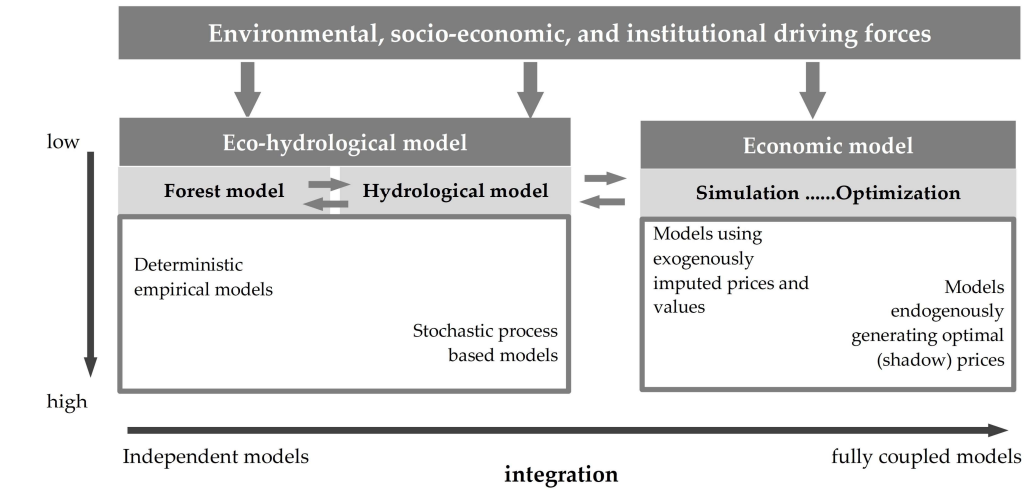
- Effort for integrating forest and water into economic decision models can be traced back to the early 70's: e.g., Worley & Patrick (1971), Calish et al. (1978), Krutilla & Bowes, 1983.



- Renewed attention to F&W economic nexus, in connection to PES literature (e.g., *Bouwer et al. 2011; Calder, 2007; Martin-Ortega et al. 2013*) or watershed services economic valuation (e.g. *Lele, 2009*).

Economic approaches to address forest watershed management decisions: **Forest hydro-economic models**

FOREST – WATER – ECONOMIC NEXUS



Source: Ovando and Brouwer (under revision).

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CONTENTS

- Forms of economic evaluation (different alternatives)
- An overview of cost-effectiveness analysis (CEA)
- CEA applied to forest for water interventions/projects
- CEA from different stakeholders perspective

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WHAT IS ECONOMIC EVALUATION?

Comparative analysis of at **least two interventions** or **alternatives** in terms of their **costs** and **consequences**.

Alternatives: (a) **Base line** (initial state, status quo, business as usual) compared to (b) one or more ***j*** intervention (changes respect to the BL).

Costs: Additional (or differential) costs of the intervention respect to BL.

$$\Delta \text{ Costs} \rightarrow (C_j - C_{BL})$$

Outcomes: Additional outcomes of the intervention respect to BL.

$$\Delta \text{ Outcomes} \rightarrow (E_j - E_{BL}); (B_j - B_{BL})$$

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FORMS OF ECONOMIC EVALUATION

Approach (Analysis)	Description
Cost minimization analysis (CMA)	- Estimates total costs of alternative intervention, assuming outcomes are identical or very similar (e.g. a target) - Choose the minimum cost to achieve this target
Cost-effectiveness Analysis (CEA)	-Cost per unit of effect (additional), different interventions, contexts or times, embracing different costs and outcomes in natural units (i.e. m^3 of blue water) -Alternative(s) with the highest achievable performance with available resources (the most cost effective)

- Estimates either the **unit cost** (average of marginal) of a **given level of effectiveness**: (e.g., unit costs of reducing nitrate concentration in water by one mg/L)
- Or, measure the effectiveness **level for a given cost**, additional environmental outcomes by increasing expenditure by a certain amount of money

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FORMS OF ECONOMIC EVALUATION

Approach (Analysis)	Description
Cost minimization analysis (CMA)	- Estimates total costs of alternative intervention, assuming outcomes are identical or very similar (e.g. a target) - Choose the minimum cost to achieve this target
Cost-effectiveness Analysis (CEA)	-Cost per unit of effect (additional), different interventions, contexts or times, embracing different costs and outcomes in natural units (i.e. m^3 of blue water) -Alternative(s) with the highest achievable performance with available resources (the most cost effective)
Cost-benefit analysis (CBA)	-Comparison of **monetary value of benefits and costs** (requires non-market valuation) -Alternative that maximizes the present value of net benefits

