Risks, costs, & benefits

https://www.architecturaldigest.com/story/architect-new-yorks-central-park-incredibly-unexpected-legacy

Prof. Gabriele Manoli
gabriele.manoli@epfl.ch

Today's session

Outline

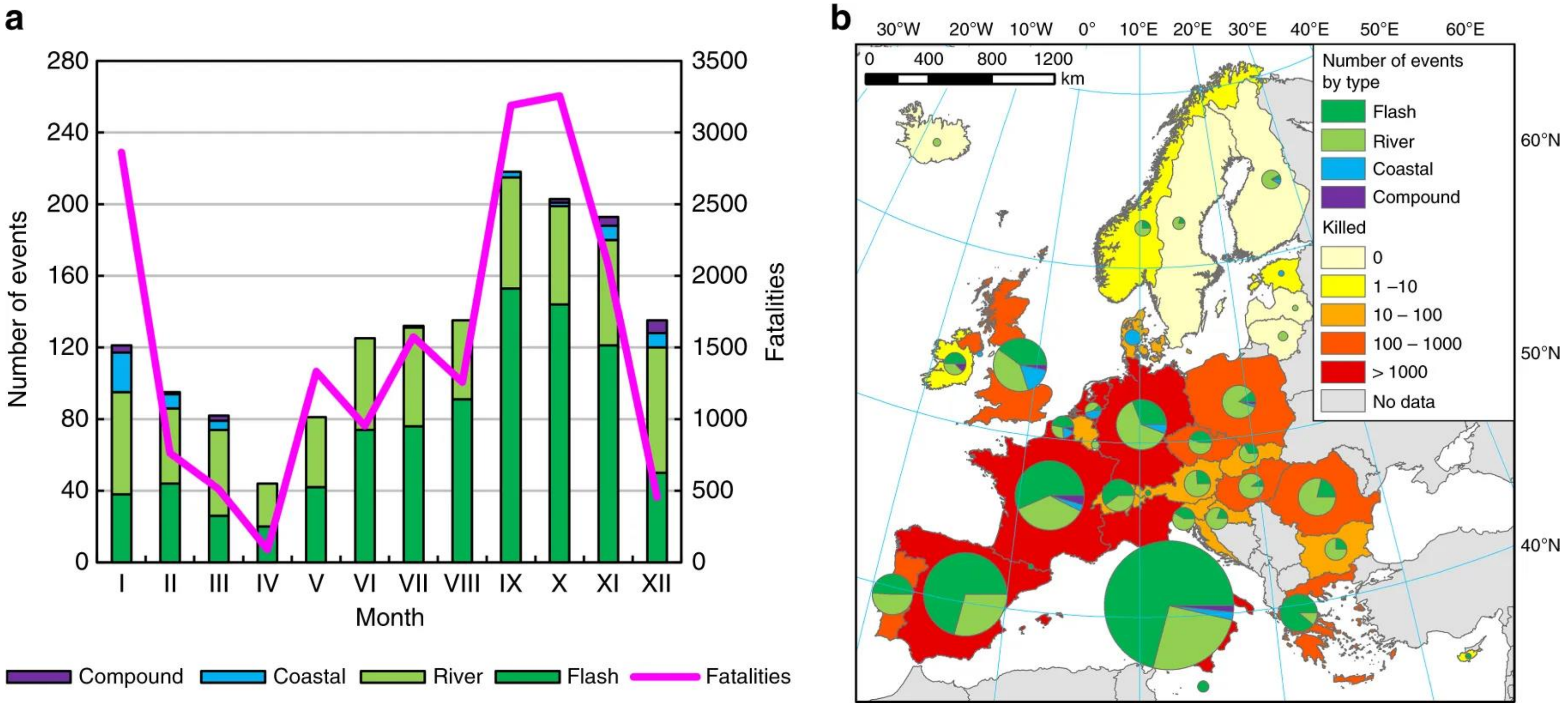
- **Flood & Climate risks**
- Costs & Benefits of Urban Green Spaces/SuDS

Flood risk



Source: Google images

Flood risk



Flood occurrences and fatalities. Total number of flood events and fatalities (unadjusted, reported values) between 1870 and 2016, **a** by month and **b** by country. Source of data: HANZE database

Paprotny et al. (2018)

Flood risk

MENU

nature communications

Article | Open Access | Published: 15 May 2019

Local floods induce large-scale abrupt failures of road networks

Weiping Wang, Saini Yang, H. Eugene Stanley & Jianxi Gao

Nature Communications **10**, Article number: 2114 (2019) | Cite this article

Cumbria floods: at least one killed as 45,000 homes remain without power

A man in his 70s reportedly died in Cumbrian village of Staveley as thousands of homes are flooded following record levels of rainfall

▲ Flood water surrounds a damaged road sign as it covers a road at the northern end of Ullswater, near Pooley Bridge. Photograph: Paul Ellis/AFP/Getty Images

Flood risk

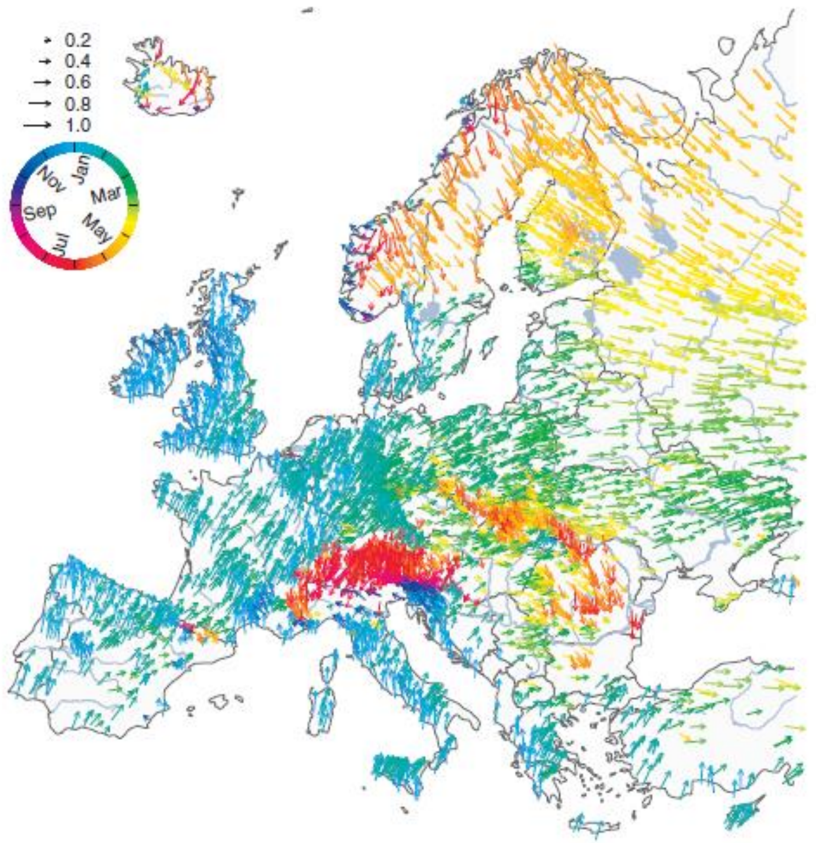


Fig. 3. Observed average timing of river floods in Europe, 1960–2010. Each arrow represents one hydrometric station (n = 4062). Color and arrow direction indicate the average timing of floods, as indicated by the circular color scale (light blue, winter floods; green to yellow, spring floods; orange to red, summer floods; purple to dark blue, autumn floods). Lengths of the arrows indicate the concentration of floods within a year (0, evenly distributed; 1, all floods occur on the same date).

