Evaluating Multiple Benefits of Blue-Green Infrastructure schemes though GIS

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Introduction

Aims and Project Overview

A systems approach

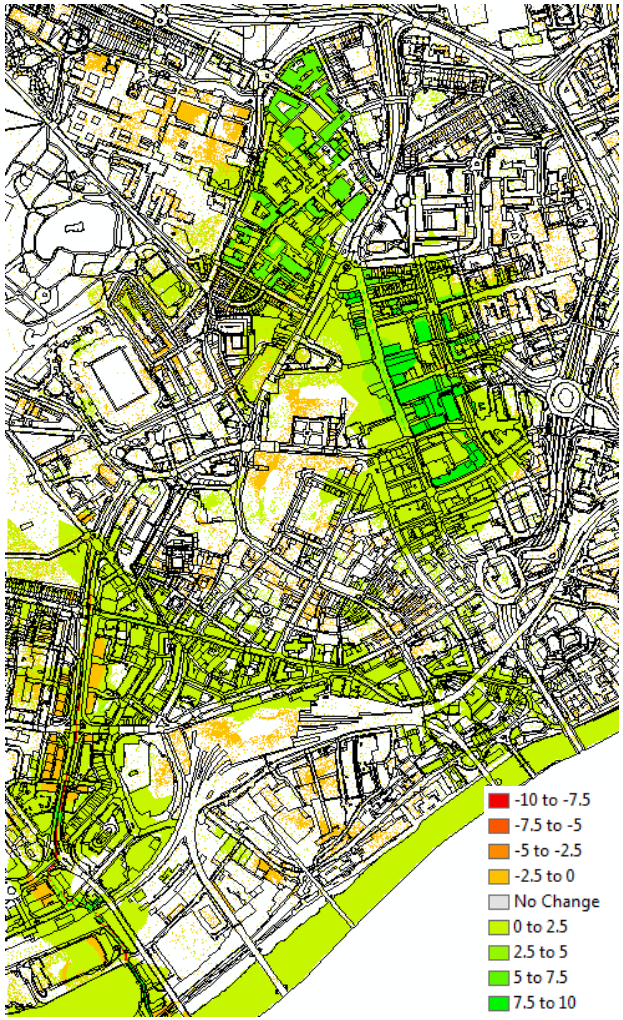
Why multiple benefits

New terms **Benefit dependency**
Benefit profile
Benefit intensity

Initial work (Portland)

Case Study : Newcastle
- Newcastle Great Park
- Wingrove
- Urban Core

Conclusions and where next?

