Evidence and Solutions for improving **SPONGE** Functioning at Land**SCAPE** Scale in European Catchments for increased Resilience of Communities against Hydrometeorological Extreme Events

Assessing the socioeconomic value of sponge measures: between co-benefits and trade-offs

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Benefits and trade-offs of sponge measures

Main hydrological benefits:
absorb, store, slowly release water
→ flood reduction & drought resilience

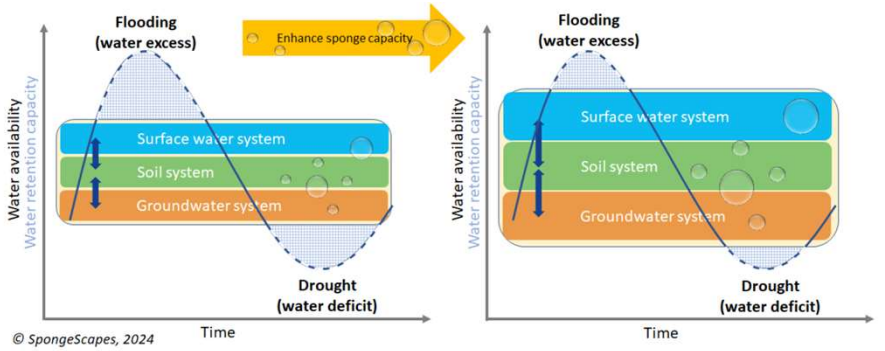
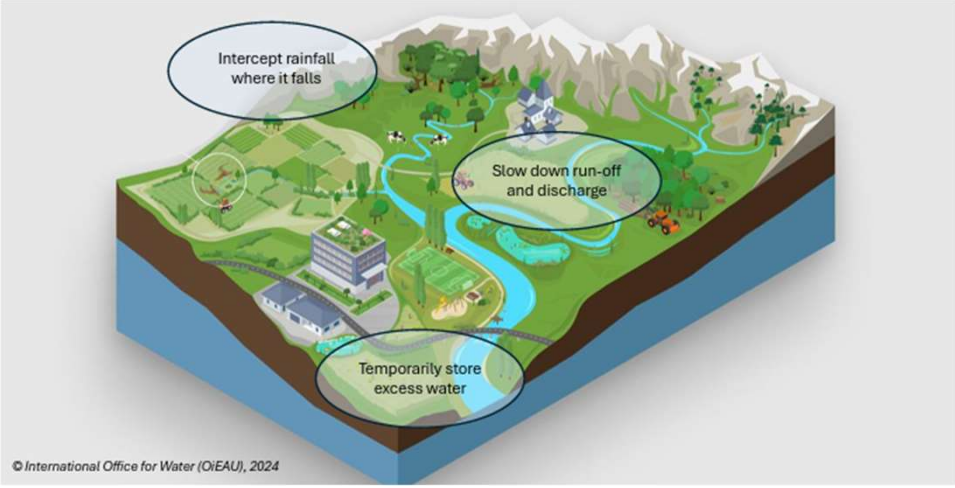


Figure 5: Enhancing the water retention capacity of the three compartments of the sponge and expected benefits on rainfall runoff-transfer in a landscape (Penning et al., 2024)



Source: SpongeScapes Policy Brief, Sep. 2024

Multifunctional nature: restoring and maintaining ecosystems (NWRM.eu, 2014; Kabakchieva and Vasileva, 2023)

- **direct and indirect co-benefits** (Fribourg-Blanc et al., 2015; Wang, 2021; Staccione et al., 2021)
- potential **trade-offs** (Giordano et al., 2020; Choi et al., 2021; Wang, 2021; Ommer et al., 2022)

Why socio-economic assessment matters

- Limited implementation (Yu et al., 2019; Pagliacci et al., 2022):
  - low stakeholder awareness and acceptance
  - uncertainty about costs
  - socio-economic and cultural constraints

Socio-economic assessment is needed to convince stakeholders and citizens

Co-benefits

- Make wider values visible
- Identify (additional) benefits that matter locally, to support engagement



Trade-offs



- Understand competing outcomes
- Identify who bear costs and inform measures design and mitigation

Key research questions

1. What **co-benefits** and **trade-offs** do sponge measures generate?
2. What are their **socio-economic impacts**?
   How can we assess them?



Socio-economic assessment supports informed decisions, by asking:

- Who benefits?
- Who bear the costs?
- Over what timescale?

