Improving sponge functioning at the landscape scale

Sponge measures

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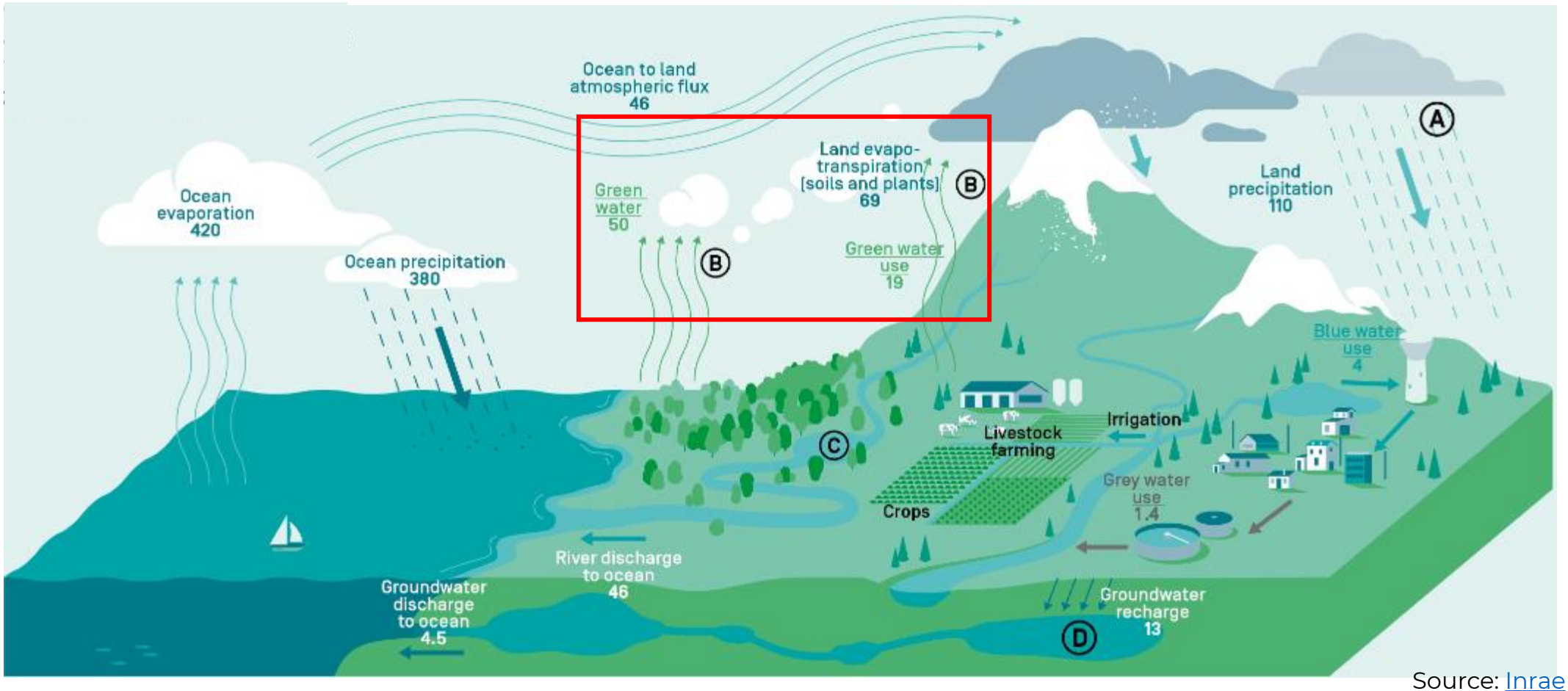
UK Research and Innovation