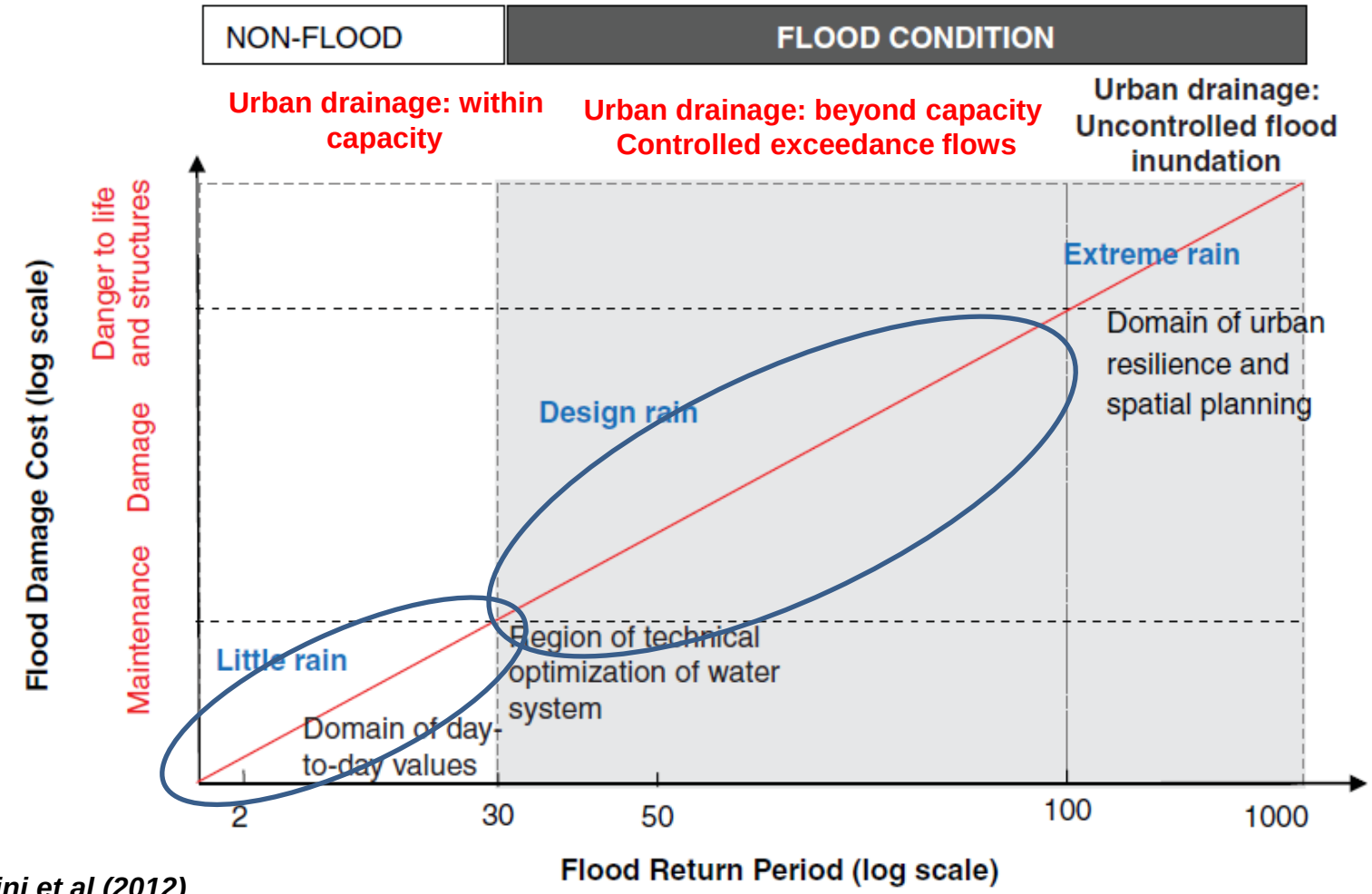


Initial questions

How do components of flood risk management systems interact with the wider urban environment under both FLOOD and NON-FLOOD conditions ??

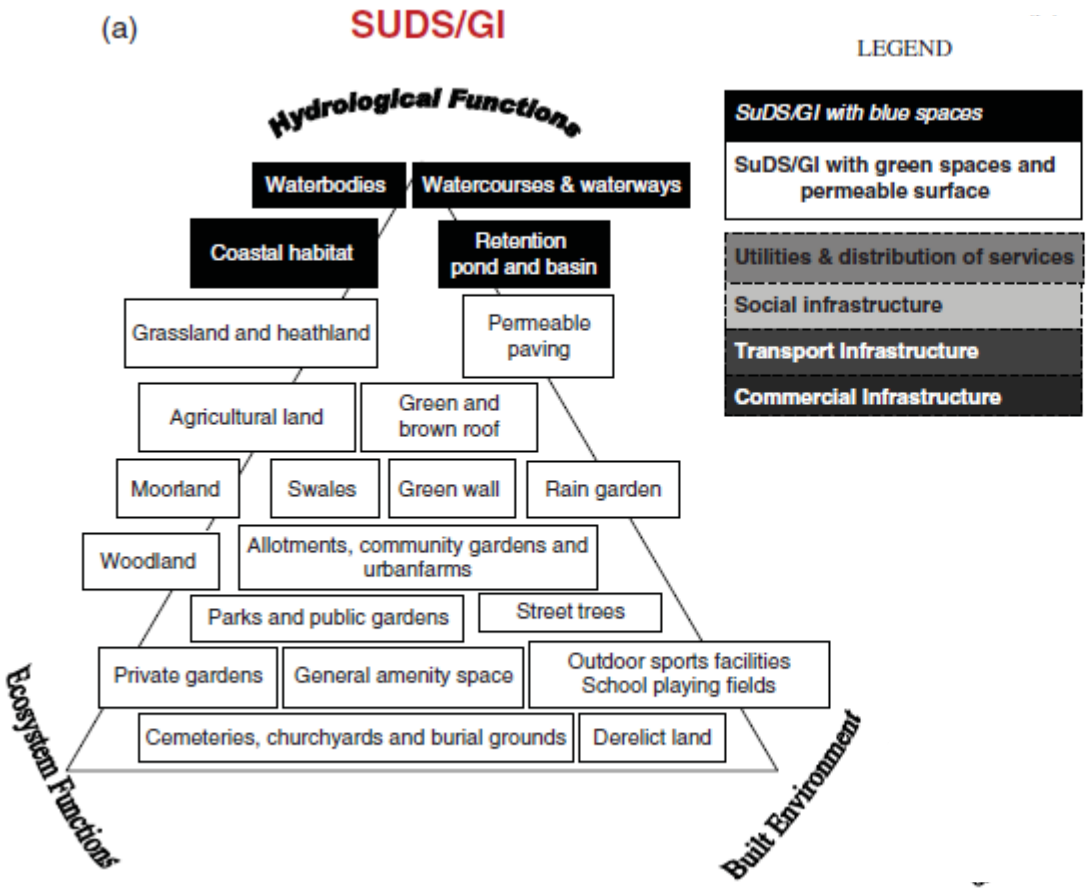
How can the multiple benefits of flood risk mitigation interventions be evaluated with respect to local context and stakeholder perceptions and preferences ??

Scope and condition states



After Fratini et al (2012)