RESEARCH

FLOODING

Changing climate shifts timing of European floods

Blöschl et al. (2017)

Flood risk

Flood Risk

- The combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event. (Technische Universiteit Delft)

Risk = [Probability x Intensity] x [Exposure x Vulnerability]

hazard-related (Probability x Intensity); target-related ("Sensitivity to hazard") (Exposure x Vulnerability)

= **Hazard** x **Exposure** x **Vulnerability**

Source: Google images

Flood risk

Flood Risk

- The combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event. (Technische Universiteit Delft)

- **Hazard** corresponds to the likelihood of a flood event of certain magnitude and characteristics
- **Exposure** is defined as the people, property, systems, or other elements present in hazard zones that are thereby subject to potential damage.
- **Vulnerability** corresponds to the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of flood hazard; it can be considered as a combination of susceptibility and value.

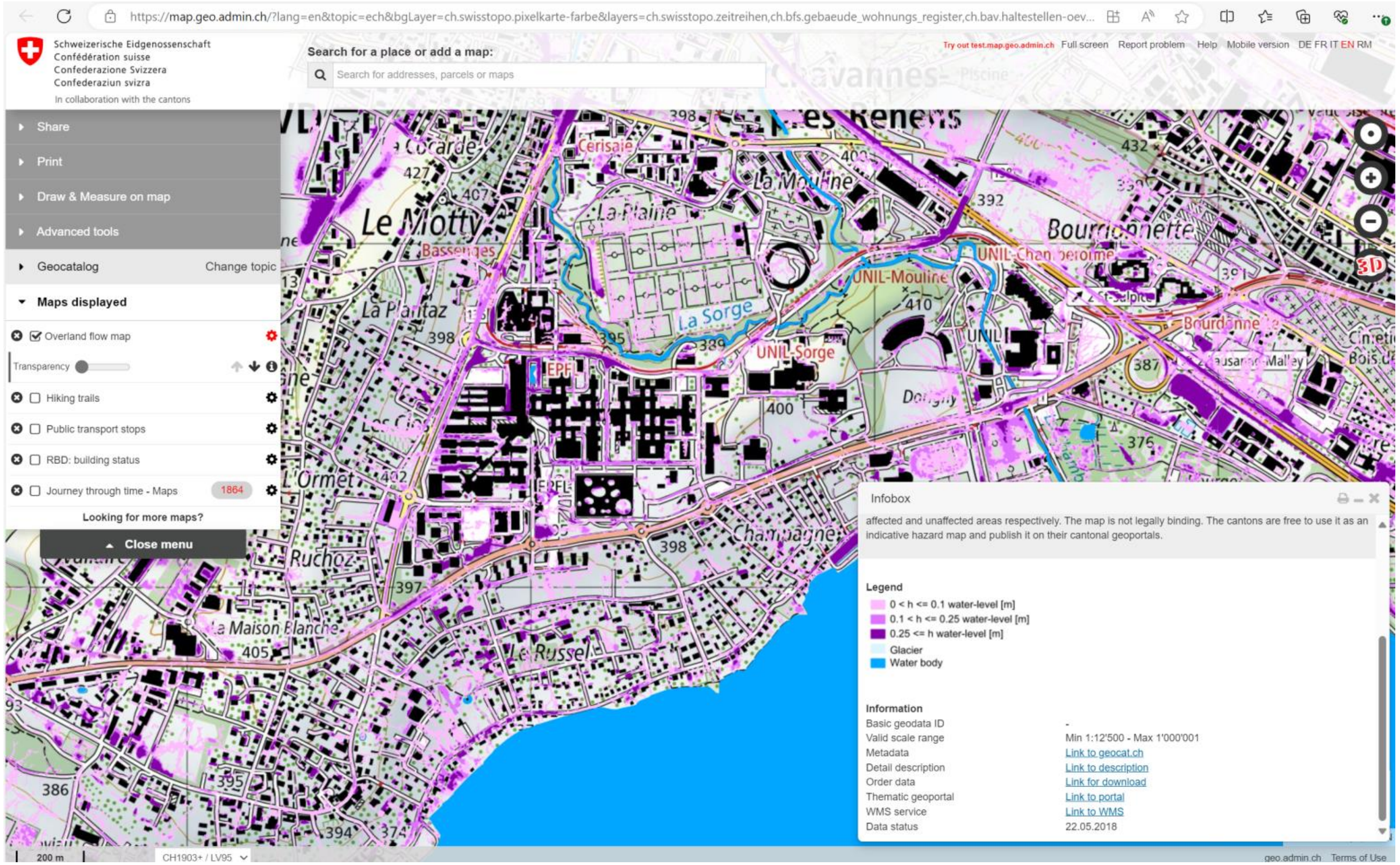
Source: Google images

Flood risk

swissinfo.ch
Swiss perspectives in 10 languages
Climate change ›

Flood map highlights areas at risk

▲ Up to half all floods in Switzerland are not caused by overflowing rivers and lakes, but by excess rainwater not being absorbed into the ground. Keystone



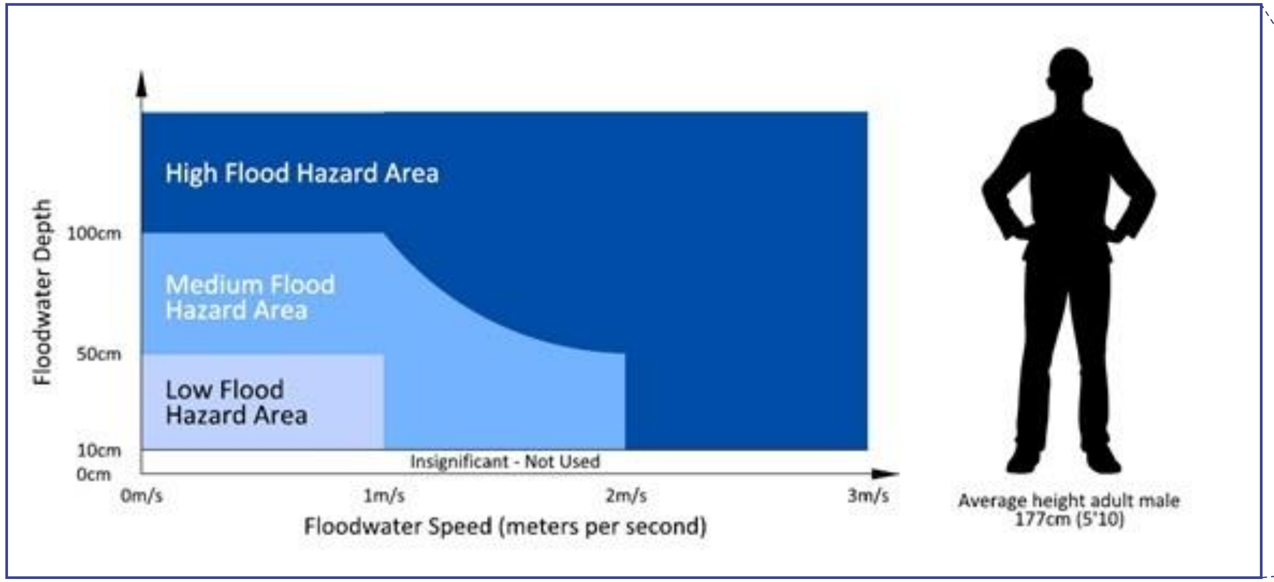
[Surface runoff risk map (admin.ch)](#)