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COST EFFECTIVENESS VS. COST EFFICIENCY

- **Cost-effectiveness** is the **success of an intervention** to **deliver an outcome** (e.g. a nature based solution reduces water pollution levels). The **most cost effective** is the intervention with **highest achievable performance given available resources** and **intervention alternatives**

- **Cost-efficiency** is a state in which the inputs and methods used for an outcome/product (e.g., delivering an ecosystem service) result in the **maximum feasible outcome**.

The best possible use of resources

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COST EFFECTIVENESS VS. COST EFFICIENCY

	Inefficient	Efficient
Effective	Pursuing right goals (**environmental additionality**), but inefficient (the costs are high).	Pursuing right goals (environmental additionality), and efficient (**at a lowest cost possible**). All the relevant alternatives are considered
Ineffective	Pursuing wrong goals and insufficient (no environmental additionality) and the costs of the alternatives are high	Pursuing wrong goals and insufficient (no environmental additionality) but the costs are low

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COST EFFECTIVENESS VS. COST EFFICIENCY

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Effective	Pursuing right goals (**environmental additionality**), but inefficient (the costs are high).	Pursuing right goals (environmental additionality), and efficient (**at a lowest cost possible**). All the relevant alternatives are considered
Ineffective	Pursuing wrong goals and insufficient (no environmental additionality) and the costs of the alternatives are high	Pursuing wrong goals and insufficient (no environmental additionality) but the costs are low

Environmental effectiveness is a precondition for cost-effectiveness

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COST EFFECTIVENESS ANALYSIS

- **Cost-effectiveness analysis** (CEA) measures the **ratio** of the costs of an intervention to the effect that this intervention has in one outcome (i.e., reducing nitrates concentration in water):

Cost – effectiveness ratio (CER)

CER_j = Costs of intervention j / Effects of intervention j

$$CER_j = C_j \ / \ E_j$$

$$CER_j = \frac{€2{,}000}{10 \ \ mg/L \ \ NO_3^{-1}} = € \ 200 \text{ per mg/L } NO_3^{-1}$$

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COST-EFFECTIVENESS ANALYSIS

Incremental cost – effectiveness ratio (ICER)

$$ICER_j = \Delta C_j \ / \ \Delta E_j$$

Dominance of alternatives

Alternative	Costs	Effect	CER	
No intervention	0	0	0	
Intervention 1	3,000	12	250	
Intervention 2	1,500	3.5	429	
Intervention 3	4,500	15	300	
~~Intervention 4~~	~~5,000~~	~~10~~	~~500~~	Dominated alternative

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COST-EFFECTIVENESS ANALYSIS

Incremental cost – effectiveness ratio (ICER)

$$ICER_j = \Delta C_j \ / \ \Delta E_j$$

Dominance of alternatives

Alternative	Costs	Effect	ICER	ΔC_j	ΔE_j	$\Delta C_j/\Delta E_j$
No intervention	0	0	0	0	0	0
Intervention 1	3,000	12	250	3,000	12	250
Intervention 2	1,500	3.5	429	1,500	4	429
Intervention 3	4,500	15	300	4,500	15	300

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COST-EFFECTIVENESS ANALYSIS + UNCERTAINTY

Alternative	Costs	Effect	CER	ΔC_j	ΔE_j	$\Delta C_j/\Delta E_j$
Business as usual/benchmark	1000	2	500	0	0	0
Intervention 1	3,000	12	250	2,000	10	200
Intervention 2	1,500	3.5	429	500	2	333
Intervention 3	4,500	15	300	3,500	13	269

Alternative	Costs	Effect		ΔC_j	ΔE_j		$\Delta C_j/\Delta E_j$	
		min	max		min	max	min	max
Business as usual/benchmark	1000	1	3	0	0	0	0	0
Intervention 1	3,000	9.5	14.5	2,000	8.5	11.5	235	174
Intervention 2	1,500	1	6	500	0	3	no-eff	167
Intervention 3	4,500	5	20	3,500	4	17	875	206