Today's presentation is about **two case studies** from SpongeScapes

SpongeScapes Project and case studies in a nutshell

14 case studies:
different climate and landscapes

Common framework,
indicators adapted
to local conditions



Case Study groupings



Surface Water (SW)

- IT2 Timonchio pond
- FR1 Leze buffer strips & bends
- UK1a Littlestock bunds, ponds, leaky barriers
- UK1b Riseholme ponds
- UK1c Lymington floodplain restoration
- UK1d Cole floodplain restoration



Soil Water (SoilW)

- UK2ab ASSIST buffer strips
- UK3 COSMOS crop rotation
- UK4ab LANDWISE low till, cover crops, controlled traffic



Vegetation-Soil (Veg)

- SI1 Gradascica forested catchment
- IT4 Bosco Limite forest infiltration area



SW-GW

- GR1 Kavouropotamos
- NL1 Chaamse
- NL2 Aa & Maas
- PL1 Biebrza
- IT1abc Santorso
- IT3 Agripolis

The assessment framework



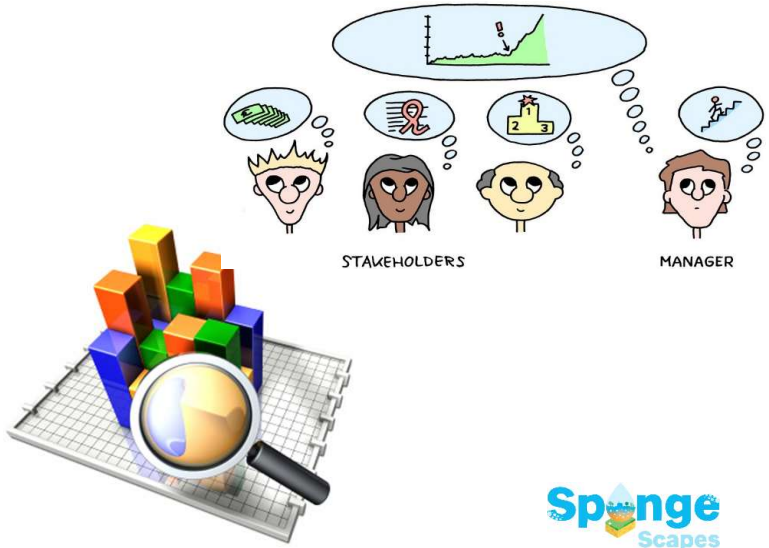
SpongeScapes Project **assessment strategy**

1. Literature review (86 studies on impacts methods/indicators)
2. Partner consultation
3. Case study assessment



Advantages of this approach:

- Combine complementary methods and address data gaps
- Quantitative and qualitative evidence informs further economic assessment