Comparing functions of SuDS/GI and Grey infrastructure



Comparing functions of SuDS/GI and Grey infrastructure

Functional complexities

- Related to the physical dimensions of the urban space

Relational Complexities

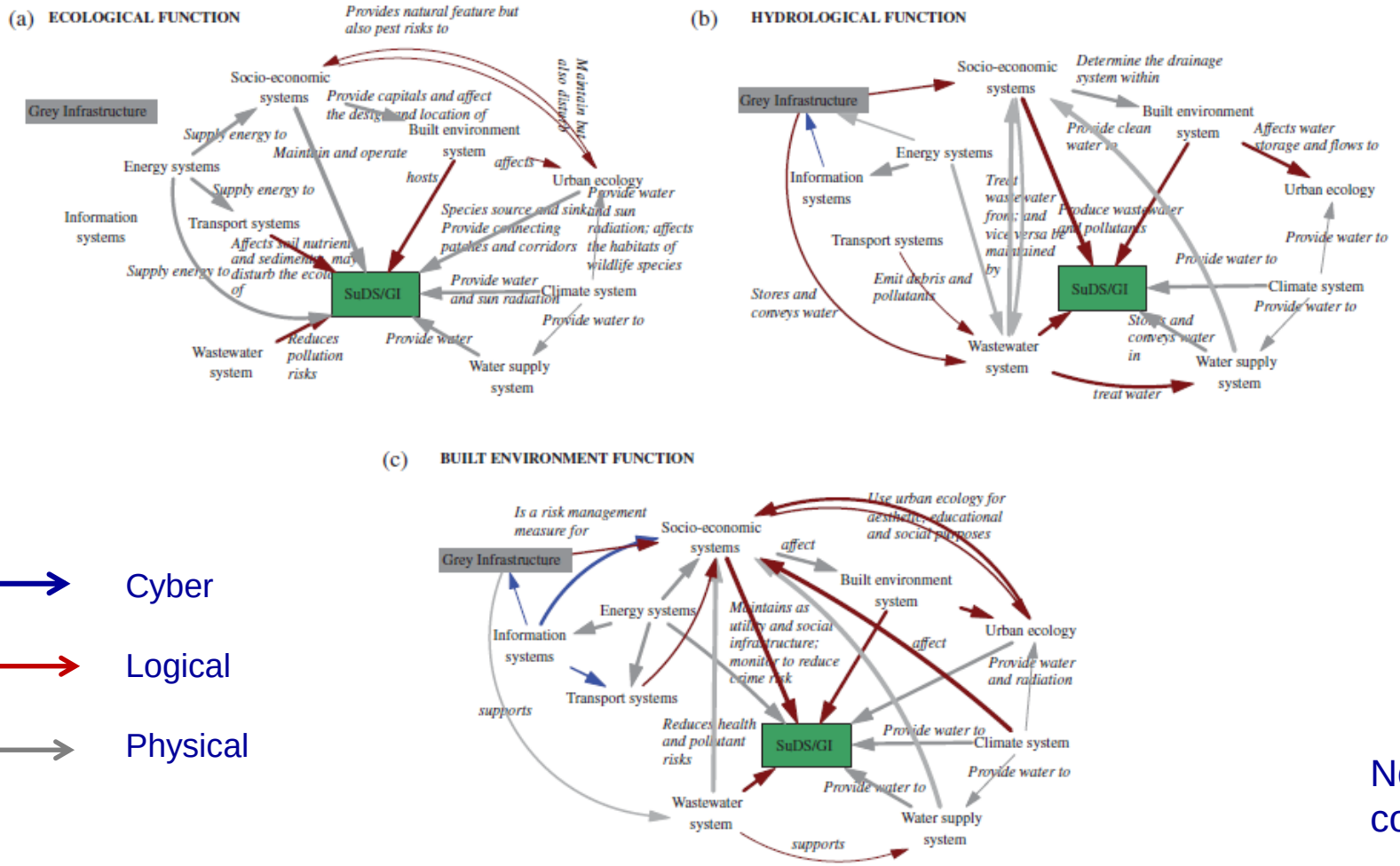
- Related to humans and the different views of actors and organisations in the decision making process

- **Physical** interdependancies
- **Cyber** interdependancies
- **Geographical** interdependancies
- **Logical** interdependancies

Flood or non-flood condition

Urban interdependancies

for ecological, hydrological and built environment functions



Cyber

Logical

Physical

Non flood condition

Impact of SuDS/GI assets on other urban components

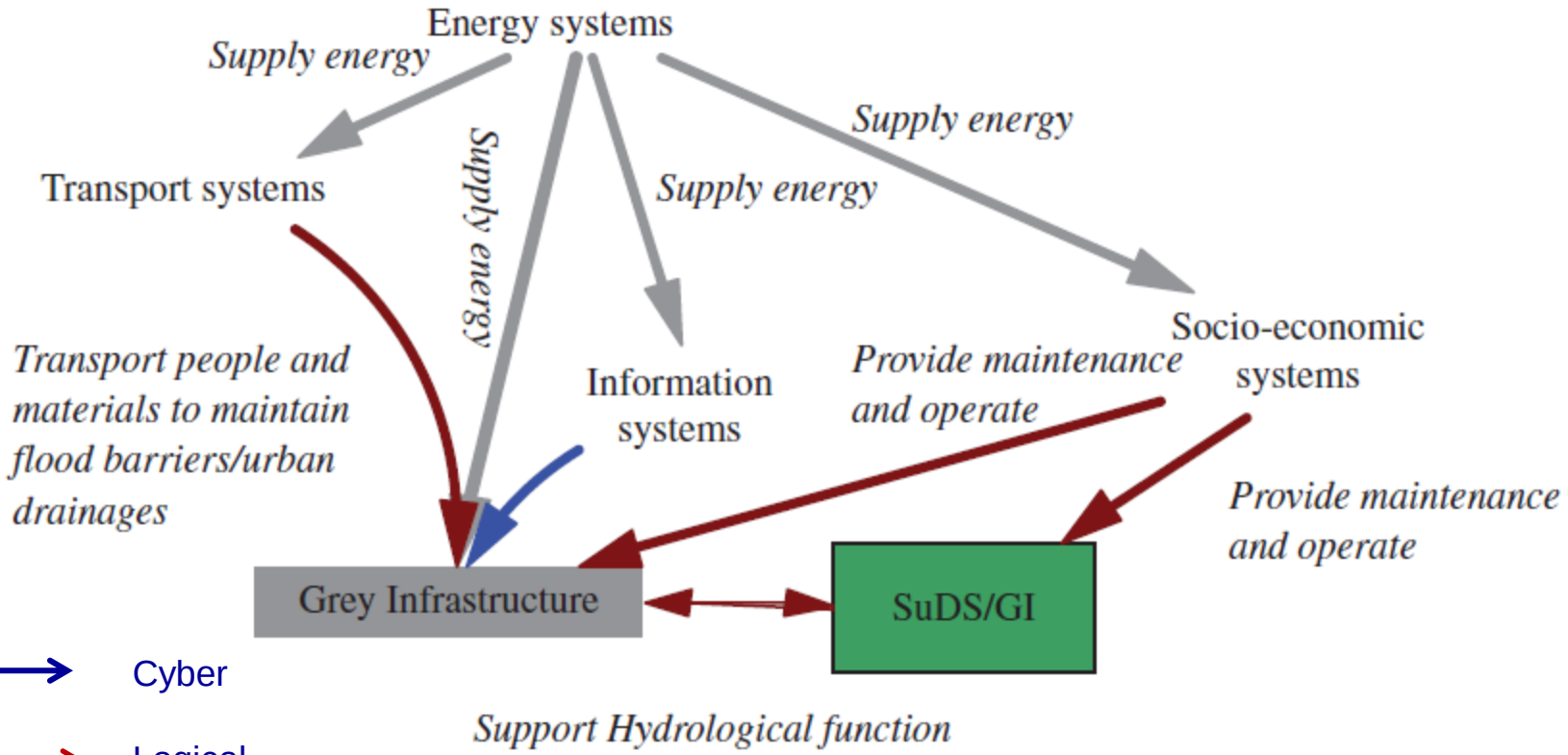
Table 1. Examples of the impacts of SuDS/GI installation on the primary functions of other urban components under the non-flood condition.