The water cycle: a complex topic

→ Significant contribution of green water to land precipitation

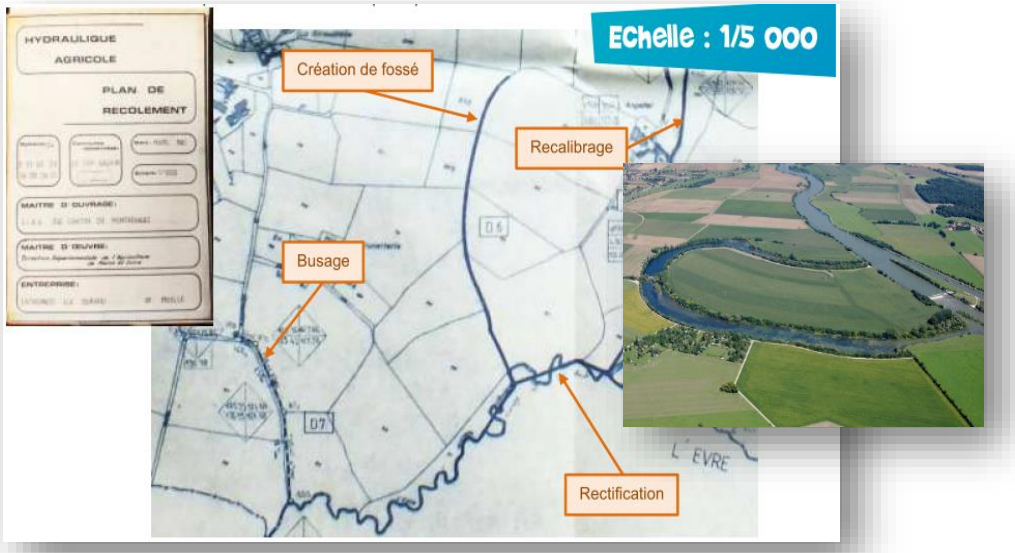


Source: Inrae

Water flow in landscape: some past trends

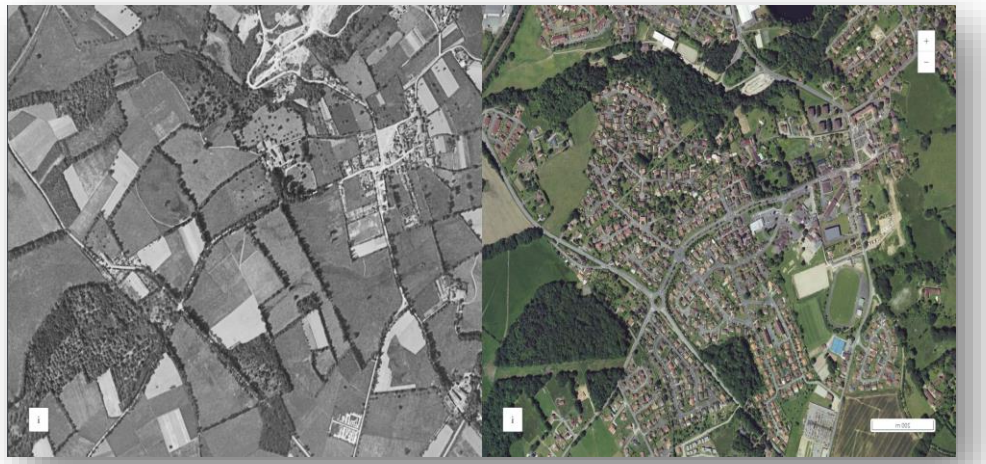
Land consolidation

Drainage



Agriculture hydraulics

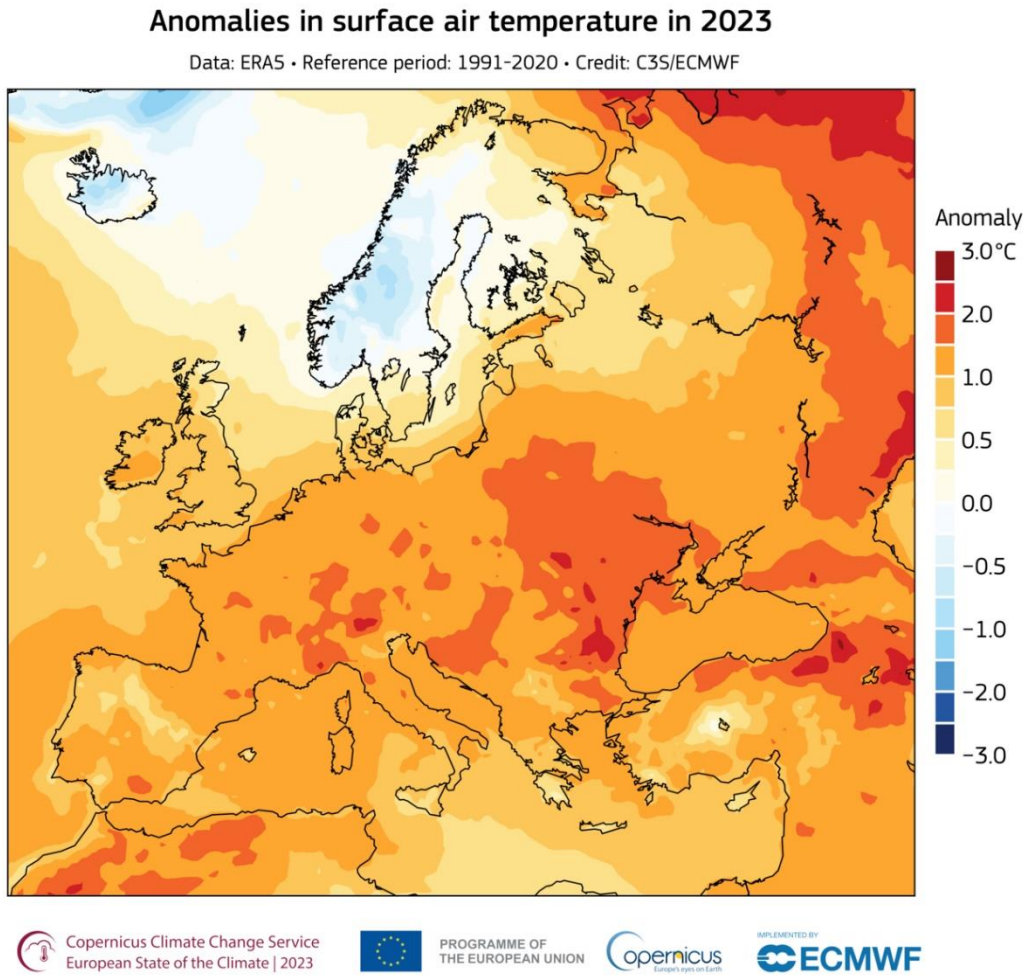
Urbanisation



➡ **Faster rainfall-runoff transfer**

Climate change in Europe

Existing evidence



Source: Copernicus, 2024.

Anticipated trends

10-30% decrease in precipitation

30% decrease in snow

Increase in evapotranspiration

Increase in frequency of droughts

Trend towards decreasing soil moisture content

Change in seasonal river flow patterns

Recent development in water management

At EU level, progressive maturation of water-related legislation to **more integrated approaches** to cover better the range of problems and interactions, and **integrate** recent knowledge development on **ecosystem functioning**.