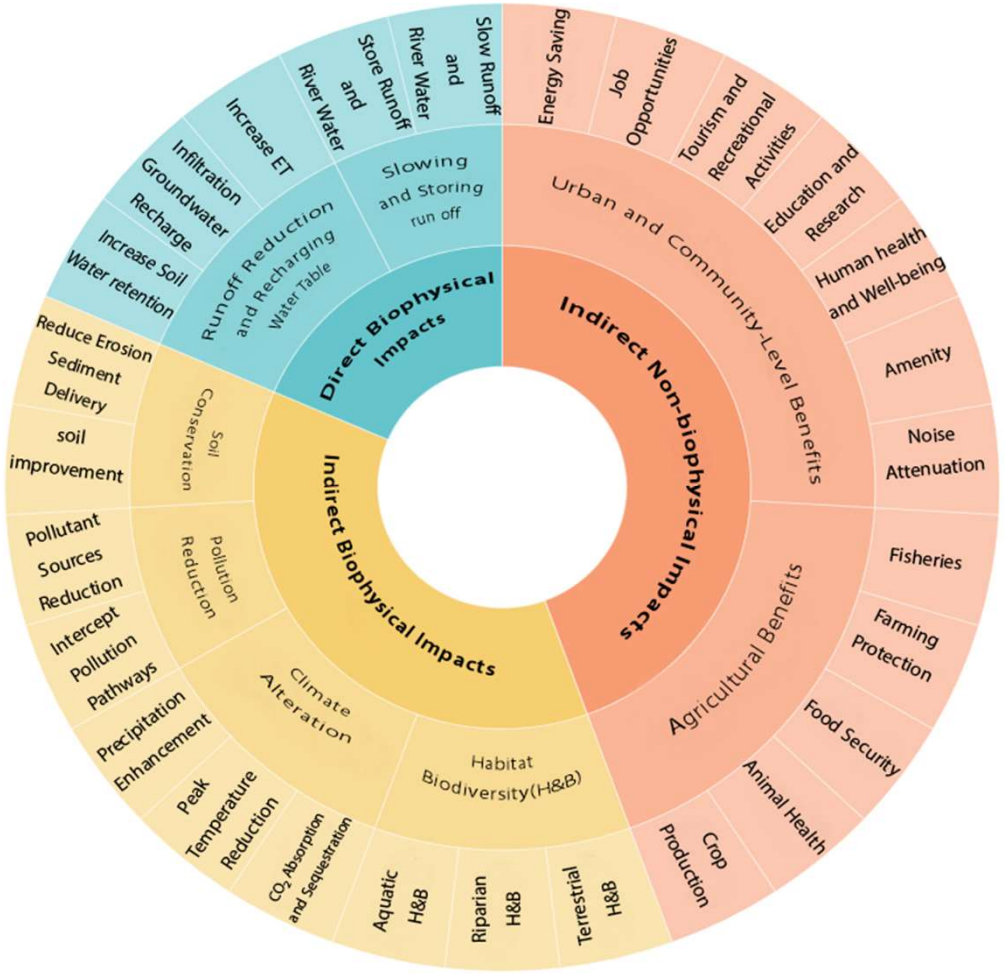
Results from the literature review

Co-benefits of sponge measures include (Fribourg-Blanc et al., 2015):

- **direct biophysical impacts**
- **indirect biophysical impacts**

Almasi et al. (2025) added:

- **indirect non-biophysical impacts,** (provision of additional ecosystem services)



Example from two case study from Italy (Veneto Region)











Municipality of Santorso

Int1: Underdrained bioretention with a rain garden

Int2: Grass swale and bioretention area

Int3: Rain garden, infiltration trench, pervious pavement

Giavenale di Schio

Int4: Retention pond in agricultural area



Example from one case study: Santorso and Timonchio

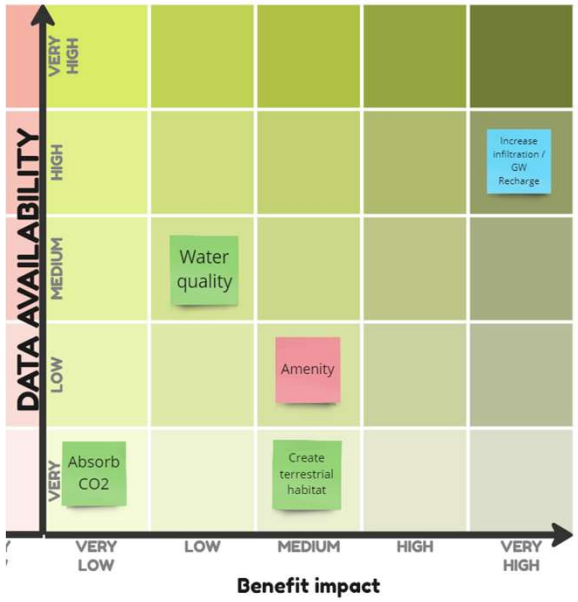
Main benefit:

- Store and slow runoff

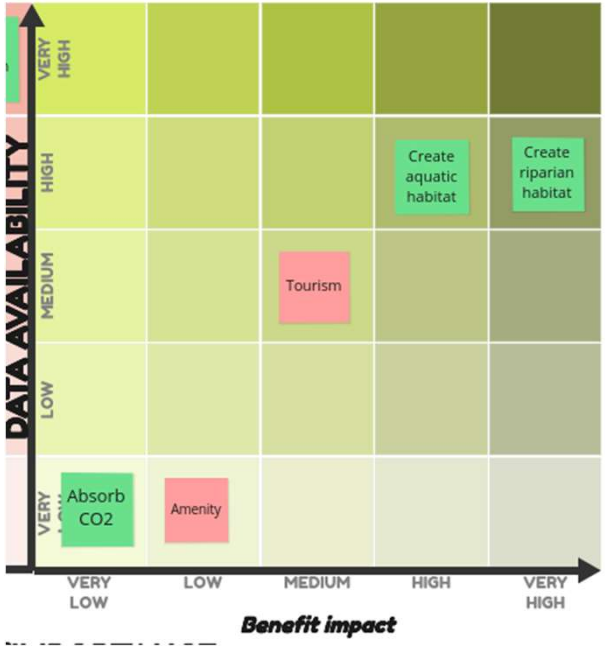
Co-benefits:

- Flood damage reduction
- Drought resilience
- Water quality
- Amenity and tourism
- Create new habitats
- Climate mitigation benefits

Municipality of Santorso measures

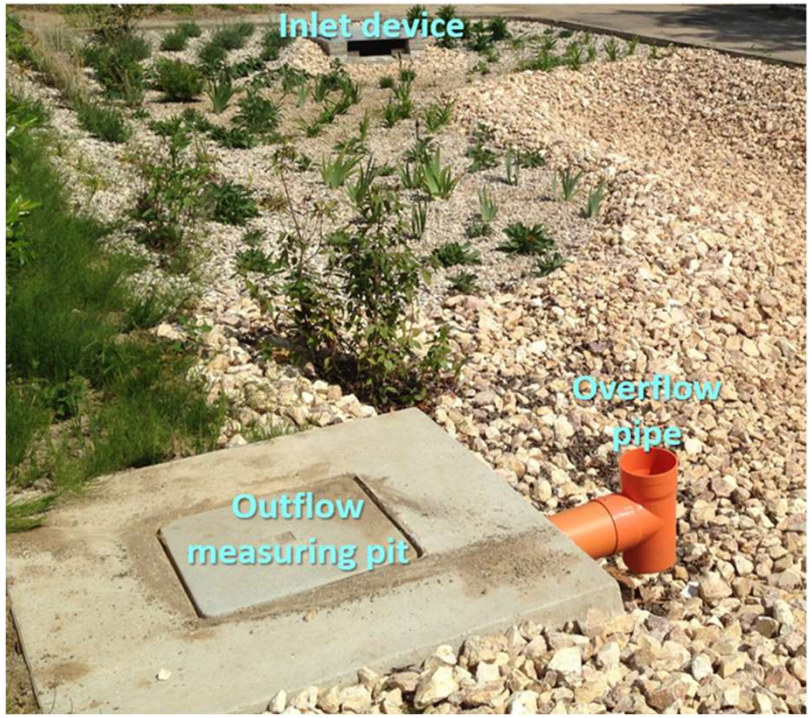


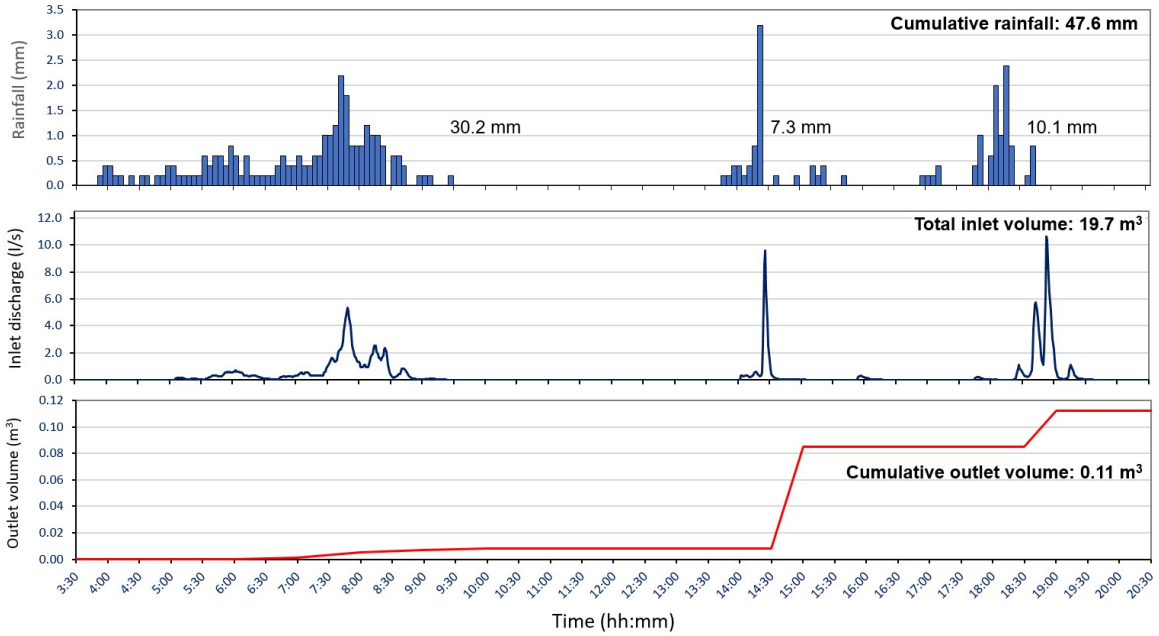
Giavenale retention pond



Main benefits: Infiltration / Ground water recharge

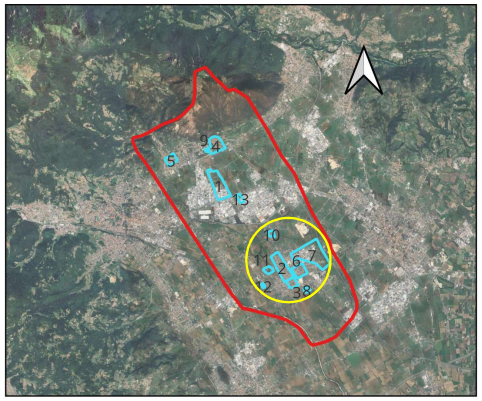
Infiltrated volume:
3200 m^3/year



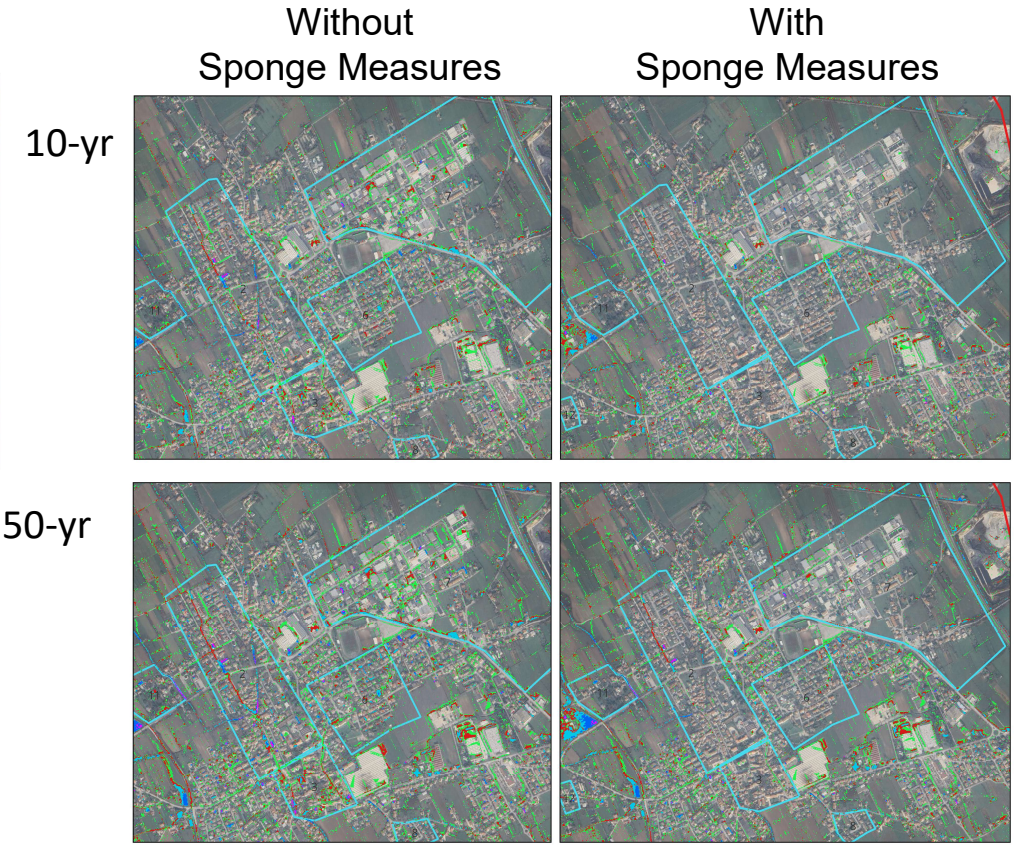


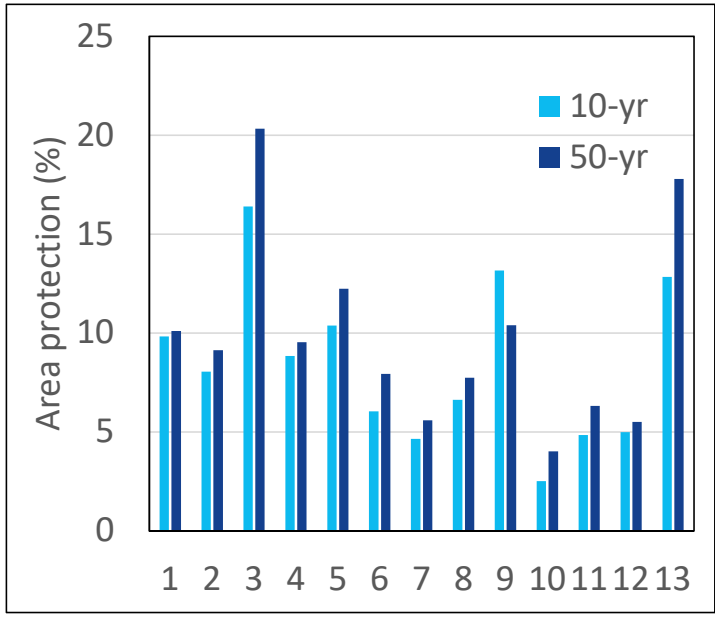
Co-benefits: Flood damage reduction (i)

Hydrological modelling approach at the landscape scale
Using FLO-2D PRO model: A grid-based, two-dimensional model to calculate flow depths and velocities over the grid cells