Urban components	Services	Potential disruptions
Water supply (sources)	Trap pollutants, reduce water treatment need and can release water back to the water system and underlying ground	Become a pollutant source if not treated properly
Wastewater (conveyance and treatment)	Provide local solution for wastewater treatment	Tree roots can damage sewer pipes
Food and agriculture	Reduce pollutants and provide pollination and grazing sites	Pest and disease hotspot if not maintained properly
Transportation	Traffic calming, traffic noise reduction	May block views if trees are too high, risk of branch and leave falling in strong wind
Energy	Urban cooling from heat island effect, carbon sequestration which might reduce climate change impacts fuelling energy demand	May require energy to maintain such as pumping water
Communication	n/a	n/a
Ecology	Provide corridors and habitats for wildlife species	May host pests and pollutants
Health	Provide spaces for physical activities and	Pollen allergy, may host disease vectors
Social	Provide space for socialising	Opportunity for crime, -ve aesthetically
Buildings	Provide shading (green roof) and reduce carbon footprints via carbon sequestration	reduced vision, may be aesthetically unpleasant Might increase water-related risks around the building and loads on the structural strength of the building
Economic	Provide services that might have economic values such as carbon sequestration	May incur costs for maintenance and cleaning

Non flood condition

Urban interdependancies

for hydrological functions



Controlled Exceedance

Un Controlled Flooding

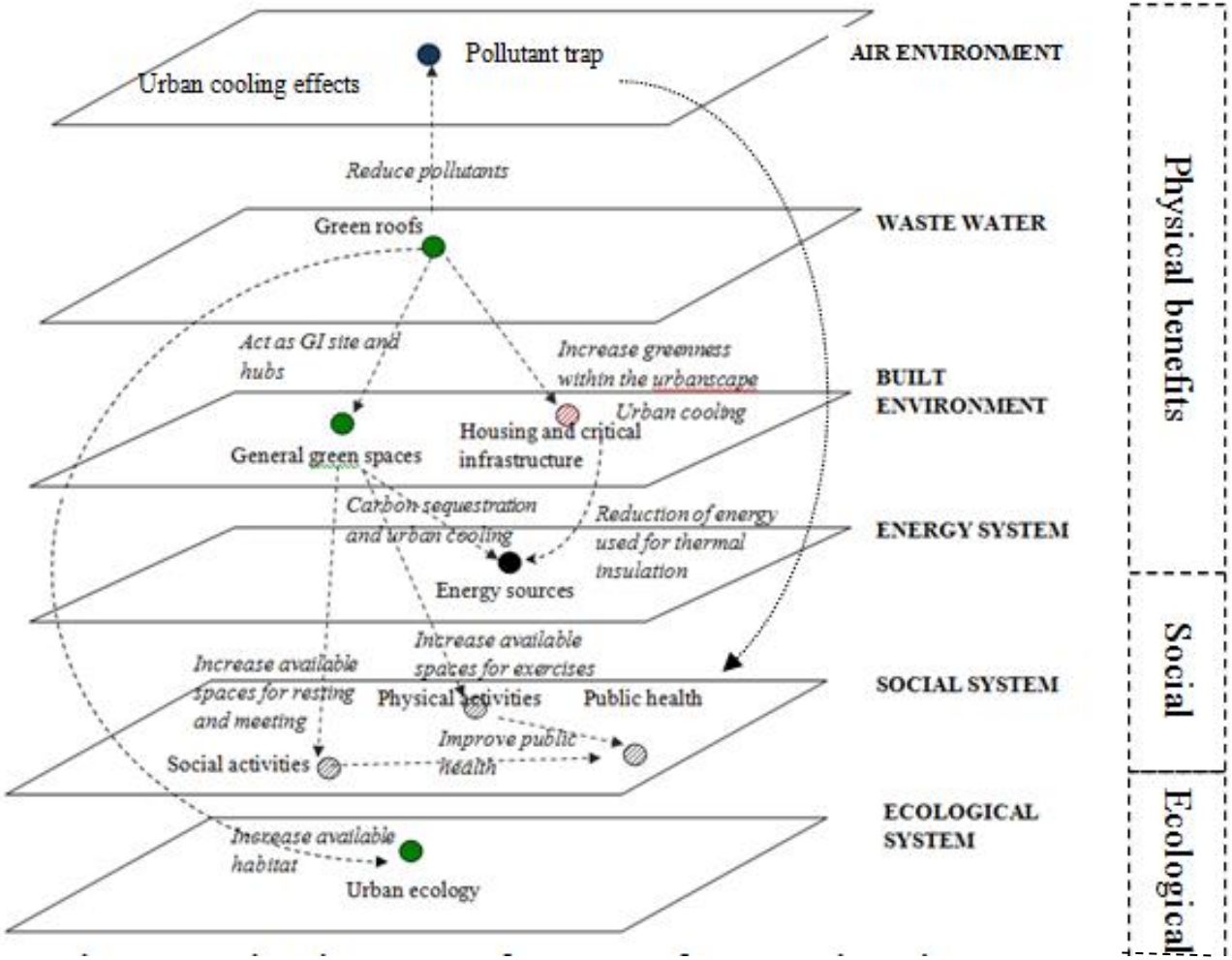
SuDS/GI interactions on the urban system