→ growing interest for a range of solutions **inspired by nature** (EU & international)

→ EU developed the concepts of **Green Infrastructure** and **Natural Water Retention Measure (NWRM)** (2011) in support of **WFD implementation**

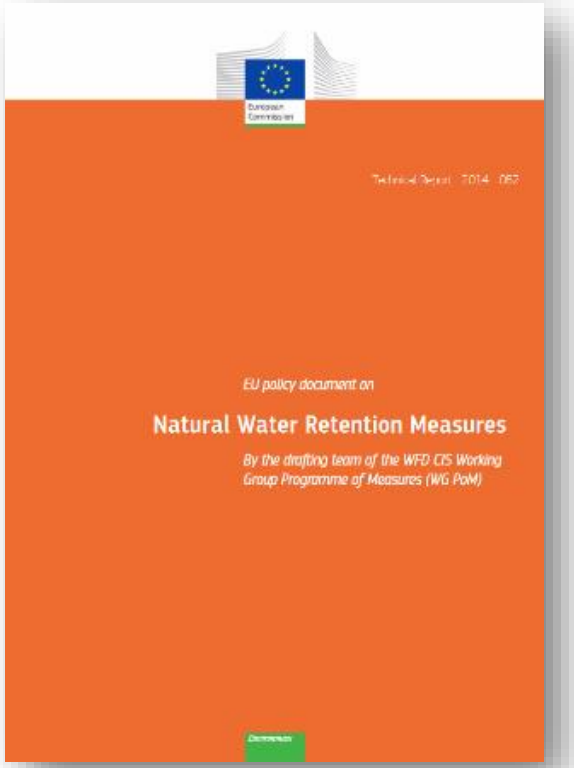
→ IUCN and EU developed the concept of **Nature Based Solution**

→ Various other institutions developed other similar concepts (**NSWRM, SLM, EbA, SUDS**, …)

NWRM & Sponge: Origin of the concepts

NWRM

- **In 2012,** the mid-term review of the Water Framework Directive (*A Blueprint to Safeguard Europe's Water Resources*) highlights that **"Natural water retention measures"** could contribute **significantly**
  - to limit the negative effects of floods and droughts
  - and be included in the 1st pillar of the CAP 2014-2020
- **Projects to support its development:**
  - 2012 and 2013 (EC): NWRM for the implementation of the water and green infrastructure directives
  - 2013-2015 …2019 (OIEau et al.): NWRM pilot project
  - 2014 (EC): Community policy document on NWRM
  - 2014 (EC): inclusion of the list of NWRM in CAP annex



EU NWRM policy document

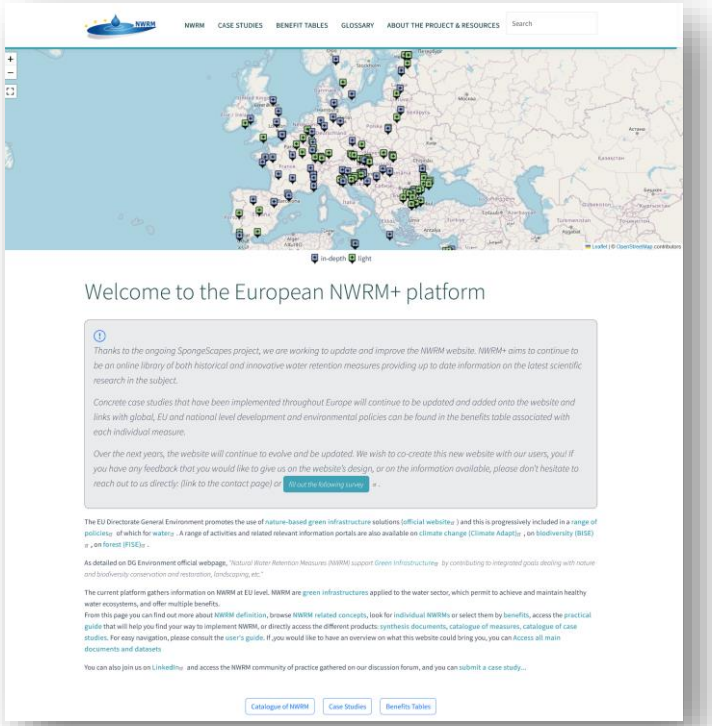
Sponge

- **"Sponge theory"** existed already **•for wetlands since 18th century and** amongst foresters in the **19th century**
- In the **early 2000s "sponge cities"** were tested by Kongjian Yu, a Chinese landscape architect
- In 2022 HORIZON programme - *Boost **the sponge function** of **landscape** as a way to improve climate-resilience to water management challenges*

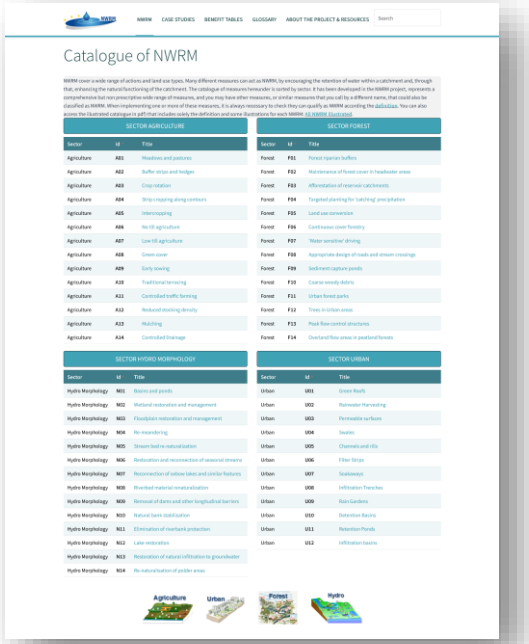
The knowledge hub nwrm.eu

http://nwrm.eu

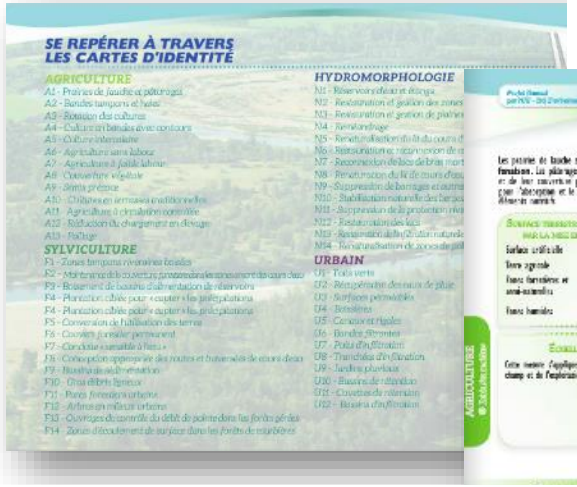
- A technical guide and annexes (*15 languages)*