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COST-EFFECTIVENESS ANALYSIS

Alternative	Costs	Effect	CER	ΔC_j	ΔE_j	$\Delta C_j/\Delta E_j$
Business as usual/benchmark	1000	2	500	0	0	0
Intervention 1	3,000	12	250	2,000	10	200
Intervention 2	1,500	3.5	429	500	2	333
Intervention 3	4,500	15	300	3,500	13	269

Competing alternatives and portfolio of alternatives (increasing costs per unit of environmental outcome achieved: e.g., increasing opportunity costs)

Alternative	Costs	Effect	CER	C'_j	E'_j	$MC=C'_j/E'_j$
BAU/benchmark	1,000	2	500	0	0	0
Intervention 2	1,500	3.5	429	500	1.5	333
Intervention 1	3,000	12	250	1,500	8.5	176
Intervention 3	4,500	15	300	1,500	3.0	500

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COST EFFECTIVENESS ANALYSIS

Alternative	CER	$MC=C'_j/E'_j$
BAU/benchmark	500	0
Intervention 2	429	333
Intervention 1	250	176
Intervention 3	300	500

Marginal cost refers to the cost of delivering **another unit of output** as the investment levels change . For example increasing the afforestation area (e.g. , wider buffers strips).

$$MC=\frac{C'_j}{E'_j}=\frac{(C_j-C_{j-1})}{(E_j-E_{j-1})}$$

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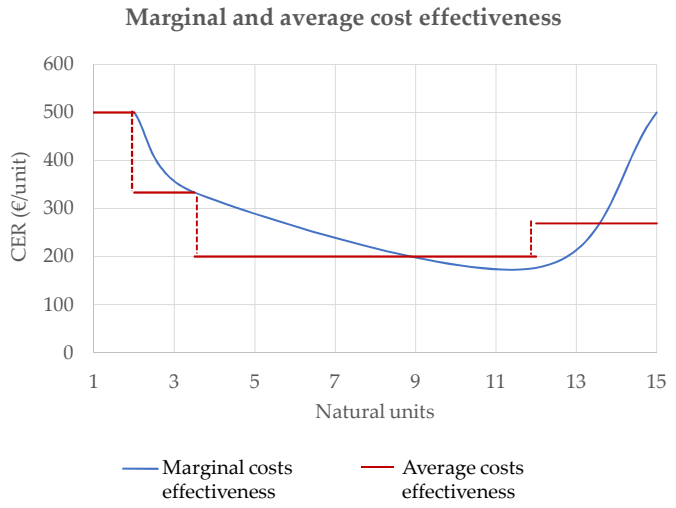
COST EFFECTIVENESS ANALYSIS



Alternative	CER	MC=C'j/E'j
BAU/benchmark	500	0
Intervention 2	429	333
Intervention 1	250	176
Intervention 3	300	500

$$MC = \frac{C_j'}{E_j'} = \frac{(C_j - C_{j-1})}{(E_j - E_{j-1})}$$

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ASSESING COST-EFFECTIVENESS: FOREST FOR WATER

Relevant issues to be considered in cost effectiveness analysis when forest and water are concerned:

- Time scale of forest investment and environmental outcomes (how to consider cost time variability in economic and environmental variables?)
- Multidimensionality of water quality indicators (how to deal with multiple indicators / outcomes?).
- Multiple benefits of forest and trade-offs? (how to integrate co-benefits or environmenmental costs?)

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ACCOUNTING FOR TIME

Net present value of expected cost:

$$NPV_{\Delta C} = \sum_{t=0}^{T} \frac{\Delta c(t)}{(1+r)^t}$$

- T: Evaluation period (T in number of years)
- $\Delta c(t)$: Net additional cost over time (forest operation costs are variable)
- r: Discount rate (constant)

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ACCOUNTING FOR TIME

Net present value of expected cost:

$$NPV_{\Delta C} = \sum_{t=0}^{T} \frac{\Delta c(t)}{(1+r)^t}$$

What about time-dependant outcomes?