Systems	Con	uDS/GI Ur
Water supply (sources)	✓	×
	✓ Pollutant and sediment sink, hence:	× Might prolong attenuation flows, affect minimum flows of receiving waters
	✓ Reduce contamination risks on water sources	× Might affect local groundwater quality and flood mounding
	× Might prolong attenuation flows, affect minimum flows of receiving waters	
	× Might affect local groundwater quality and flood mounding	
Wastewater (conveyance and treatment)	✓ Relieve pressure on downstream treatment	× Might increase debris load and blockage on the urban drainage system
	✓ Reduce pollutant loads	
Food and agriculture	✓ Reduce crops contamination and livestock impacts due to pollutant reduction	× Might spread pathogen and pest risks previously contained
	× May require short term flooding of marginal land	
Transport	x Roads as flow pathways	x Sediment Load on highways
		to fallen leaves / branches or sites being used for flood purposes
	× Ice risk under low temperature	
Health	✓ Reduce widespread health risks due to restricting and treating pollutants at sources	× Might increase health risks to surrounding areas due to pathogens and pests when surface storage is surpassed
	× Potential for creating unpleasant smells, allergy or health risks due to rotten leaves/ trees or pollens	× Risks of physical impacts from branches and trees falling due to weakened soil structure
	× Possible exposure to waterborne diseases	× Danger from drowning at amenity sites
Energy		× Fallen branches might affect power lines
Communication		× Fallen branches might affect network connectivity
Social	x Nuisance loss of amenities	x Psychological fears
	× Increase the visibility of exposure to floods	× Can induce psychological impacts due to fear of falling tree branches and pest risks
	× May add to insurance risk	
Ecology	✓ Act as a refugia for wildlife species	× Might spread pest or water-borne diseases onto other ecosystems
	× Might disturb the existing ecosystem	
Economic	✓ Reduce economic impacts via reducing pollution and exceedance risks to property	✓ May reduce flood damages but
		× Could also increase costs regarding subsequent maintenance and other impacts