- 53 NWRM measures: http://nwrm.eu/measures-catalogue



…with an organised list of measures



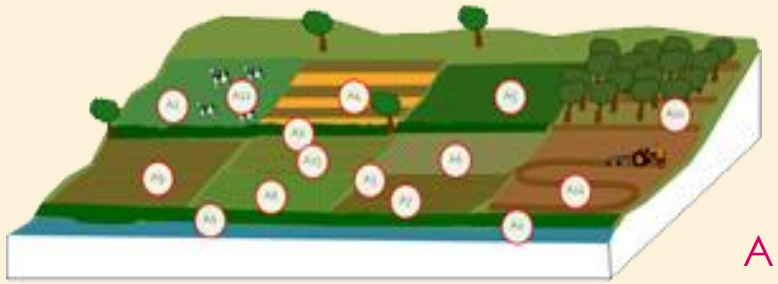
…a fiche for each of the 53 mesures

http://nwrm.eu/implementing-nwrm/practical-guide

- Transferred to **Wise** *Nature based solutions for water retention*
- Updated in a **Sponge Knowledge Platform**

NWRM: a catalogue of 53 measures in 4 sectors

Agriculture



A1 – Meadows and pastures

Hydromorphology

N3 – Floodplain restoration and management

Urban

U1 – green roof

Forest

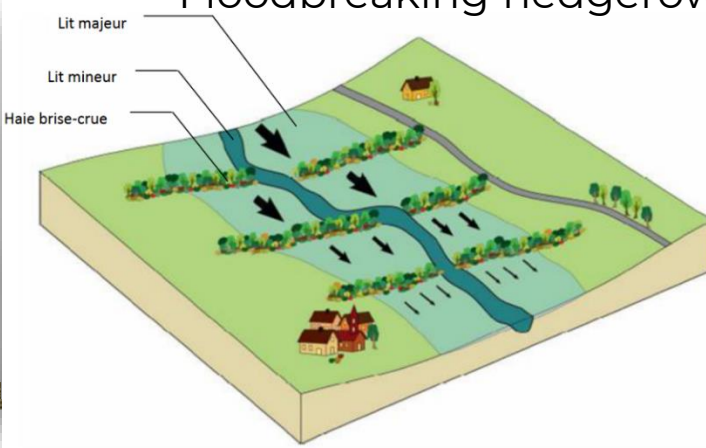
F5 – Land use conversion

SpongeScapes/Spongeworks Example – Agriculture & Hydromorphology – La Lèze (FR, Smival)

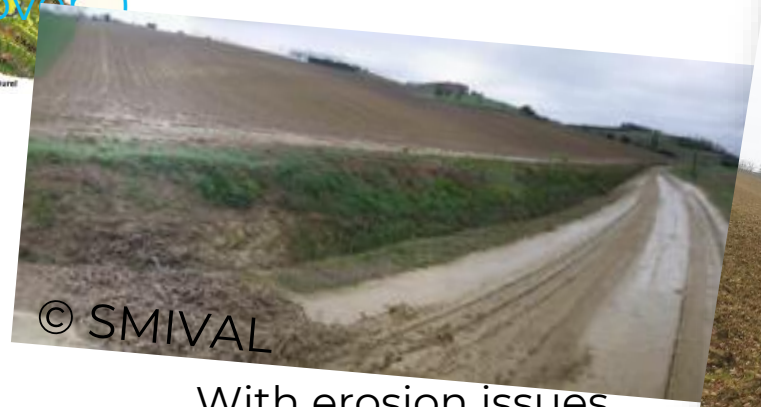
- A long and narrow river, 350km²
- Recent shift in agriculture
- Large crop fields
- Irregular rainfalls (600-1000mm/y)
- An approach at river basin scale
  - Floodbreaking hedgerows
  - Leaky dams
  - Hedges
  - Agriculture practices (low till, green cover…)
  - Urban measures
  - …