- One option is to estimate the equivalent annual annuity (C) and compare to the average environmental outcomes ($\overline{\Delta E}$) over the time period T.

$$\Delta C_a = \frac{r(NPV_{\Delta C})}{1-(1+r)^{-T}} \rightarrow \overline{\Delta E} = \sum_{t=0}^{T} \frac{\Delta E\,(t)}{T} \rightarrow ICER = \frac{\Delta C_a}{\overline{\Delta E}}$$

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DIMENSIONS OF WATER QUALITY

- While cost effectiveness is a **rather simple concept**, computing the cost-effectiveness of forest-based solutions for improving water quality is a challenging task given the **multidimensional character of the outcomes**

- Water quality is a **multidimentional concept**, as water quality is referred to chemical, physical, biological and radiological characteristics of water.

How to evaluate the performance of forest-based intervention when multiple water quality indicators are concerned?

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DIMENSIONS OF WATER QUALITY

Posible solution*:

Aggregated index of water quality improvement

Based on the definition of :

(i) a set of **relevant indicators** to evaluate improvements in water quality (*can vary according to water uses, specific local conditions and data availability*);

(ii) the **minimal acceptable levels** (thresholds) (*e.g., official standards (WFD), or targets agreed with the stakeholders)*

(iii) a set of **weights** indicating the **relative importance** of each indicator (*also define with the stakeholders*)

* Source: Abildtrup et al. (in preparation). Assessing the cost-effectiveness of payments to woodland owners for water services. Internal Working Paper, PESFOR-W WG3 on PES cost-effectiveness.

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AGGREGATED INDEX OF WATER QUALITY

Performance of the alternative *j* for indicator *i*, relative to its target

$$d_{ij} = \frac{x_i^{ex-ante} - x_{ij}^{ex-post}}{x_i^{ex-ante} - x_i^{target}}$$

only if, ➡ $x_i^{ex-ante} \geq x_i^{target}$

Where d_{ij} is a performance indicator that shows:

- if $0 \leq d_{ij} < 1$, the alternative *j* **fails to meet the target** for the indicator *i*.
- if $d_{ij} > 1$, the alternative *j* **meets the target** for the indicator *i*
- if $d_{ij} < 0$, the alternative *j* is dominated by the baseline (**no environmental effectiveness for the indicator *i***)

* Source: Abildtrup et al. (in preparation).

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AGGREGATED INDEX OF WATER QUALITY

Aggregated index of water quality improvement (PP_j)*

$$PP_j = \sum_{i=1}^{n} w_i \cdot d_{ij} \quad \Rightarrow \quad ICER_j = \frac{C_j}{PP_j}$$

Where **PP represents the partial performance** of the alternative *j* respect to the standards (or targets), and accounting for the weights assigned by the stakeholder to each water quality indicator *i*.

being w_i the weight assigned to each indicator: $0 \leq w_i \leq 1$, and $\sum_{i=1}^{n} w_i = 1$

ICER is the relative incremental cost-effectiveness ratio (note that is not anymore a unit cost)

* Source: Abildtrup et al. (in preparation).

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AGGREGATED INDEX OF WATER QUALITY

Alternative(j)	Water quality indicator (i)				PPj	Cj (€/ha)	ICERj (Cj/PPj)
	Concept	Nitrate (mg/L)	Phosphate (µg/L)	Pesticide X (µg/L)			
	Target	**10**	**10**	**2**			
	weight	**50%**	**25%**	**25%**			
BAU (no intervention)	*ex-ante*	25	18	4		0	
Tree buffer strips (3 m x 100 m)	*ex-post*	8	13	3	0.85	450	530.7
	d_{ij}	1.13	0.63	0.50			
Tree buffer strips (6 mx100 m)	*ex-post*	4	11	2	1.17	600	513.4
	d_{ij}	1.40	0.88	1.00			
Plantation (0.1 ha)	*ex-post*	4	6	3	1.20	1000	833.3
	d_{ij}	1.40	1.50	0.50			

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ACCOUNTING FOR CO-BENEFIT/COSTS

Net present value of NET expected total cost:

$$NPV_{\Delta C_{S,E}} = \sum_{t=0}^{T} \frac{\Delta C_{j,M}(t) - [B_{j,E}(t) - C_{j,E}(t)]}{(1+r)^t}$$

When additional environmental benefits and cost have an economic value, that can be observed in the market place (e.g., carbon sequestration and CO_2 emissions).

When there are no market for those benefits and costs, those could be treated in a similar way as the aggregated index of water quality improvement (multicriteria analysis techniques can be useful).