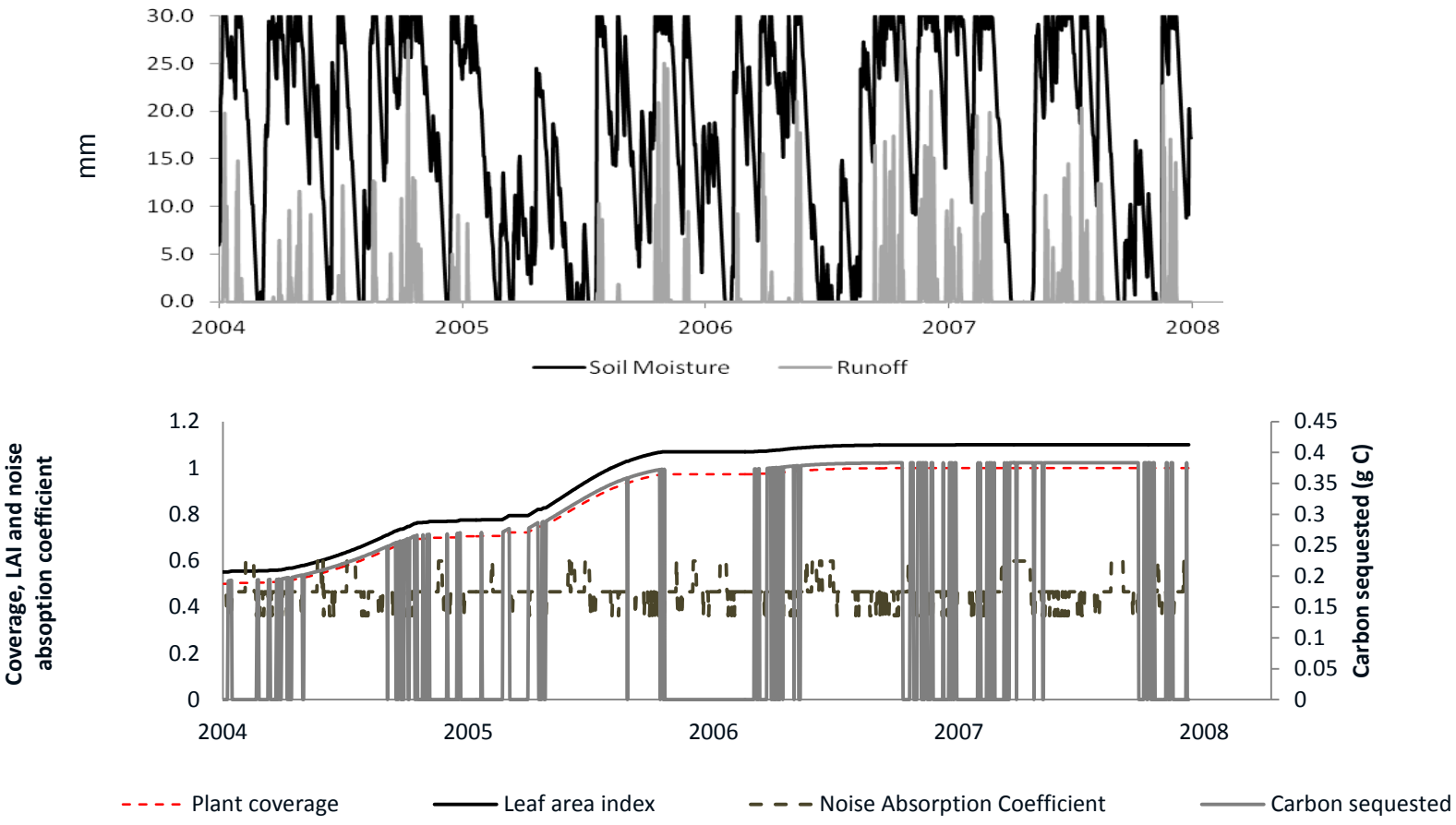
Flood condition

blue green CITIES

Focus on Green roofs



Modelling a hypothetical Green Roof



Multiple benefits of green roofs

under different condition

Potential functions of green roofs under different conditions.
+, ++, +++ denote the potential level of functions from low to high; - denotes small or zero functioning

Soil Moisture	Low		High		Saturation	
Air temperature	Low	High	Low	High	Low	High
Water storage capacity	++	+++	+	++	-	-
Pollutant trap	++	++	+++	+++	+	+
Thermal building insulation	++	++	++	++	+	+
Thermal exchange	+	++	+	+++	-	+
Carbon sequestration	+	+	++	+++	-	-
Noise attenuation	+++	+++	++	++	+	+
Biodiversity	Cold and drought resistant ecosystem	Drought resistant ecosystem	Cold resistant ecosystem	Multiple species	-	-
Visual amenity	+	++	+++	+++	-	-

Connectivity Models Cambourne Cambridgeshire

Green model (Lamb Drove)

Grey model (no SuDS)

The Integral Index of Connectivity $IIC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{a_i \times a_j}{1+nl_{ij}}}{A_L^2}$

a_i : Area of each habitat patch

nl_{ij} : Topological distance between patches i and j

A_L : Area of study

After Pascual-Hortal and Sauroa(2006)

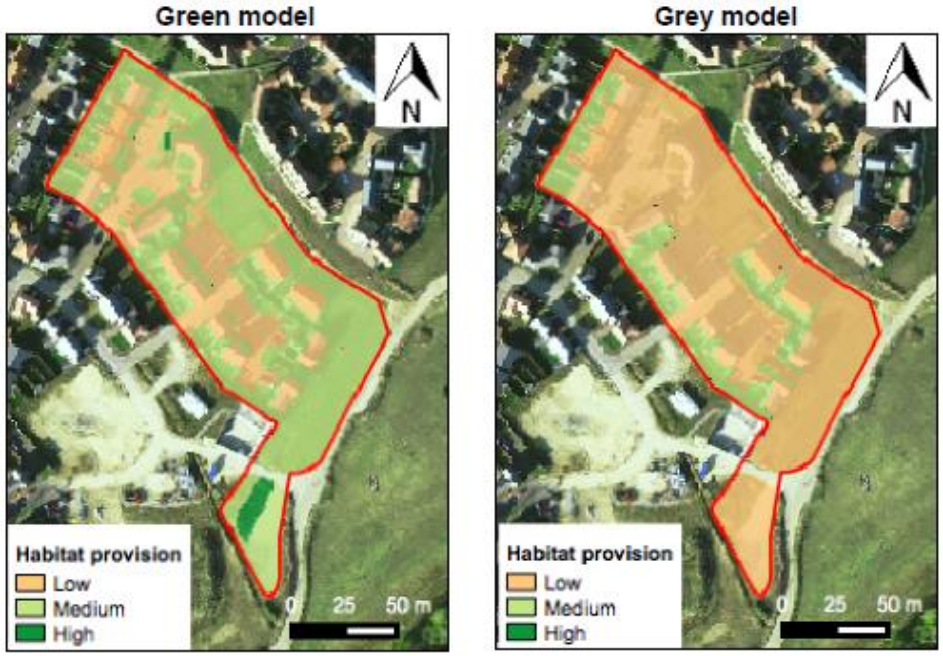
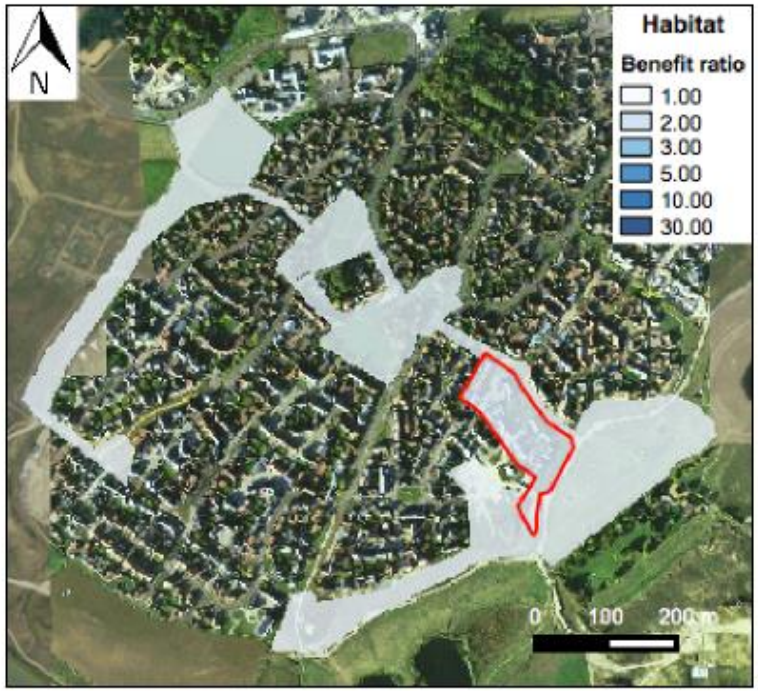