Agriculture hilly landscape

Floodbreaking hedgerow

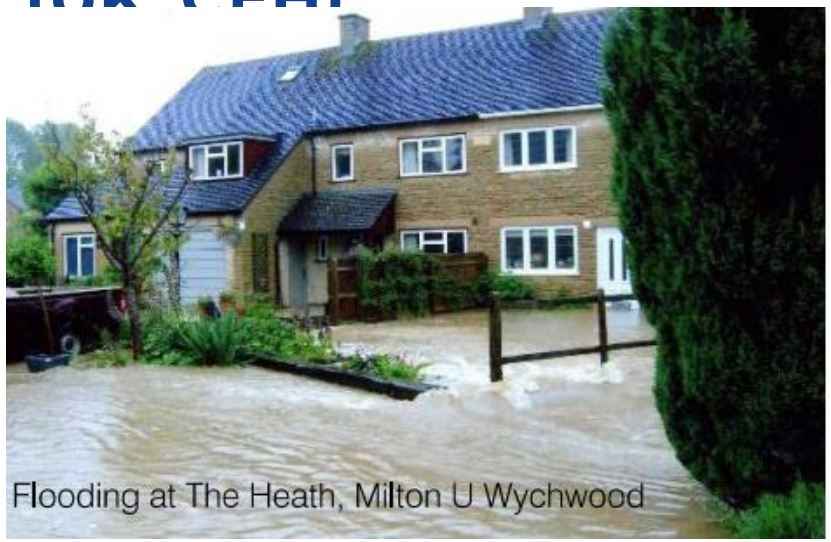


Buffer strip along a crop fi
and forest riparian buffer

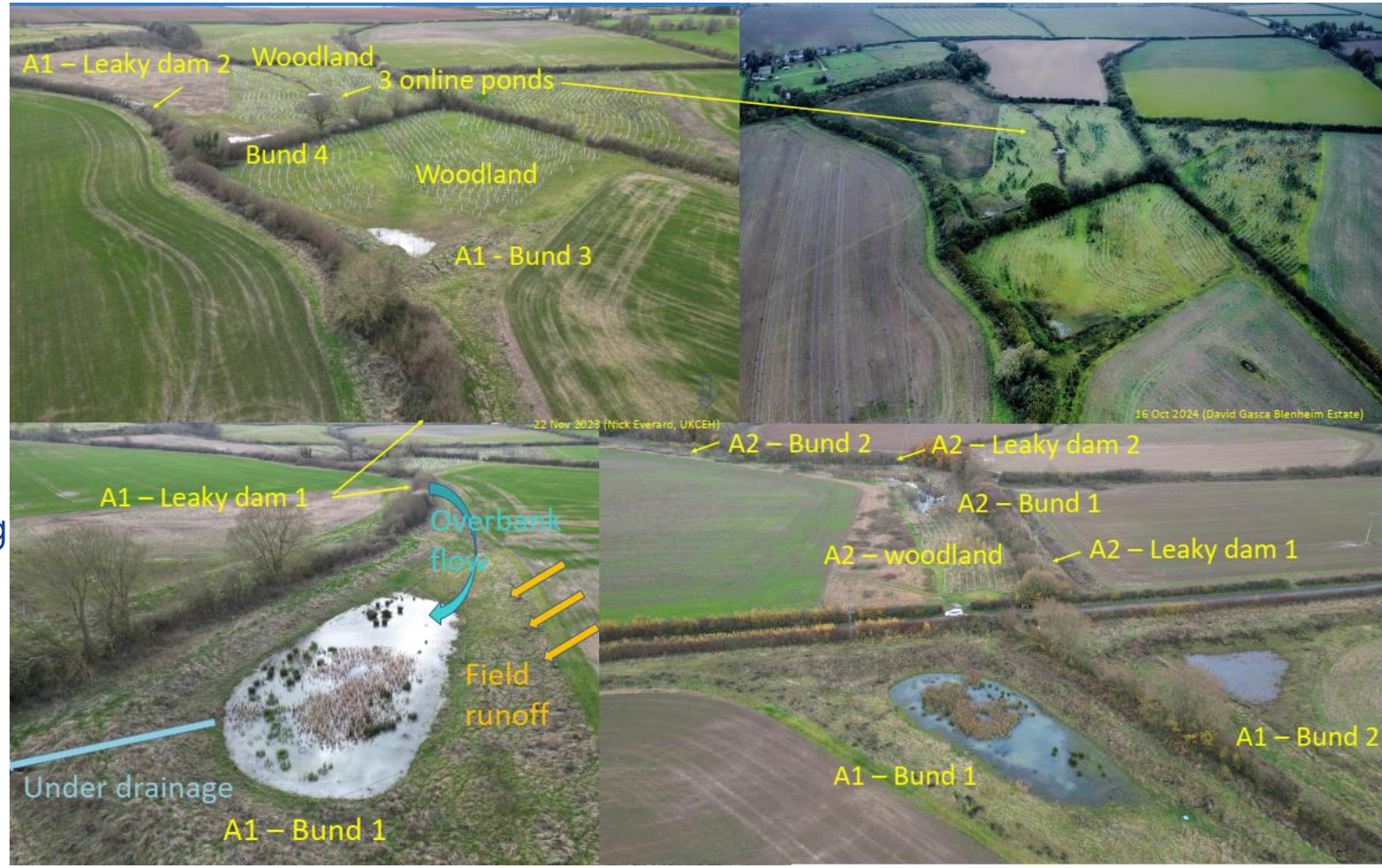


With erosion issues…

SpongeScapes Example – Agriculture & Hydromorphology – Littlestock (UK, CEH)



- A narrow river constrained by building
- Recurrent flooding
- An approach at river basin scale
  - Woodland
  - Retention pond
  - Leaky dam + overbank flow
  - Bunds and permanent grass



Source: SpongeScapes project posters, CEH

SpongeScapes Example – Forest: Bosco limit (IT, Etifor)

- Started in 2013
- 2,5 ha converted for 20y
- 2,300 trees selected (venetian forest)
- Forest Infiltration Area (FIA)
- 1,200m waterway, **infiltrate 1Mm3/y**
- Multifunction:
  - protect water and recharge ground
  - Reduce impact of use of chemicals,
  - produce biomass,
  - reconstitute fertile soil,
  - promote biodiversity…

Source: https://www.etifor.com/en/portfolio/boscolimite/

SpongeScapes Example – Hydromorphology –Check dams on Paros island (EL, WWF)

- Intermittent rivers
- Drought and unsustainable water use
- Use of 34 traditional stone check dams
- Multifunction:
  - recharge groundwater,
  - Enhance biodiversity
  - Increase vegetation
  - …

Source: SpongeScapes project posters, WWF greece

Examples of Urban measures

- Effectively **Sustainable (urban) Drainage Systems**
- Although can be applied outside of urban areas!