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COST OF FOREST INTERVENTION FOR WATER

What are the elements / concepts that should be accounted for to estimate the cost function?

Landowner perspective

Implementation costs (*materials, labour, and other costs associated with applying the practice on the ground*) + **Landowner transaction** costs (*including costs of negotiation and agreements, and costs of gathering information*) + **Opportunity costs** (*net revenues forgone, for example from agriculture production*)

- Market based incentives, such as Payment for ecosystem services.
- Other incentives (subsidies, agri-environmental schemes, tax exemptions),
- Other policies (taxes to pollution).

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COST OF FOREST INTERVENTION FOR WATER

- From the social point of view the cost-effectiveness is based on **economic cost and not financial costs**.
- A transfer of money, e.g. a compensation paid to a landowner, is not considered an economic cost, but just **a transfer of wealth**.
- Landowners' **opportunity costs** or implementation costs are included.
- **Positive or negative impacts** in terms of public **environmental benefits and cost**, but also **socioeconomic effects** (e.g. on employment opportunities) are also included.

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Many thanks…

UICN. Draw me a tree. https://www.iucn.org/fr/node/5296

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CONTENTS

- Forest – Water – Economic Nexus
- Economic foundations for water valuation
- Total Economic Value of Water
- Water demand and economic valuation
- Integrating water and timber into economic decision-making

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ECONOMIC FOUNDATIONS FOR WATER VALUATION

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What confers a value to water?

It is essential for life: human and non human (well-being)

What confers an ***economic*** value to water? Scarcity

Everyone human agent and most of business are water consumers

The economic value is a measure of the benefits that water provides to those economic agents. It is measured in **monetary terms**, and represents "what is the **maximum amount of money** a specific actor is willing and able to pay for a water-related service"?

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ECONOMIC FOUNDATIONS FOR WATER VALUATION

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Water has **economic value only when its supply [quantity and quality] is scarce** relative to its demand. Whenever water is available in unlimited supply, it is free in the economic sense.

Scarce water takes on economic value because **many users compete for its use**.

In a market system, economic values of water, defined by its price, serve as a **guide to allocate water among alternative uses**, potentially directing water into uses **yielding the greatest total economic return**

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ECONOMIC FOUNDATIONS FOR WATER VALUATION

Rivalry	Exclusion costs	Definition	Provision mechanisms	Example
High	High	Common-pool resources	Sometimes common property rights	*Irrigation system or fishing grounds*
High	Low	Private goods/services	Often in markets	*Treated water available for delivery to retail industrial or household users (closest to private good concept)*
Low	High	Public goods/services	Some nonmarket mechanisms	*Water quality improvement projects, by flood-risk reduction programs, or by provision of natural recreational and aesthetic services of rivers, lakes, and reservoirs.*
Low	Low	Toll/club goods	Nonmarket mechanisms	*The EU membership*

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ECONOMIC FOUNDATIONS FOR WATER VALUATION…

The Total Economic Value of Water Resources

Multiple dimensions of water uses, services and values

Use values			Non-use values
Direct	**Indirect**	**Option**	**Existence**
e.g., Drinking water Hydropower Irrigation, livestock Fishing, aquaculture Water in production (industry) Recreation (water – landscapes)	e.g., Salinity control Microclimatic stabilization (land-water nexus: mass flow regulation, water quality regulation)	e.g., Future use of direct and indirect values Future value of information	e.g., Genetic pool (aquatic ecosystems) Cultural heritage Bequest values
Provisioning services Cultural services	**Regulating services**	**P +R + C**	**Regulating services Cultural services**

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ESTIMATION OF ECONOMIC VALUES

Economic concepts of value: **total, marginal, and average** value.

The **total value** from a given supply of water is measured by the **total willingness to pay** for a given level of water used (**quantity and quality**).

The **marginal value of water** represents the contribution of an incremental unit of water to whatever public or private objective is under consideration (**relevant policy analysis and water resources allocation (optimization)**)

The **average value** of water is the **total value** divided by the **quantity of water supplied**. The average value of water is typically of **less policy interest for water allocation** than marginal or total value, but its **conceptual simplicity** and ease of calculation may engage the further estimation of marginal value.