Boundary
Flood-prone Zone
Maximum Flow Depth (m)
0.05 - 0.1
0.1 - 0.2
0.2 - 0.5
0.5- 1.0
>1





Co-benefits: Flood damage reduction (ii)

1. Benefit Estimation

Damage Level by Flow Depth

Flow Depth (m)	Damage Level
< 0.10	no damage
0.10-0.20	1
0.20-0.30	2
0.30-0.40	3
0.40-0.50	4
>0.50	5

Vulnerability Weights by Building Type

Damage Level	Garage	Ground floor	Shops/Offices	Factories	School	Productive (agricultural)	Hospital
no damage	0	0	0	0	0	0	0
1	0.25	0.1	0.05	0.05	0.05	0.05	0.05
2	0.25	0.25	0.25	0.25	0.25	0.25	0.25
3	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5	1	1	1	1	1	1	1

Vulnerability Weights * Unitary damage (€) = Damage $_{(10\text{-yr, } 50\text{-yr})}$

Benefit (avoided damage) = Damage $_{\text{without NBS}}$ – Damage $_{\text{with NBS}}$

2. Cost Estimation

1. Retention Basin
2. Rain Gardens
3. Infiltration Trenches
4. Mixed Scenario *

Initial construction costs : Year 0

differentiated by NBS type and required storage volume per zone

NBS type	Construction cost (€/m³)
Retention basin	97.7
Rain gardens	366.3
Infiltration trenches	299.6

Annual maintenance: Years 1–30

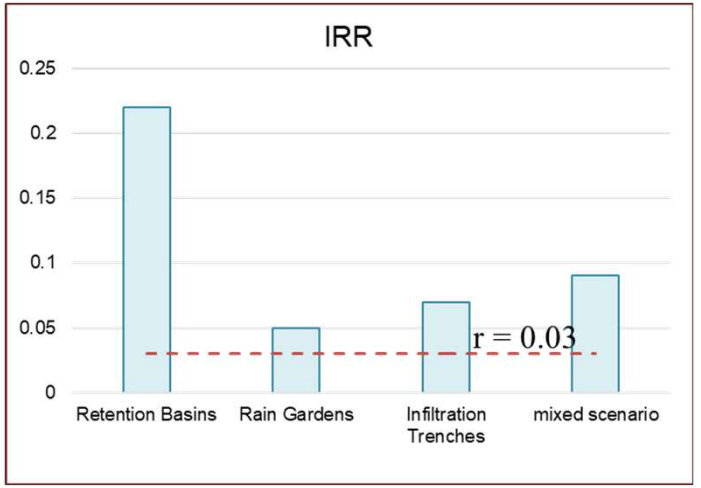
3.5% of construction cost for retention basins and 1.3% for rain gardens, infiltration trenches