Green roof

Infiltration trenches

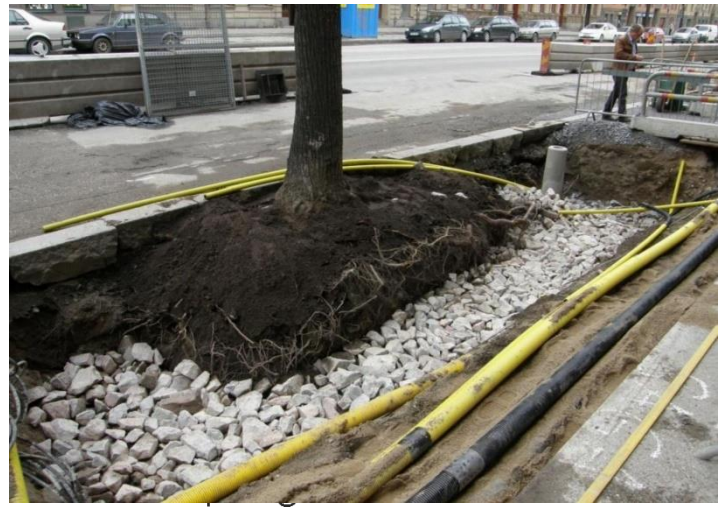
Swale

Stockholm trenches

Rain garden

Infiltration pave way

Retention basin



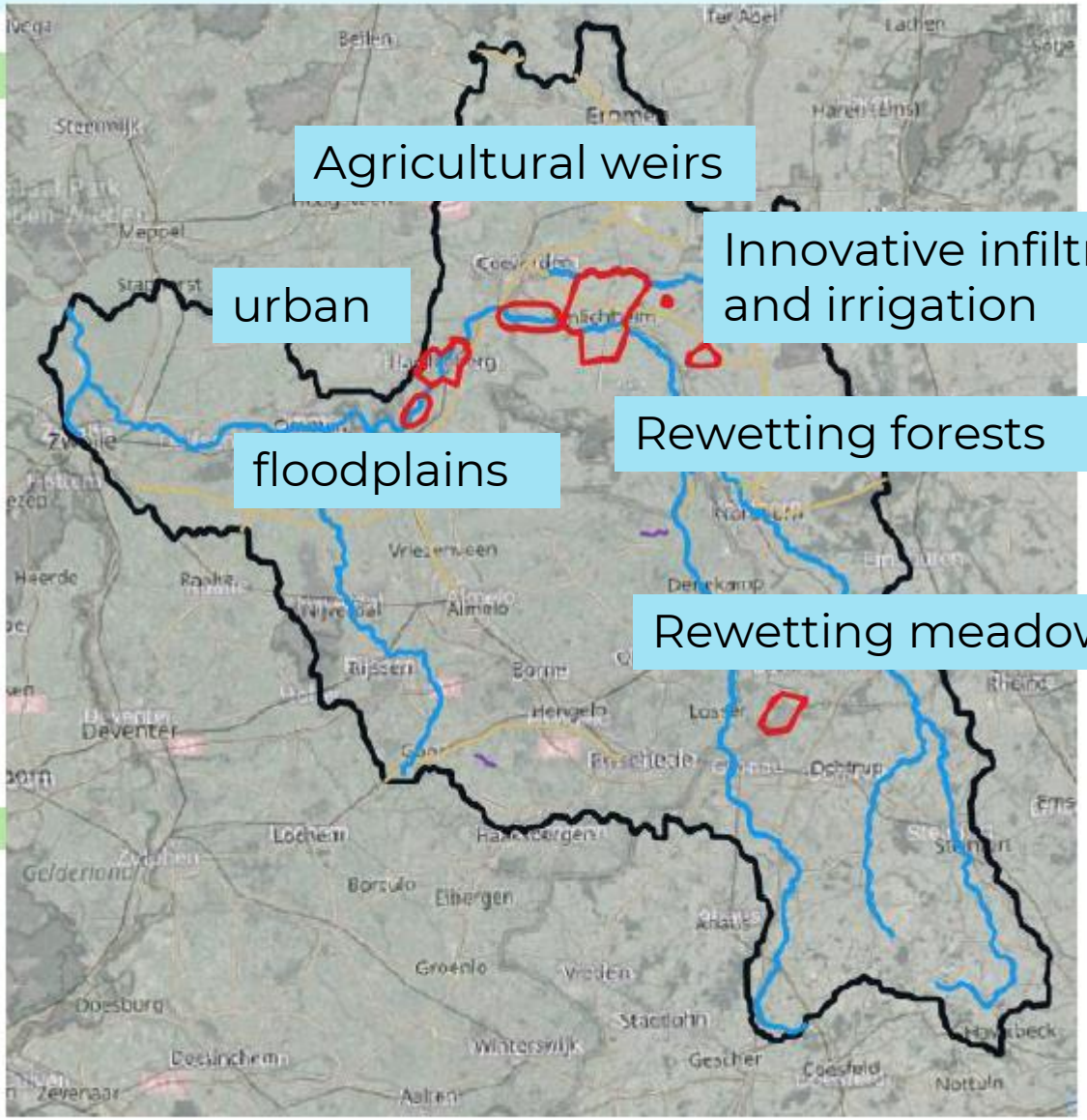
SpongeScapes Example – Urban – (Agripolis & Santorso, IT, Padova uni.)

- Veneto region from mountains to plain, North of Italy
- Pluvial flooding, droughts, landslides, erosion
- Test, monitor and improve
- An approach at the city and its surrounding catchment scale
  - Rain garden
  - Bioretention
  - Swales
  - Retention pond in rural suburb
  - Rain garden at university

SpongeWorks Example – Vecht basin

Location and characteristics

- The cross-border Vecht basin (Germany – the Netherlands)
- Area: 4,190 km², approximately 55% of the basin in the Netherlands and 45% in Germany.
- River length: 167km (107km in DE and 60km in NL).
- Average annual rainfall: 800mm
- Land use: agriculture (55%), grassland (22%), forests (10%) and urban areas (10%), and wetlands (2%).
- Total population: 2.3 million people live in the basin (1.5 million in DE, 0.8 million in NL).



Key challenges

- Surface and groundwater quality and quantity improvement.
- Mitigation of impacts from climate extremes (floods and droughts).
- Quality of life and awareness

In the field you hear things you don't see in literature… Evidences?