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ESTIMATION OF ECONOMIC VALUES

When water supply is exchanged in a functioning market, its **market price is a good measure of its marginal value** ➡ **observe water's economic value directly.**

- Water supplies are often sold under what amounts to an **administered price** (*fixed prices for water for irrigations, fees paid to water utilities).*

Valuation options:

- **Cost-based aproaches** (based on market data), e.g., water protection.
- **Changes in net income (productivity)** (when water is an intermediate good: i.e., irrigation, hydropower production). The water user would be **willing to pay** for the water **up to an amount equal to changes in net income produced by water.**
- **Non-market valuation**: elicit individuals WTP for specific water-related services

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REVIEW OF VALUATION METHODS

Group of methods	Valuation methods	Water-related or Forest good and service	Value captured	Benefits	Limitations
Reveled preferences methods	Market price	Traded in markets, mainly resources (timber, cork, NTFP)	Direct and indirect use	Market data avialable and robust	Limited to market good and services
	Cost-based *(avoided costs, replacement costs, substi-tution costs)*	Ecological services: soil and water protection, climate regulation	Direct and indirect use	Market data avialable and robust	Actual values can pottentially over- or under-estimated
	Hedonic price	Services that contribute to the quality of attributes of certain market good and services)air quality, green species on properties price)	Direct and indirect use	Based on market data	Data intensive, limited to data related to property
	Travel cost	All ecosystem services that contribute to recreational uses/activities	Direct and indirect use	Based on market data	Limited to recreation, problems with mutiple destination trips (potential double counting)

REVIEW OF VALUATION METHODS

Group of methods	Valuation methods	Water-related or Forest good and service	Value captured	Benefits	Limitations
Stated preferences methods	Contingent valuation (single WTP specific G&S)	All good and services *(water qualiy regulation, water supply, cultural services)*	Use and non use values	They can capture all use and non use values	Resource intensie, potential bias in response (hypothetical markets, hence not observed behaviour)
	Choice experiment (effect of attributes and their level of provision on WTP for a nonmarket G&S)	All good and services *(water qualiy regulation, water supply, cultural services)*	Use and non use values	They can capture all use and non use values	Resource intensie, potential bias in response (hypothetical markets, hence not observed behaviour)

Benefit transfer: typically requires less resources and time. Not a valuation method, as it uses values estimated in other valuation studies, for similar goods or services, and then transfers this values to estimate the value of goods or services on another site by using **correction factors** or **meta-data analysis**.

STEPS TOWARDS ESTIMATING TEV

1. Identify Uses and Functions
2. Identify Stakeholders
3. Choose Appropriate Valuation Methodologies
4. Estimate Monetary Values of Uses

Source: Koundouri, P. (2005) Economic Valuation Methods for Efficient Water Resources Management: Theory and Applications. ARID CLUSTER, May 2005.

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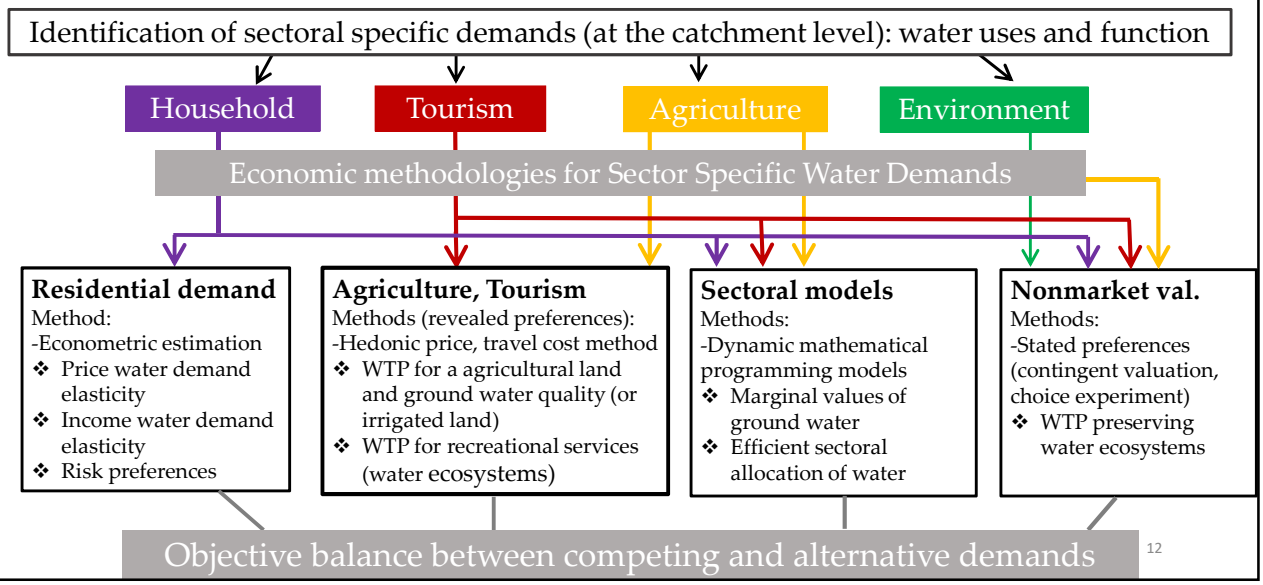
VALUING WATER IN ABSCENSE OF MARKET PRICES