Extraordinary Maintenance: Year 30

Major rehabilitation at 20% of the initial construction cost to restore full intervention functionality

Internal Rate of Return (IRR)

Attractive when IRR > 3%,
i.e. a social discount rate



Co-benefits: Drought resilience



- Max storage volume: 2300 m^3
- Agricultural area with three highly specialised, high-income farms (each 10 ha of UAA) :
  - permanent meadows
  - cereals
  - orchards and horticultural production (organic)





- During severe droughts: estimated **avoided losses of €12,559 / year** (over a 20-year horizon)

Co-benefits: Water quality

Comparison between inlet and outlet water quality in the rain garden Prati Street (Municipality of Santorso)



Compound	Unit	27/04/2021		12/05/2021		15/07/2021		05/10/2021		16/11/2021	
		27/04/2021 IN	27/04/2021 OUT	12/05/2021 IN	12/05/2021 OUT	15/07/2021 IN	15/07/2021 OUT	05/10/2021 IN	05/10/2021 OUT	16/11/2021 IN	16/11/2021 OUT
Biochemical Oxygen Demand (BOD_5)	mg/L	70,0	<5,0	<5,0	<5,0	7	5	5	<5,0	8	6
Animal and vegetable fats and oils	mg/L	1,2	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total hydrocarbons	mg/L	1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total oils	mg/L	2,2	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0	< 1,0
Total suspended solids	mg/L	210	< 5	< 5	6	11	42	11	< 5	12	34

Co-benefits: Amenity and tourism

Increased attractiveness and desirability of the area, improved well-being of both visitors or residents (Horton et al., 2019)

Rain garden at Libertà square:

Indicators	Value	Units
Improved area of green space	60	m^2
Benefitting (total) area	2200	m^2
Visitor numbers to green spaces/ potential visitors living walking distance	???	people





Photo of the field visit conducted with high school students from ITET Pasini (Schio) (21/03/2025)

Retention pond at Giavenale:

Indicators	Value	Units
School visits	3398	students

Co-benefits: Terrestrial habitat / biodiversity

New aquatic and riparian habitats for 2948 m^2



Domain	Results
Amphibian species	0 → 4 species (ex-post monitoring)
Water-associated bird species	0 → 8 species (ex-post monitoring)
Total bird species	• 34, in 2019 • 48, in 2020 • 40, in 2021
Threatened wetland-associated birds (according to the Italian Red List of breeding birds)	• Garganey (Vulnerable) • Eurasian teal (Endangered) • Reed Bunting (Critically Endangered)
Plant species of conservation interest	Jacobaea paludosa (+28%)
Aquatic vegetation establishment	two new aquatic plant species







Co-benefits: Climate mitigation benefits

Positive effects

- Lower energy use and emissions
- Avoided embodied carbon
- Carbon sequestration

i-tree design estimates tree carbon sequestration by species, size, conditions and over lifespan (Horton et al., 2019).

Rain garden at Libertà square:

Species	Quantities	Carbon sequestration
Alnus glutinosa	1	2476 kg / 60 years



Trade-offs: Balancing benefits and local needs

Potential trade-offs must be assessed locally

Trade-off	Mechanisms	Potential solution
Water retention vs. productive land use	Ponds and restored habitats may require the use of productive lands	• Appropriate site selection • Specific compensation to limit losses
Drought storage vs. flood capacity	Water retained during dry periods can reduce space for stormwater during the following rainy season	• Adapt storage and operation to seasonal needs
Local costs vs. wider benefits	Landowners may bear costs while benefits extend downstream	• Agree on cost sharing and maintenance responsibilities

Good design and fair cost sharing help realise wider benefits

What we can assess, what is still missing!

- Common framework for identifying relevant effects and possible indicators
- Monitoring and Indicators:
  - Challenges in identifying indicators:
  - Standardization
- Grouping Case Studies
- Challenges in Transfer Method:
  the biophysical context (e.g., climate, geology, soil, land use) matter

Conclusions and take home messages

- **Assess the wider value:** connect hydrological performance with environmental and social outcomes
- **Consider distribution:** identify who benefits, who bears costs, and how outcomes vary across places and time
- **Combine evidence:** use indicators and stakeholder knowledge to address gaps and inform implementation

SpongeScapes

Francesco Pagliacci

(with the collaboration of the whole University of Padova team: Vincenzo D'Agostino, Francesco Bettella, Parisa Almasi)

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