Flood risk

Flood Damage

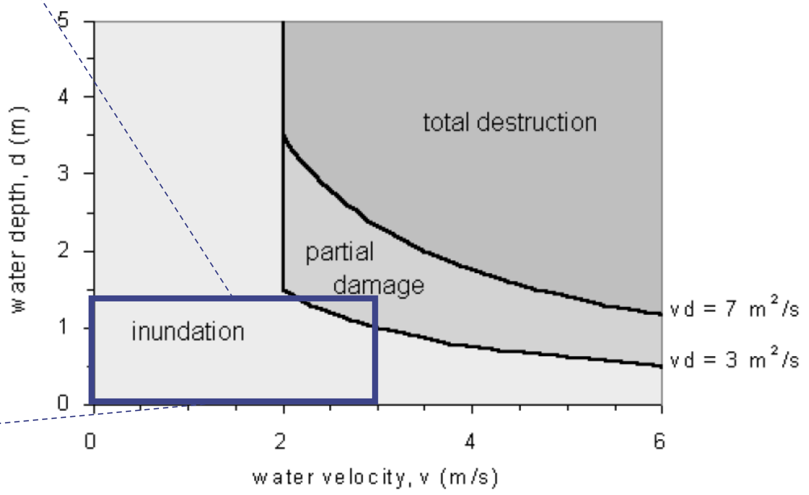
- All varieties of damages caused by flooding (human, economic, structural) but seasonal flooding can also have some benefits (e.g., Nile agriculture)

Damage Factor = **Velocity** x **Depth**



https://www.hamilton.govt.nz/our-council/council-publications/districtplans/flood/Pages/Flood-FAQ.aspx