Source: Based on Koundouri (2005).



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CASE STUDY: WATER SERVICES VALUATION

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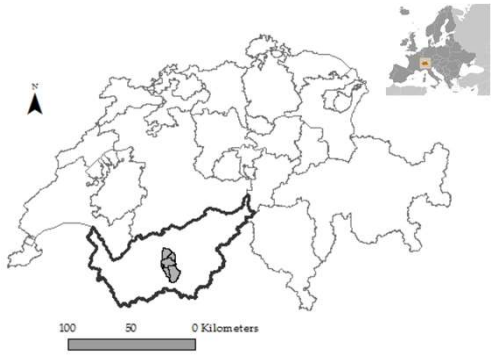
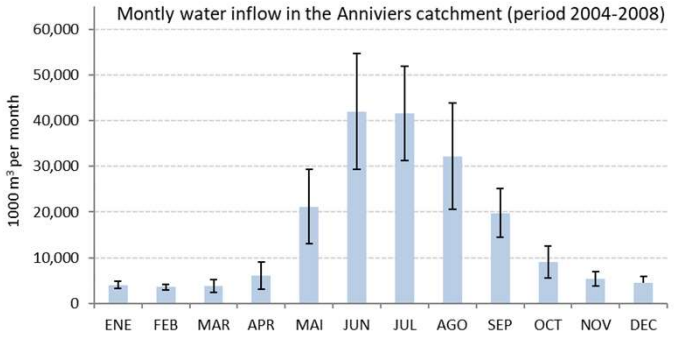
Case study Anniviers (Valais-CH)





Covers close to 250 km^2, with 50 km^2 glaciers and 46.8 50 km^2 of forest

600 – 2400 m ASL

Water yield (inflow 5 sub-catchments /reservoirs)

Total water inflow Anniviers 2004-2008	Average	191,666,265	m^3
	Min	182,660,805	m^3
	Max	200,671,724	m^3

Source Ovando and Speich (in preparation)

CASE STUDY: WATER SERVICES VALUATION

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Water consumption and value

Sector	Drinking water consumption (m^3/ year)		Agriculture m^3/ year	Total consumptive demand m^3/ year	Water use for Hydropower m^3/ year
	Residents	Tourist/night (+ secondary residents)			
Consumption	479,709 -1,599,022 (0.170-0.567 m^3/day-person, and 7,731 permanent residents in 2015)	146,100 (0.1994 m^3/tourist-night, and 732,637 t/n in 2015)	4,969,031 (827 m^3/ha and 6,066 ha year 2015)	5,594,839 - 6,714,152 **3% of water yield**	182,660,805-200,671,724 0.074 kW/h
Environmental prices of water (CHF/m^3)					
Revenues	1.20 ± 0.46				0.23-0.25
Production costs	1.05 ± 0.32				0.23-0.25
Environmental price	0.11-0.19 (0.003-0.006)		2.04-4.15 * (0.09-0.15)		0.013-0.014

*Irrigation: Gross margins by crop type in Switzerland and agricultural land distribution in canton Valais

Environmental price of water: 0.10±0.02 CHF/m^3

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Source Ovando and Speich (in preparation)

Many thanks…

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References (ongoing research)

- Abildtrup et al. (in preparation). Assessing the cost-effectiveness of payments to woodland owners for water services. Internal Working Paper, PESFOR-W WG3 on PES cost-effectiveness.
- Ovando, P., Brouwer, R., 2018. A review of economic approaches modeling the complex interactions between forest management and watershed services. Submitted (*under revision*).
- Ovando, P., Speich, M. 2018. Optimal harvesting decision paths when timber and water have an economic value. In progress (Preliminary results presented at the EU ESP 2018 Conference, and the 125th IUFRO Anniversary Congress, 2017).