Some nice numbers:

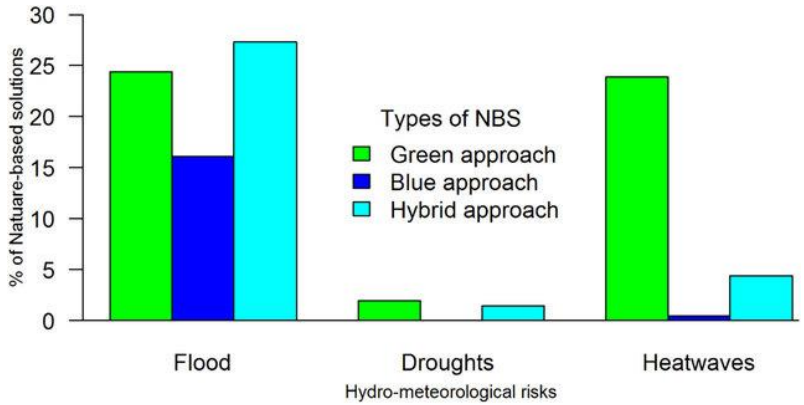
- Infiltration rate from 4,5 min to 23 seconds
- Bird diversity from 44 to 89
- 17 K€ woody dam or 4 M€ dredging project
- From 16,5 days in 1850 to 9 hours now (lowland stream of sandy soil and 50km)

- 'the only grazing place left'
- 'peace of mind'
- 'I've not been flooded this year'

Photo: David Gasca – Blenheim Estate

How about the evidence?

*While there is **substantial scientific evidence supporting the sponge functioning concept**, the effectiveness of landscape-based flood and drought mitigation may vary depending on the specific local conditions, climate, and land use practices. **It's essential to consider the local context and consult with experts** when implementing landscape management strategies for water regulation and risk reduction.*

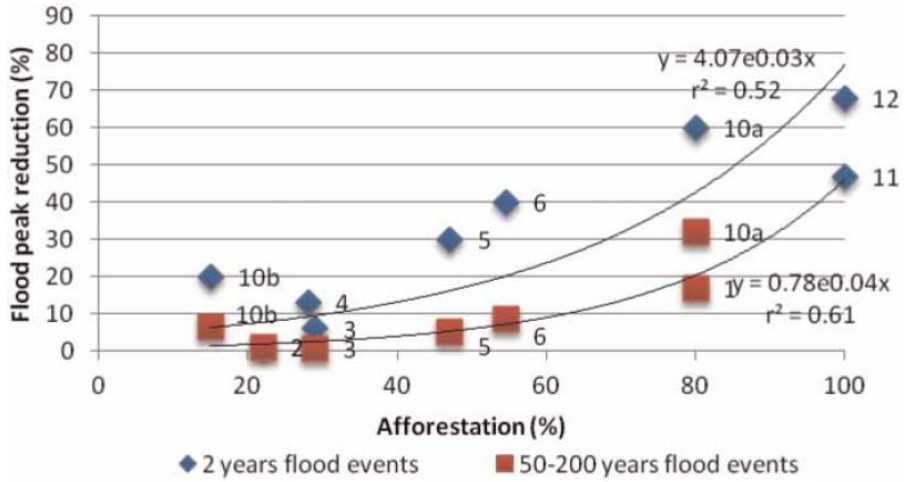


(Sahani et al 2019 https://doi.org/10.1016/j.scitotenv.2019.133936)

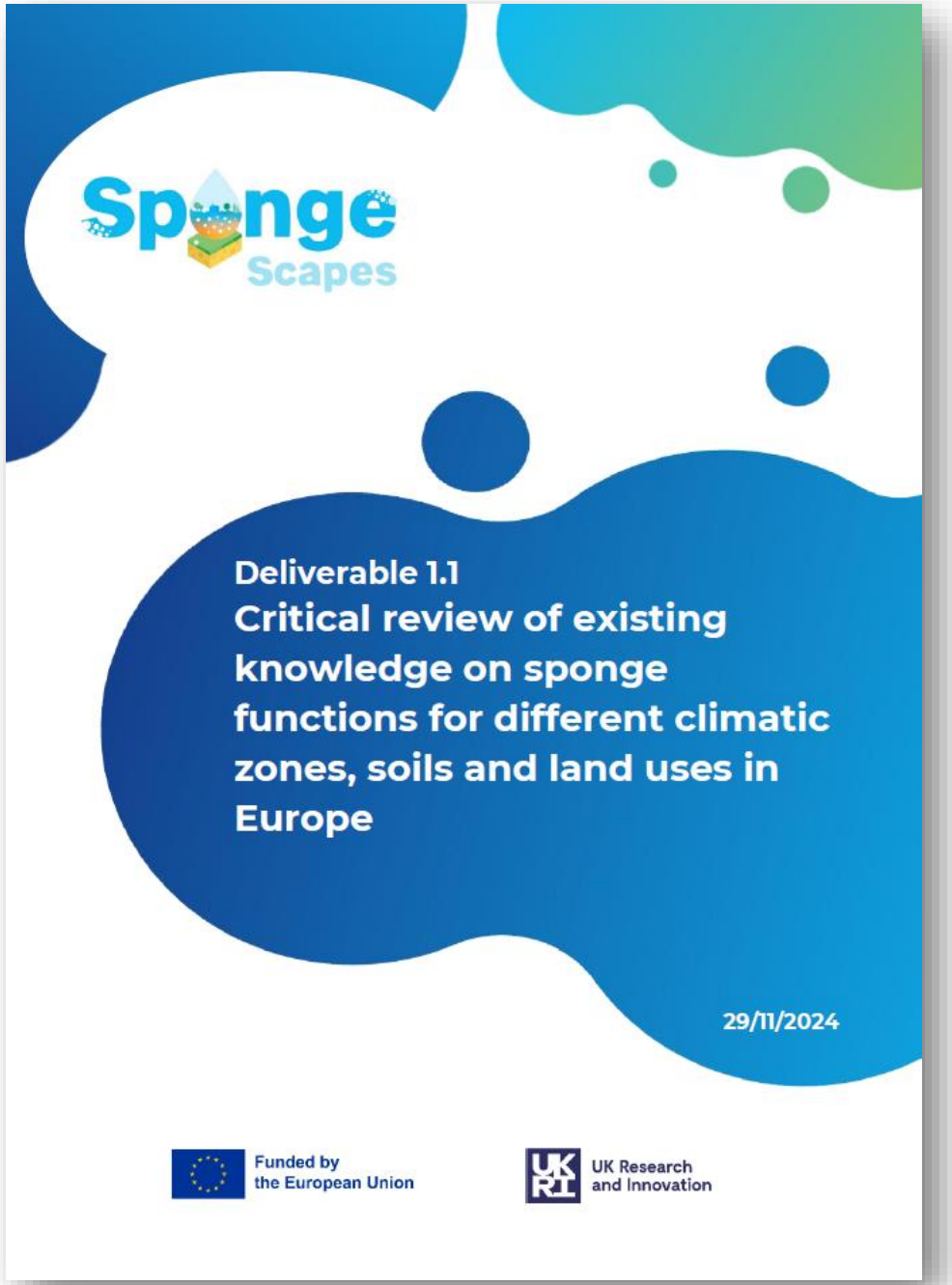
database	#cases	F&D	F&D&B	F&B	D&B
Nwrm.eu	140	8	5	18	7
World Bank	72	12	7	23	9