Figure 4.26. Habitat provision for both models.



Uplift in green space connectivity as a result of Lamb Drove

Grey Condition
Integral Index of Connectivity (IIC) = **0.0085**

Green Condition
Integral Index of Connectivity (IIC) **= 0.0114**

Benefit uplift in connectivity = **1.34**

blue green CITIES

Examples of potential multiple benefits from SuDS / GI

Potential Benefits from SuDS and Blue Green Infrastructure	Mechanisms
Pollutant trapping	e.g. Adsorption of PM_{10} onto leaf surfaces
Biodiversity	e.g. through habitat creation
Amenity and recreation	e.g. through greater access to green space
Enhanced urban form	e.g. through landscape connectivity into green corridors
Groundwater recharge	e.g. maintenance of natural hydrology
Air temperature	e.g. through mitigating urban heat island effects
Health	e.g. by providing areas for exercise, improving air quality etc
Noise reduction	e.g. where adjacent to major roads
Traffic calming	e.g. by using street gardens as width restrictors
Carbon mitigation	e.g. by sequestering CO_2
Property value uplift	e.g. by proximity to green space

Understanding relevant dominant benefits

Key principles:

1. Impacts of SuDS/GI may include benefits and disbenefits and these are location and context specific

2 Tradeoffs may occur between benefit categories so that simultaneous optimisation of all benefits is not possible

3. The value of each benefit will be dependant on background environmental conditions

4. Benefits are incremental and need to be assessed as an improvement from an initial condition state, (and how they develop over time)

5. It can be difficult to compare between non-commensurate benefit categories, in specific local circumstances and against references of local communities

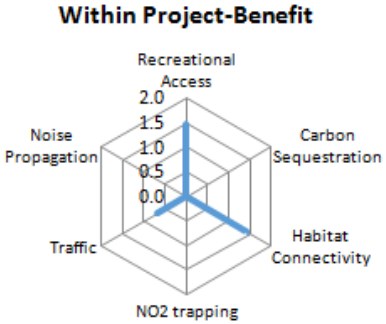
6. The spatial distribution of benefits is important and accrue to different stakeholder groups other than the asset owner, and scales from local to regional to global

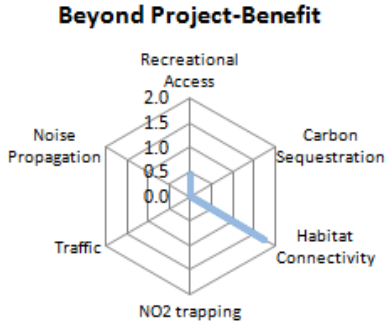
Benefit profile

For each grid square estimate:

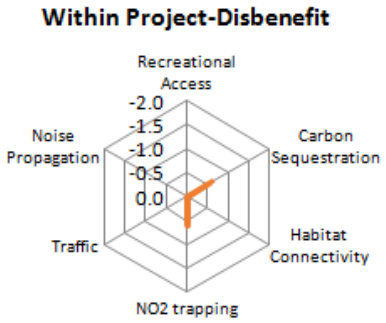
benefit quantity as a ratio to the maximum value on site
Or
benefit quantity as a ratio to the pre-existing benefit value before SuDS/GI installation benefit

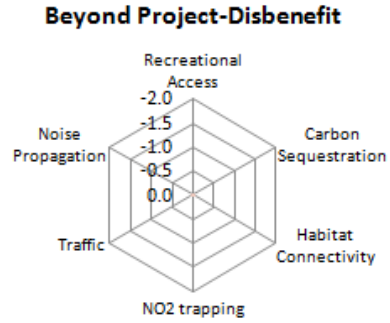
Compute an aggregated score in all the squares a benefit category occurs