Clausen & Clark 1990



Flood risk

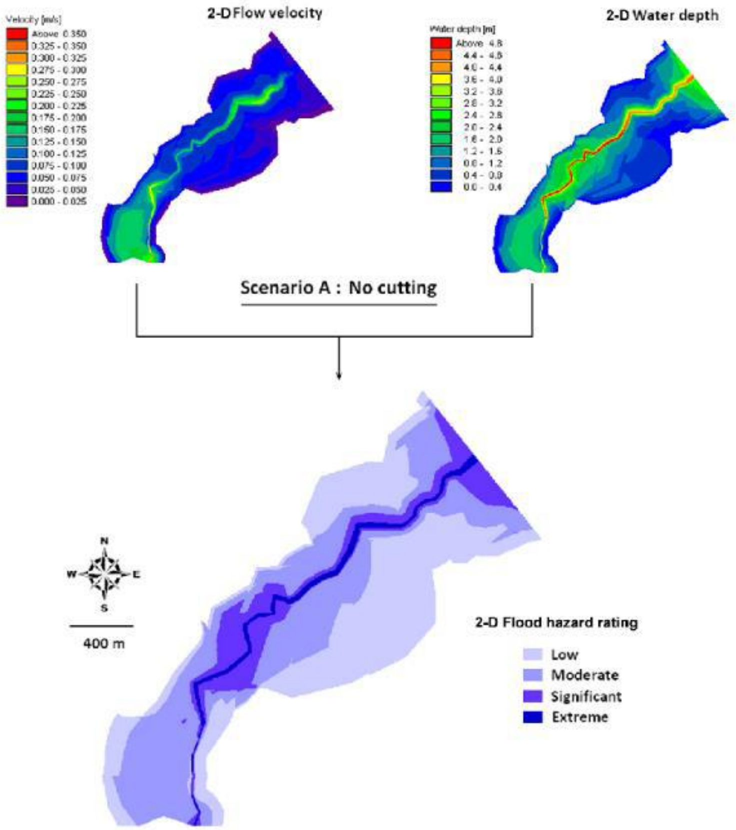
Flood Damage

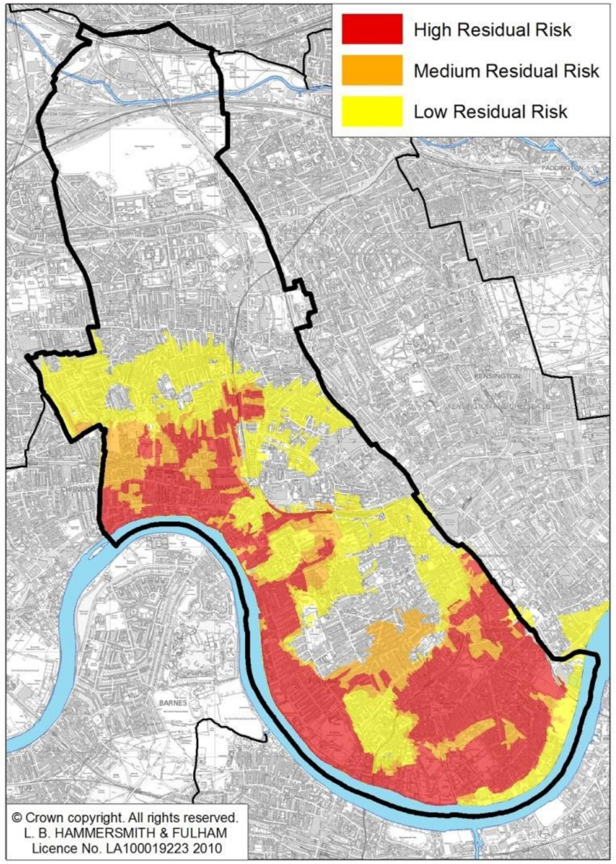
Velocity x Depth =
Damage Factor

Vx**D** < 0.5 **LOW**

Vx**D** < 1.0 **MED**

Vx**D** > 1.0 **HIGH**





Flood risk

EPFL

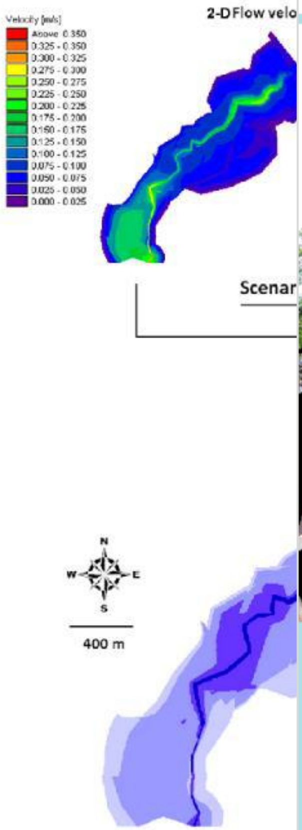
Flood Damage

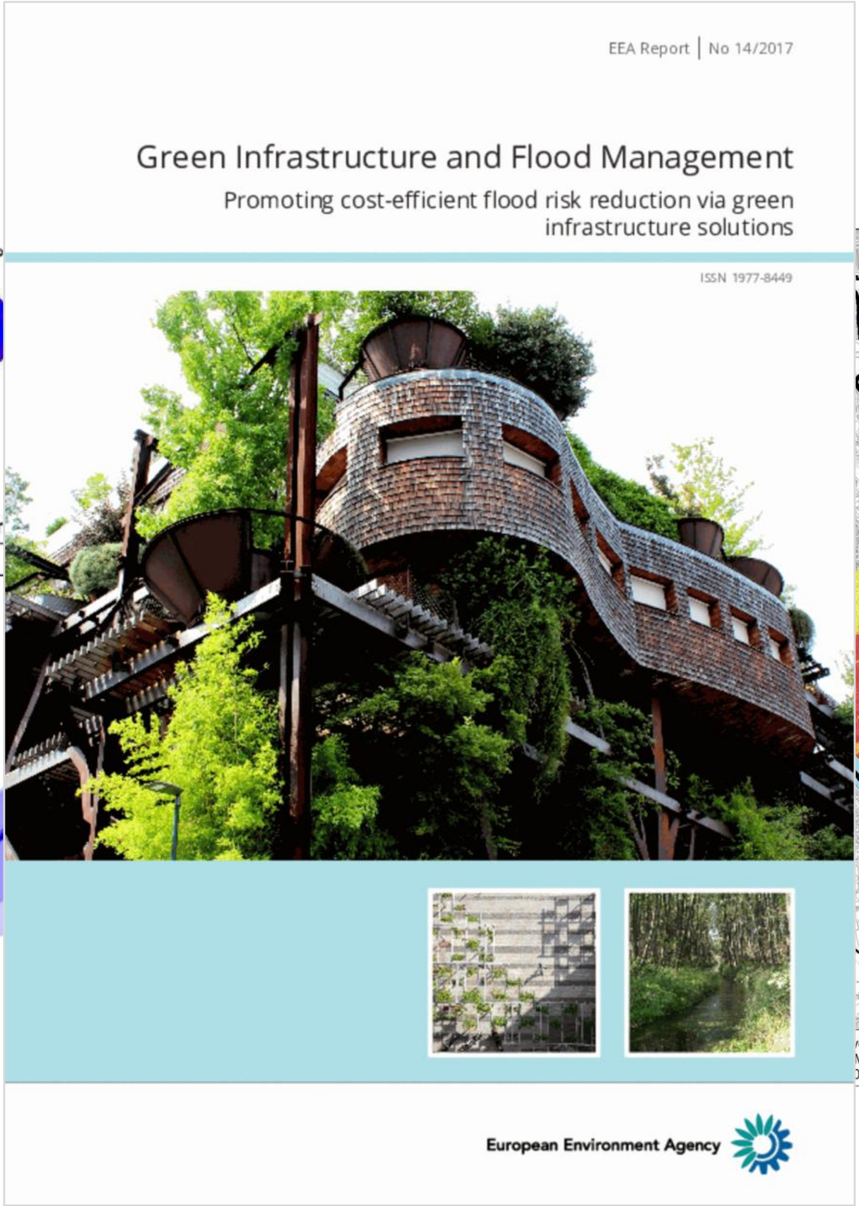
Velocity x Depth =
Damage Factor

Vx**D** < 0.5 **LOW**

Vx**D** < 1.0 **MED**

Vx**D** > 1.0 **HIGH**



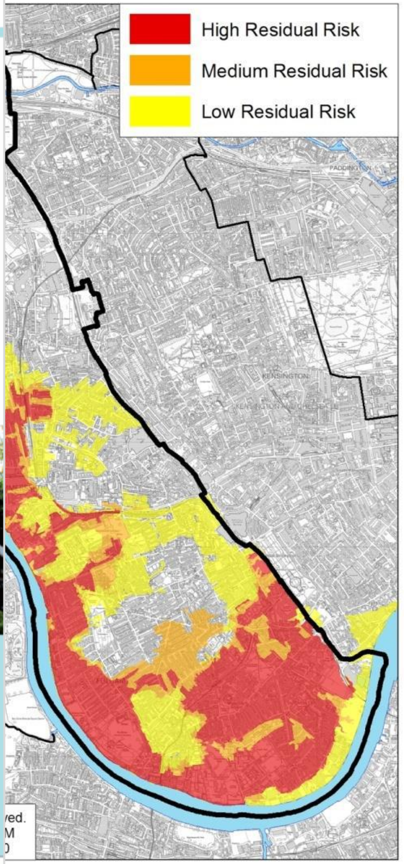

EEA Report | No 14/2017

Green Infrastructure and Flood Management

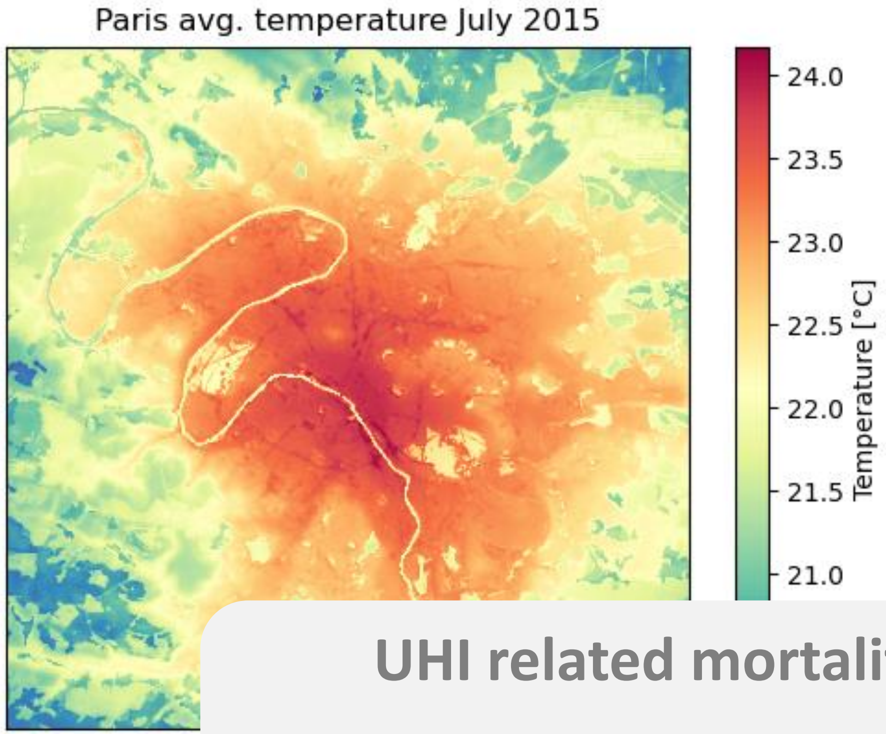
Promoting cost-efficient flood risk reduction via green infrastructure solutions

ISSN 1977-8449

European Environment Agency



Urban climate risk



UHI related mortality:

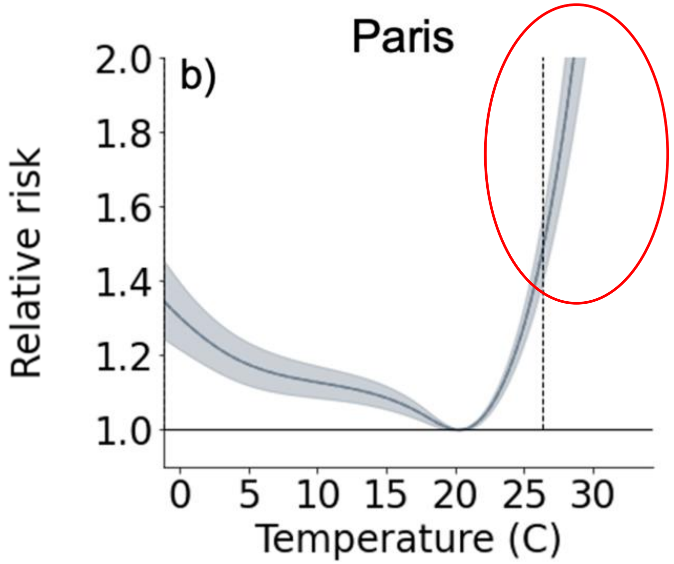
5 deaths/100’000 people/yr

Huang et al. (2023)

Article https://doi.org/10.1038/s41467-023-40599-x

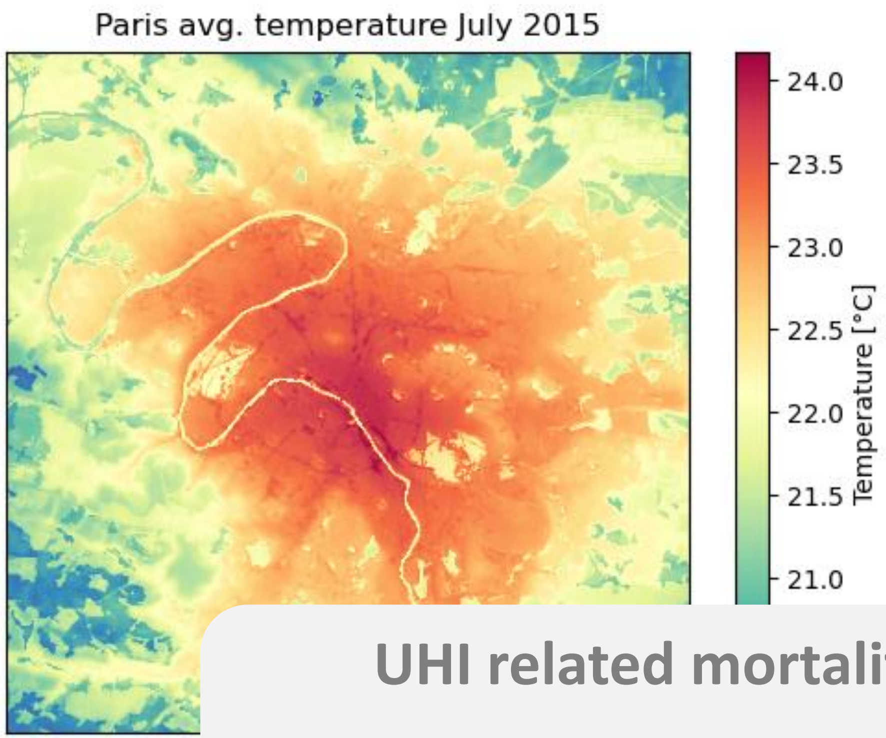
Rapid increase in the risk of heat-related mortality

Luthi et al. (2023)



Luthi et al. (2023)

Urban climate risk



UHI related mortality:

5 deaths/100’000 people/yr

Huang et al. (2023)

ARTICLES | VOLUME 401, ISSUE 10376, P577-589, FEBRUARY 18, 2023

Cooling cities through urban green infrastructure: a health impact assessment of European cities

Tamara Iungman, MPH • Marta Cirach, MSc • Federica Marando, PhD • Evelise Pereira Barboza, MPH • Sasha Khomenko, MSc • Pierre Masselot, PhD • et al. Show all authors

Published: January 31, 2023 • DOI: https://doi.org/10.1016/S0140-6736(22)02585-5 • Check for updates

Tree cover:

5% → 30%

Summer preventable deaths (Paris):