http://www.nwrm.eu/
https://naturebasedsolutions.org/projects

(Penning et al, 2023 –doi:10.1017/wat.2023.12)



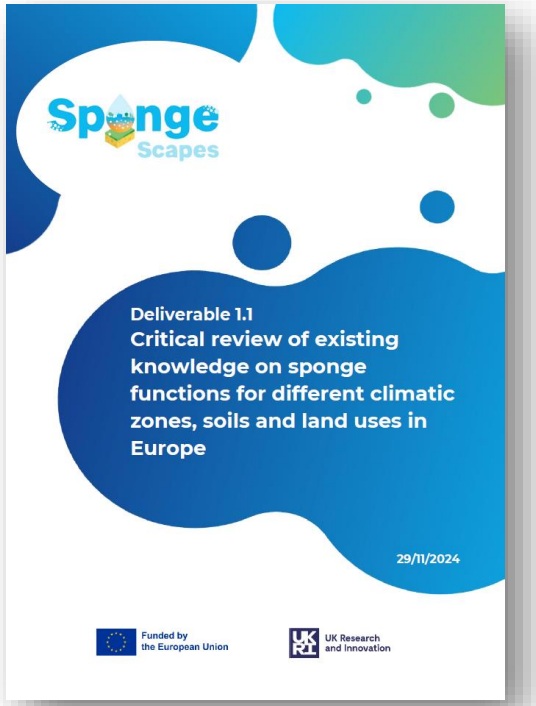
Iacop et al 2014 doi: 10.2166/nh.2014.184



Study	Sponge Measure	Location/ Region	Observed (O) or Modelled (M) Effect	Flood & Drought Management Benefit
Majidi et al. (2019); Ruangpan et al. (2020)	Water retention ponds, vegetated buffer strips	General (Urban, Agricultural)	Reduced flood volume, peak, and delay; increased infiltration and soil water retention.	Flood reduction, increased water retention and infiltration.
Lockwood et al. (2022)	Offline ponds	Tone & Parrett catchments, SW England	**Attenuation of peak flows from 3%** when ponds are filled by rain/runoff to 7% when filled from channel [O]	Flood reduction
Nauta et al. (2024), Waterloo et al. (2019)	Wetland restoration	Kylldal catchment, Germany	**12-24% reduction in annual maximum peak flows; increased low flows by up to 21%** in summer/fall, suggesting drought risk reduction. []M	Flood reduction, drought risk reduction.
Kurki-Fox et al. (2022)	Wetlands, river basin afforestation	Neuse River Basin, North Carolina, USA	**6-9% reduction in runoff, 5% reduction in peak flow** at sub-watershed level.	Flood and drought risk reduction.
Frédéric Paran (2024)	Wetland restoration	General	**Limited effect on summer low flows but effective in retaining high flows after dry periods.**	Drought and flood flow regulation, seasonal flow retention.
Ottermann et al. (2017)	restored floodplains, wetlands, peatlands	Rhine basin	**Reduced peak flows 5-8%**	Flood reduction
Shuttleworth et a. (2019)	Peat restoration	N England	**27% reduction in peak flows, longer lag times >100% increase** [O, M]	Flood reduction
URBAN				
Baggio et al. (2023)	Rain gardens, bio-retention areas	Veneto Region, Italy	**>98% runoff retention** in two years of data, even for extreme rainfall events (up to 15-year return periods).	Pluvial flood mitigation, stormwater retention.
Cerema (2020)	Schoolyard greening, de-impermeabilizatio n	France	**Reduces stormwater runoff and provides co-benefits** like heat reduction and improved health for children.	Flood reduction, heat island mitigation, health benefits.
Kõiv-Vainik et al. (2022)	Bioretention systems (ponds, rain gardens, swales)	General	**40% reduction in peak discharge** (though data on real-world runoff retention often missing, especially in cold climates).	Flood reduction, stormwater management.
Kõiv-Vainik et al. (2022)	Permeable pavements	Warm and wet climate conditions	**75-80% reduction in stormwater runoff.**	Flood reduction, stormwater management.
Quagliolo et al. (2021)	Green parking, rain gardens	Rapallo, Italy	**69-71% average water retention capacity in urban scenarios.**	Urban flood vulnerability reduction.

Gaps in evidence

1. Reported sponge measures are often not evaluated for a range of hydro-meteorological events under current and future conditions;
2. Surface water, groundwater, and soil hydrology are often analysed separately;
3. Analyses of the combined effects of sponge measures on hydrology, co-benefits, dis-benefits, and trade-offs are often lacking or incomplete;
4. The evidence base for a good understanding of the combined effects of multiple measures at landscape scale is lacking;
5. The role of maintenance over time and longevity of measures is hardly known;
6. The replicability of measures depends on local contexts that are poorly reported on;
7. The integration of quantification of system understanding with stakeholder engagement on a catchment scale is lacking;
8. Local knowledge, success stories and lessons learned are poorly communicated outside of the local context.



Over to Ellis