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

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

(1) Cost-effectiveness of woodland measures

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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.

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

Outcomes: Additional outcomes of the intervention respect to BL.

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

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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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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

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

COST EFFECTIVENESS VS. COST EFFICIENCY

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Environmental effectiveness is a precondition for cost-effectiveness

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

$$CER_j = C_j / E_j$$

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

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**

COST-EFFECTIVENESS ANALYSIS

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

Dominance of alternatives

Alternative	Costs	Effect	ICER
No intervention	0	0	0
Intervention 1	3,000	12	250
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Intervention 3	4,500	15	300

ΔC_j	ΔE_j	$\Delta C_j / \Delta E_j$
0	0	0
3,000	12	250
1,500	4	429
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

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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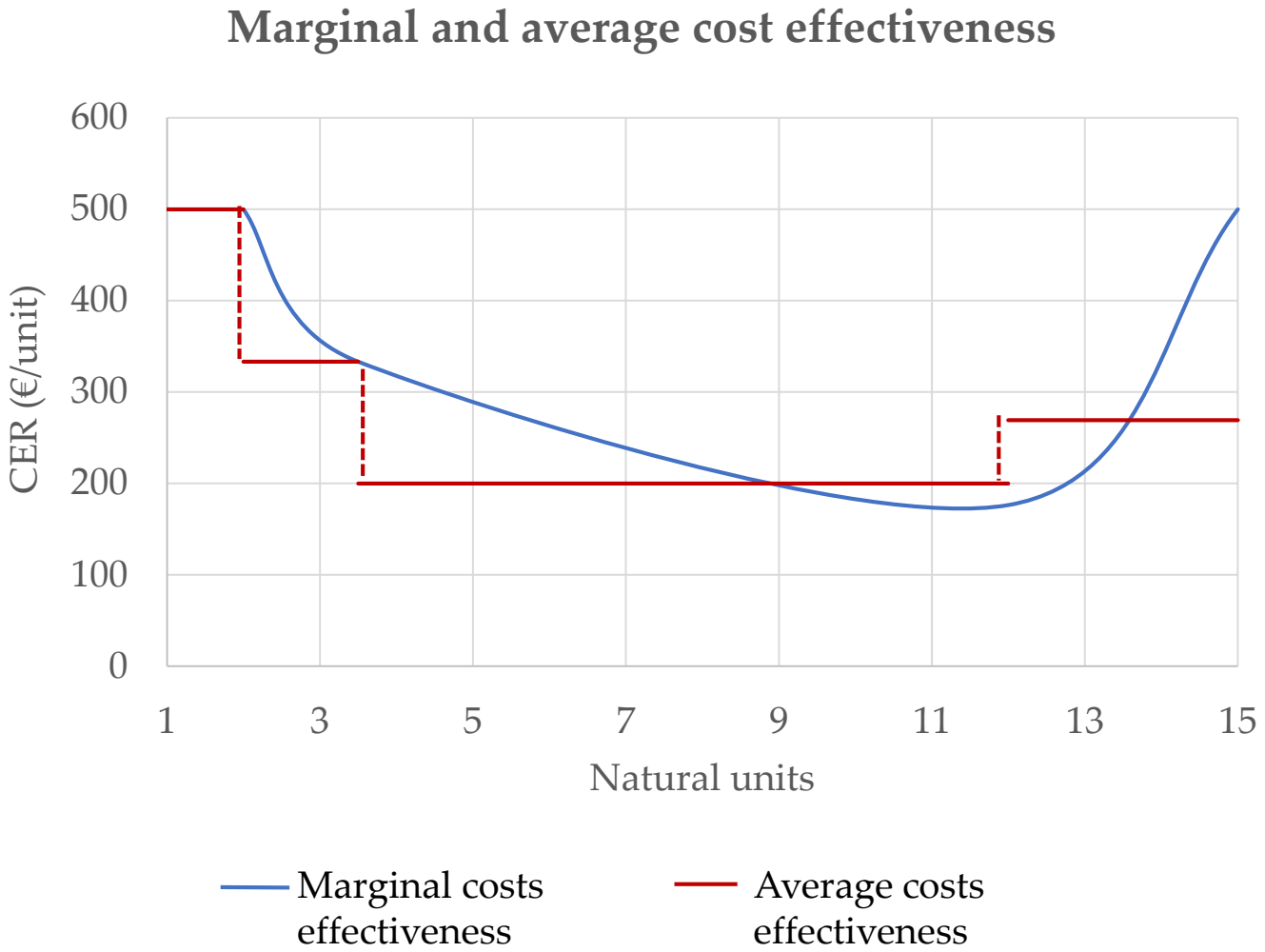
COST EFFECTIVENESS ANALYSIS



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

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

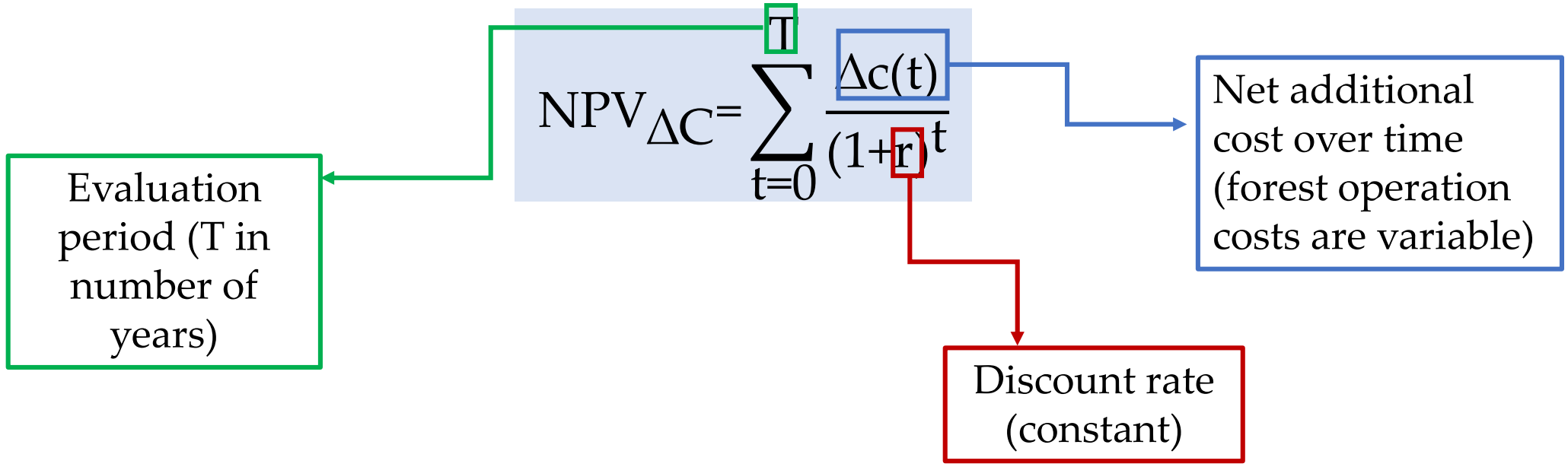
ASSESING COST-EFFECTIVENESS: FOREST FOR WATER

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?)

ACCOUNTING FOR TIME

Net present value of expected cost:



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.

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

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?

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.**

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).

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			

ACCOUNTING FOR CO-BENEFIT/COSTS

Net present value of NET expected total cost:

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

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).

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.

Many thanks…

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

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