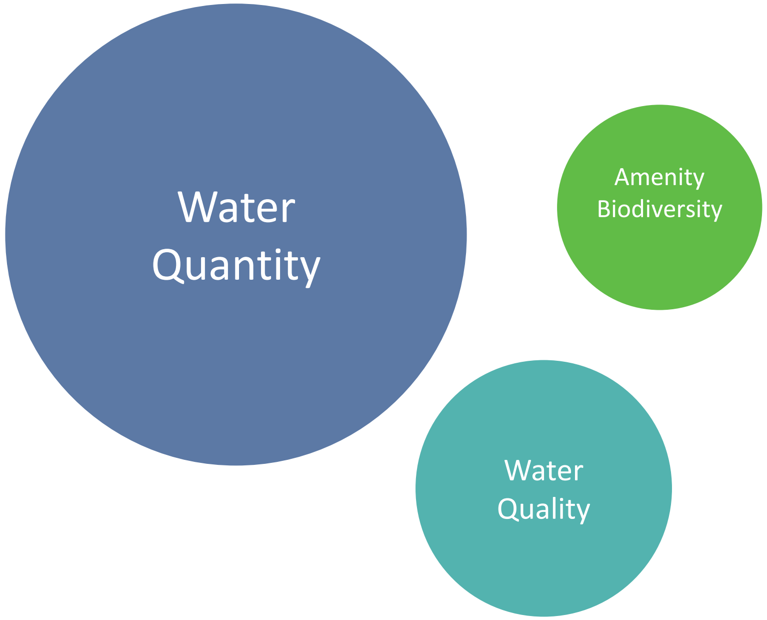
71

Today's session

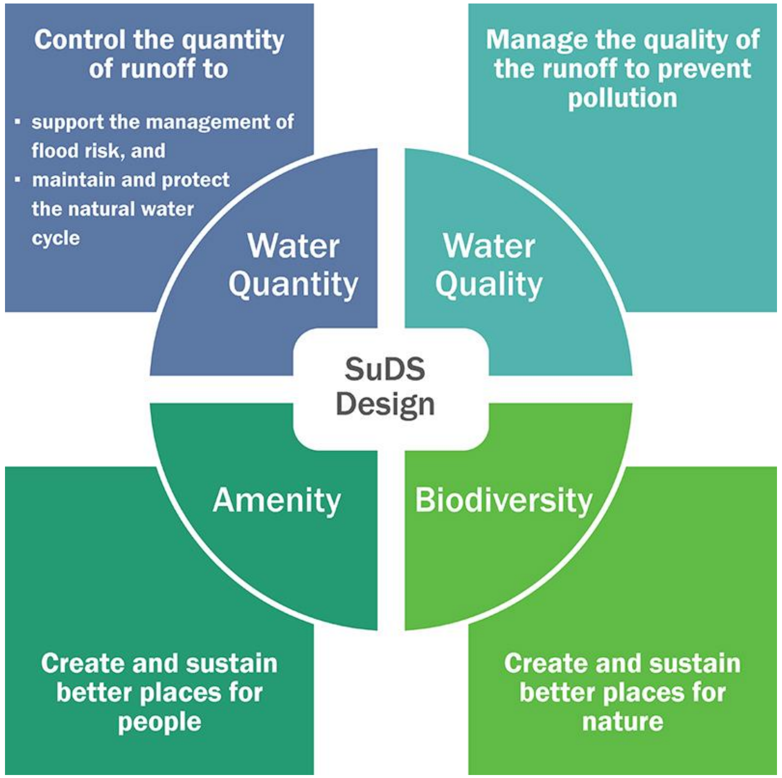
Outline

- Flood & Climate risks
- **Costs & Benefits of Urban Green Spaces/SuDS**

SuDS Costs and Benefits



Traditional approach

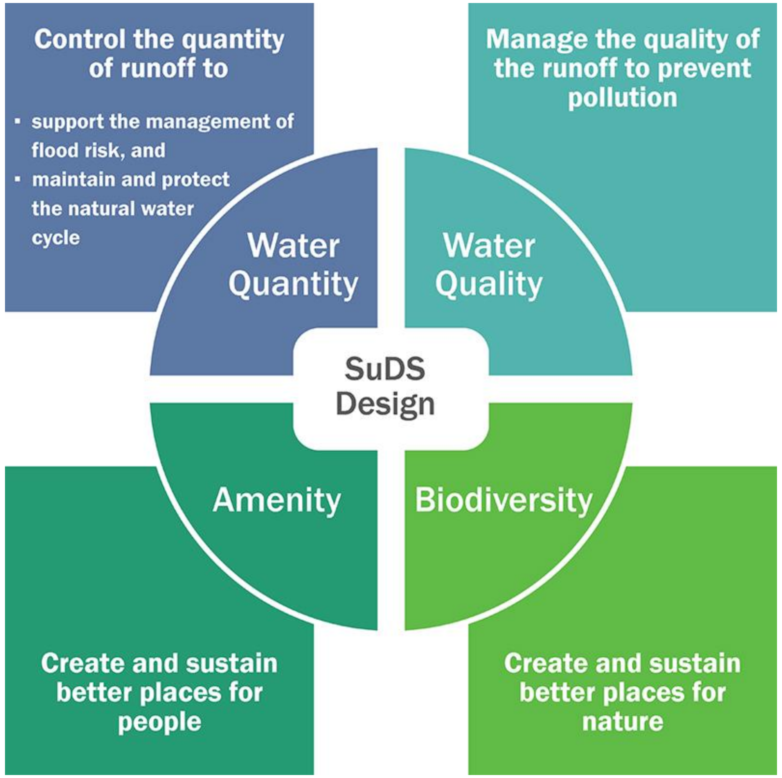


SuDS design

SuDS Costs and Benefits

Why assessing SuDS costs and benefits?

- SuDS can deliver **multiple benefits**
- The overarching principle of SuDS is that surface water runoff should be managed to **maximise these benefits**
- Quantification of costs (and benefits) key to getting **stakeholders** on board.
- Schemes increasingly delivered via partnerships e.g. more than one source of capital costs, **shared responsibility** for operation and maintenance costs



SuDS design

SuDS Costs and Benefits

What can be assessed? Costs

Costs

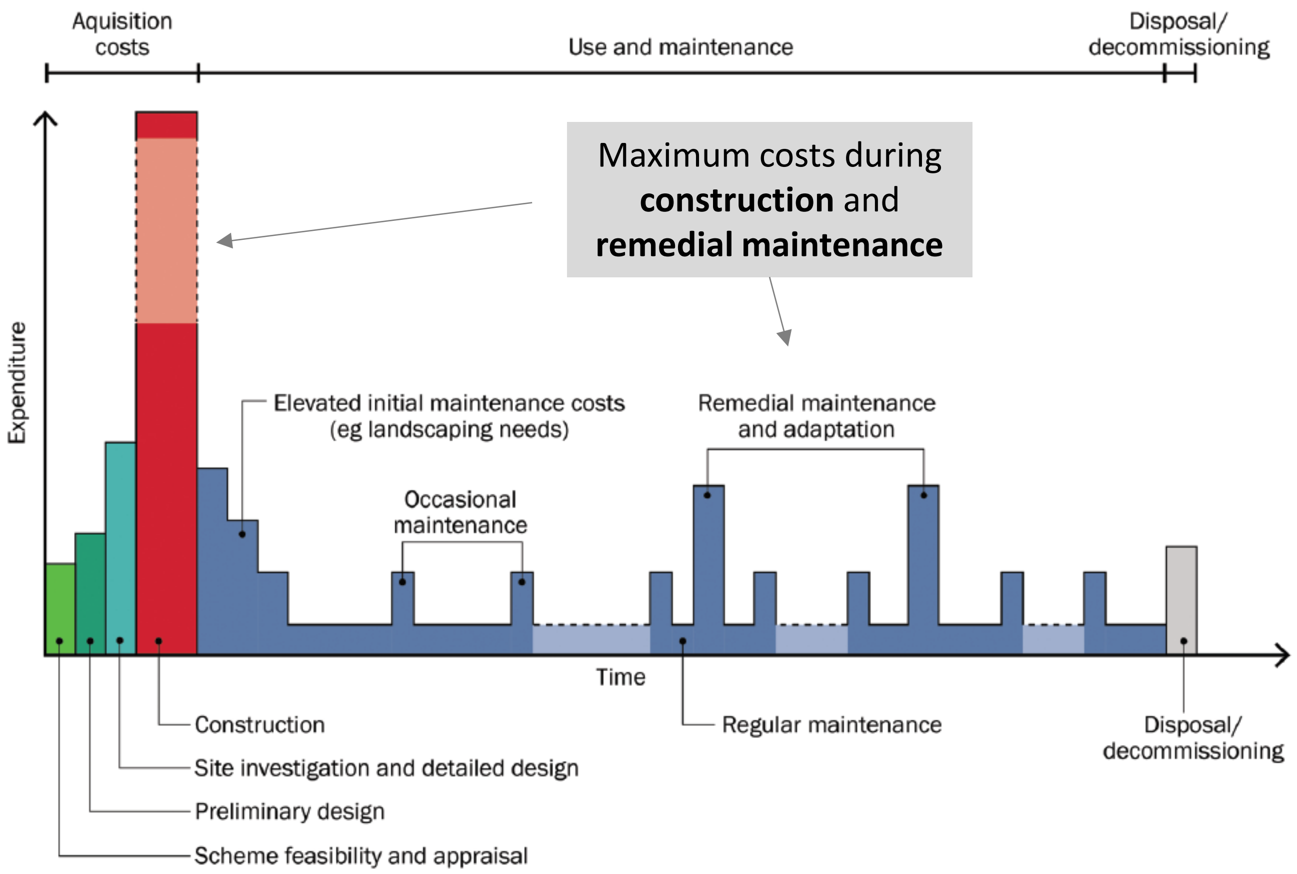
- Capital costs (**Capex**)
- Operational and Maintenance (O&M / **Opex**) costs
- Whole life cost (**WLC**)