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Training School

RESIDENTIAL WATER DEMAND

Determine the empirical evidence on the relationship between **water price** and **household water consumption.** A simple way to measure these relationships is to compute the **price elasticity** of the water demand and the **income elasticity** of the water demand.

1° Step: estimate the water consumption function ➡ $y = y^*(p, I, Z)$

y is the individual or household water consumption

I is the representative household income

p is the unit water price(supply+sewage treatment services)

Z is a vector of **exogenous variables** influencing water consumption (climate conditions, household and housing characteristics, etc.).

The demand functions usually depend on the demand of **substitutes or complements** to the commodity in question, as well as on consumer preferences. In case of water it is often assumed **weak substability** of water respect to other goods, and complementary goods are often durable equipment (wash machine). Therefore other goods are not consider to estimate residential water demand.

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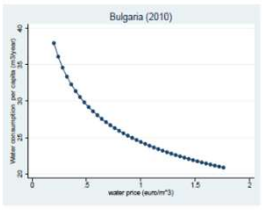
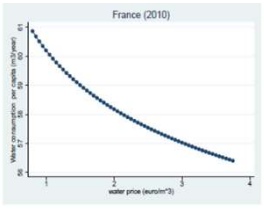
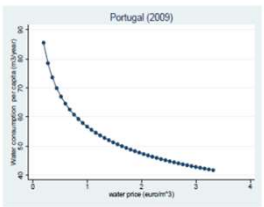
RESIDENTIAL WATER DEMAND



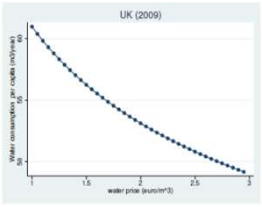
(c) Bulgaria



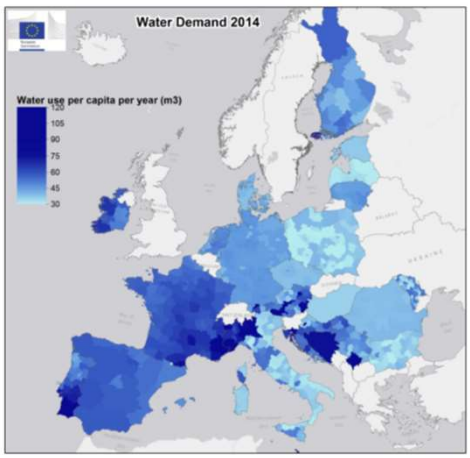
(j) France



(g) Portugal



(m) United Kingdom



Source: Reynaud, 2015. Modelling Household Water demand in Europe. Insights from a Cross-Country Econometric Analysis of EU-28 countries-Report EUR 27310 EN. JRC.

Training School

RESIDENTIAL WATER DEMAND

2° Step: estimate price (ϵ_p) and income (ϵ_I) elasticity: The price/income elasticity measures the responsiveness of the water use to a (percentual) change in water price/ in income , all other things equal:

$$\epsilon_p = \partial y^* / \partial p \cdot (p / y^*) \qquad \epsilon_I = \partial y^* / \partial I \cdot (I / y^*)$$

Many studies suggest that water demand function is price inelastic which means that water consumption decreases by less than 1% for every 1% increase in price, the **price-elasticity typically varying between -0.1 and -0.5** in EU-28 countries**.**

Water income elasticity shows more divergences, in some countries such as Spain, Austria, France or Germany is relatively inelastic (**between 0.0 and 0.25**), in other countries such as Portugal, Bulgaria, Finland or Latvia is more elastic (**greater than 0.5**).

Price elasticity varies depending on the type of water use: Water for human consumption (drinking) or for cooking are found to be very **price inelastic**, whereas water-related leisure activities (watering the garden or making use of swimming pools) are usually much more price reactive. **Policy implication**

Source: Reynaud, 2015. Modelling Household Water demand in Europe. Insights from a Cross-Country Econometric Analysis of EU-28 countries-Report EUR 27310 EN. JRC.

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