Cost Analysis

- Cost optimisation – reducing long term maintenance costs
- How these might accrue to different stakeholders
- How different elements contribute to delivery of overall cost of scheme and therefore how they can be maximised / optimised
- Cost comparison across alternative SuDS (or conventional drainage)

SuDS Costs and Benefits

What can be assessed? Costs



Example of SuDS expenditure profile (Ciria Manual 2015)

SuDS Costs and Benefits

What can be assessed? Costs

Measure	Design life	Component life
Green roofs	Unlimited	N/A
Simple rainwater harvesting (water butts)	Unlimited	No reliable information
Advanced rainwater harvesting	Unlimited	No reliable information.
Permeable paving	Unlimited	20-25 years before replacement of filter material, if required at all
Filter drain/perforated pipes	Unlimited	10 – 15 years before replacement of filter material
Swales	Unlimited	5 – 20 years before deep tilling required and replacement of infiltration surface (infiltration swales only, not needed for conveyance)
Infiltration basin	Unlimited	5 – 10 years before deep tilling required and replacement of infiltration surface
Soakaways	No available information	
Infiltration trench	Unlimited	10 – 15 years before replacement of filter material
Filter strip	Unlimited	20 – 50 years before replacement of the filter surface
Constructed wetland	20 – 50 years	Sediment disposal after 10-15 years
Retention (wet) pond	20 – 50 years	
Detention basin	20 – 50 years	Sediment disposal after 10-15 years
Source: Environment Agency (2015)		

Design Life: Minimum length of time SuDS schemes are required to perform intended function (EA, 2015)

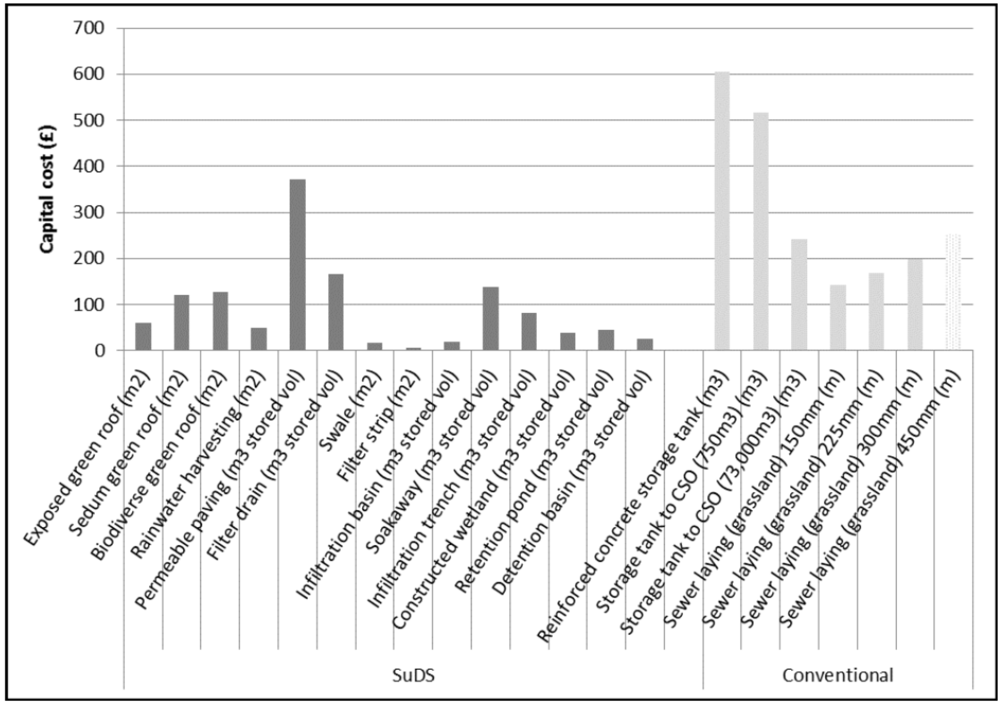


Figure 6: Component capital cost information (SuDS and conventional)

Environmental Policy Consulting, 2017

SuDS Costs and Benefits

Assessing benefits (more difficult…)

- Some benefits are **direct consequence** of green spaces/SuDS, e.g.
  - *reduced flood risk,*
  - *improved biodiversity*
  - *Improved water quality*
  - *groundwater recharge*
- However overall benefits are also **indirect** and come about in addition to the main reasons for using SuDS, e.g. health and well-being being a product of improved air quality, thermal comfort, recreation
  - *Creating attractive places where people want to live, work and play*
  - *Improving people's health and wellbeing*
  - *Supporting the creation of developments more able to cope with changes in climate*
  - *Delivering cost effective infrastructure using fewer natural resources and with a smaller whole life carbon footprint than conventional drainage*

SuDS Costs and Benefits

Assessing benefits (more difficult…)

(CIRIA 2015)

TABLE 35.1 Examples of types of benefits from using SuDS

Benefits provided by SuDS	Aspects of the SuDS design that provide this benefit	Who is likely to benefit?[1]	How soon is the benefit likely to be realised?[2]	Type of benefit[3]			
				Water quantity	Water quality	Amenity	Biodiversity
Air quality	Air particulate filtering via vegetation (eg trees and green roofs)	Community, local authority, environmental regulator	Medium term			✓	
Air and building temperature (thermal comfort and energy savings)	Green and blue spaces, green roofs	Community, businesses	Short term			✓	
Biodiversity and ecology	Habitat creation and enhancement, connecting habitats	Community, environmental regulator, local and national conservation groups, local authority	Medium term				✓
Carbon emission reduction and sequestration	Low energy needs (materials, construction and maintenance), sequestration (eg trees and wetlands)	Developer, community, businesses	Immediate (energy needs) Long term (sequestration)			✓	
Climate resilience	Designing for exceedance, adaptability of scheme; also see air and building temperature, flood risk, groundwater recharge and soil moisture levels, security of water supply, sewerage systems and sewage treatment works available capacity	Community, local authority (and many others depending on the level of climate change experienced in the future and which benefits are affected)	Medium to long term	✓	✓	✓	✓
Community cohesion and crime reduction	See visual character, economic growth/ inward investment and education	Community, local authority, local police force	Medium term			✓	
Economic growth and inward investment (including tourism, productivity and property prices)	See visual character, recreation and air and building temperature	Developer, community, businesses, local authority	Immediate (property prices) Medium term (others)			✓	

continued...

SuDS Costs and Benefits

Assessing benefits (more difficult…)

(CIRIA 2015)

continued from...

TABLE 35.1 Examples of types of benefits from using SuDS

Benefits provided by SuDS	Aspects of the SuDS design that provide this benefit	Who is likely to benefit?[1]	How soon is the benefit likely to be realised?[2]	Type of benefit[3]			
				Water quantity	Water quality	Amenity	Biodiversity
Education opportunities	Community engagement (before and after construction), legibility, information boards, education programmes, play features	Community, local schools	Immediate (community engagement) Short to medium term (others)			✓	
Flood risk reduction	Peak flow attenuation, volume control	Community, local authority, local flood authority, local emergency services	Short term	✓			
Groundwater and soil moisture recharge	Interception, infiltration, runoff treatment	Water supply company, community	Medium term	✓	✓		
Health and wellbeing	See air quality, air and building temperature, recreation, crime reduction, reduced flood risk (including mental health), plus others to a lesser extent	Community, health authority	Medium to long term			✓	
Noise reduction	Green and blue spaces, green roofs	Community	Short to medium term			✓	
Recreation	Green and blue spaces and play features	Community, local authority	Short term			✓	
Security of water supply	Rainwater harvesting; also see groundwater and soil moisture recharge	Water supply company, Community	Short term	✓		✓	
Sewerage systems and sewage treatment works available capacity (including reduced CSO spills)	Interception and further runoff volume reduction	Sewerage undertaker, community	Short term	✓	✓		
Visual character	Visual enhancement (as part of surface SuDS)	Community, developer, local authority	Short term			✓	
Water quality	Pollution prevention strategies, Interception, runoff treatment	Local authority, drainage board, environmental regulator, rivers and other waterways authorities, community	Short term		✓		

Notes

1 Only the most significant beneficiaries are listed. Actual beneficiaries will depend on the scheme.

2 Immediate = potentially even before the scheme is complete; Short term = within the first 5 years; Medium term = 5–10 years; Long term = 10+ years (Note that these are only indicative and will depend on the scheme.)

3 See Chapters 3–6 for more detailed descriptions of the types of benefits and how these can be achieved.

SuDS Costs and Benefits

Assessing benefits (more difficult…)

- Direct and indirect benefits should not be confused with those benefits that **can** or **cannot be quantified**.
- Some benefits of SuDS are readily **quantifiable**, e.g. where flooding is mitigated the reduced damage can be costed
- Some benefits are **not so readily quantified** (especially in monetary terms) but this does not lessen their importance, and they should be ignored because of this

Source: Google images

SuDS Costs and Benefits

Assessing benefits (more difficult…)

There are four key methods of quantifying benefits (ecosystem services):

1. **Contingent Value (or willingness to pay):** sample evidence from questionnaires and surveys to estimate how much people might be willing to pay for specific environmental or social benefits (e.g. water providers in England use such methods)
2. **Benefit Transfer (using other studies):** adjust the values from other studies accounting the features of the study area. Good indication of the range expected from a CB study. e.g. river basin management plans
3. **Hedonic Pricing (from indirect information):** indirect information such as that used to make property purchase location decisions. E.g. higher housing prices reveal how much people are willing to pay for access to green space / desirable locations
4. **Scale (for non-quantifiable benefits):** Qualitative assessment where benefits cannot be quantified in monetary terms

SuDS Costs and Benefits

EPFL

Assessing benefits (more difficult…)

nature communications

Article

https://doi.org/10.1038/s41467-023-43135-z

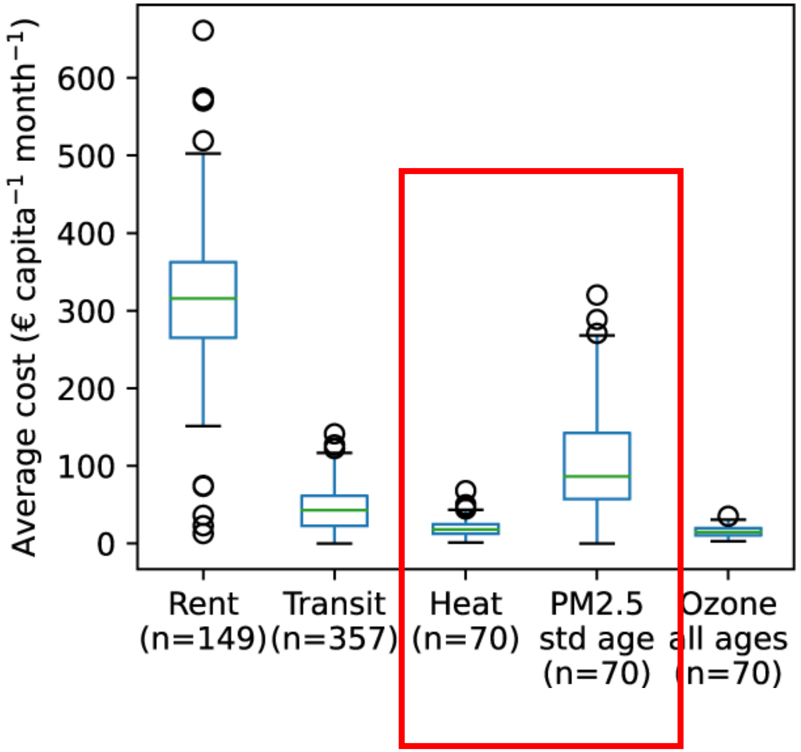
Economic valuation of temperature-related mortality attributed to urban heat islands in European cities

Received: 4 January 2023

Accepted: 1 November 2023

Published online: 17 November 2023

Wan Ting Katty Huang [1,2], Pierre Masselot [3], Elie Bou-Zeid [4], Simone Fatichi [5], Athanasios Paschalis [6], Ting Sun [7], Antonio Gasparrini [3,8,9] & Gabriele Manoli [1,10]



SuDS Costs and Benefits

Exercise

Read the report on the financial benefits of the SuDS project in Conventry, UK (see Moodle):

- What are the key data used in this case study?
- Can you use this case study to extract benchmark data on costs and benefits for your own projects?
- Where are the caveats?

Box 3.4 *Summary of the Severn Trent Water Ripple Effect investigation* : benefits of retrofitting SuDS to create green streets in Coventry (AECOM & Severn Trent Water, 2013).

Sewer flooding – During heavy rainfall, the sewer system can be overwhelmed, flooding properties. Retrofitting with SuDS would reduce and slow surface water runoff to sewers. Severn Trent Water (STW) and Coventry City Council suggest that in an average year, city wide sewer flooding compensation costs amount to £3.6-million, or £83-million over 40 years. Reducing this will create financial benefits in terms of damage avoided.

Exercise solution

Prof. Gabriele Manoli
gabriele.manoli@epfl.ch

https://www.architecturaldigest.com/story/architect-new-yorks-central-park-incredibly-unexpected-legacy

Exercise solution

Discussion

Some of the assumptions are contestable, e.g.

- No clear evidence that urban trees improve air quality – conflicting results in the literature
- Reduction in heat risk depends on actual exposure (e.g., also indoor conditions)
- The creation of 48 jobs through the provision of GI may be at the expense of jobs lost at STW as there are lower flows into the sewer systems.
- The system may result in added sewer blockages in the combined system (see Butler & Parkinson, 1997).
- Creation of green jobs may not come about as the Council may compel existing staff to take on a heavier workload.
- Etc.

Exercise solution

So what?

- A vital part of **good decision making** in design is the ability to understand both the costs and benefits associated with the decision being made.
- This needs to based on the **best evidence available**, bearing in mind the information may never be complete or perfect.
- Recognising and **dealing with uncertainty** has always been an intrinsic part of decision-making, which you will apply when you begin (or continue) working as engineers, architects, scientisits (etc) in the real world.