Benefits





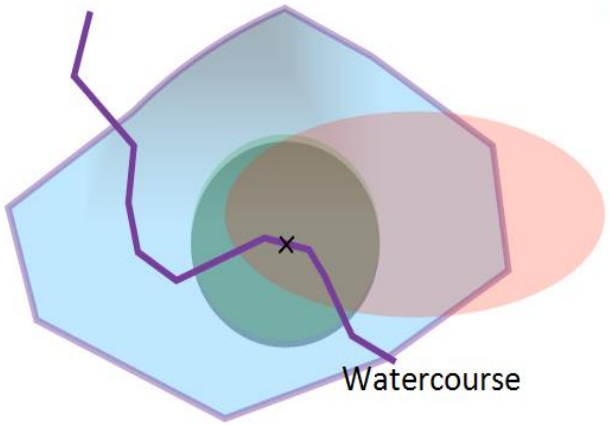
Dis - Benefits

Benefit intensity

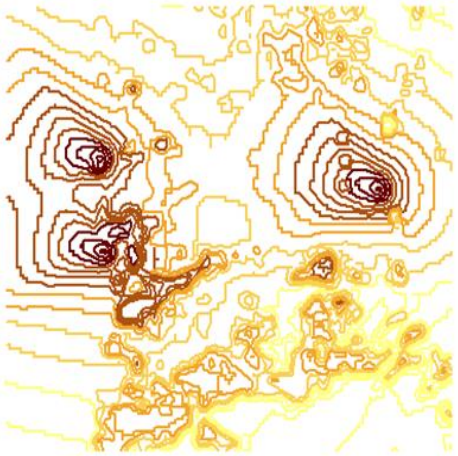
Benefit Intensity

Spatial variation of the cumulative benefit impact

a)



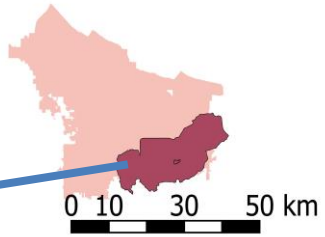
b)



Each layer can be linked to significance weightings provided by a review of stakeholder preferences

Foster Road Floodplain Restoration

Portland , Oregon



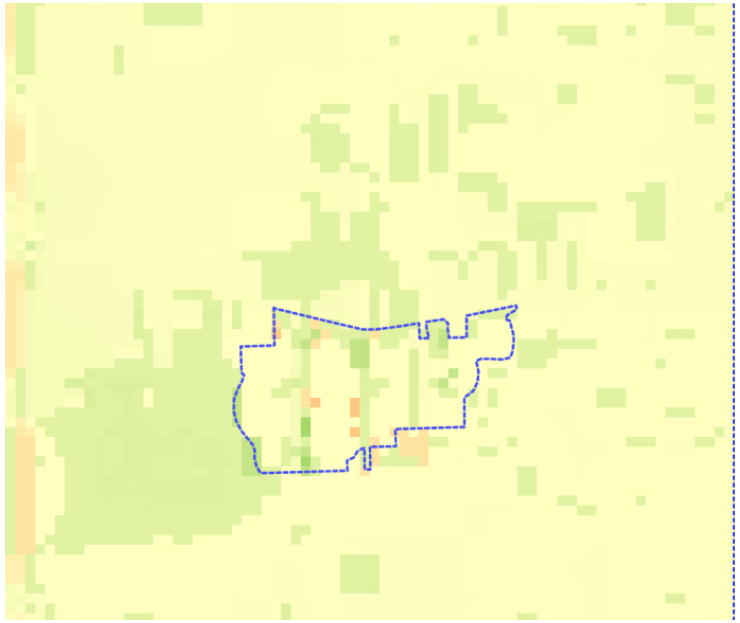
Before

After

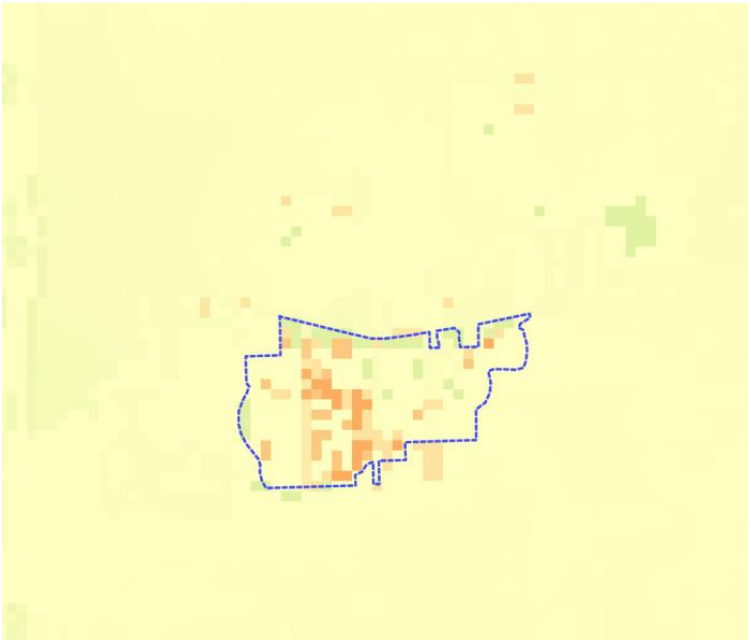
Benefit intensity

Portland , Oregon

Non-flood condition

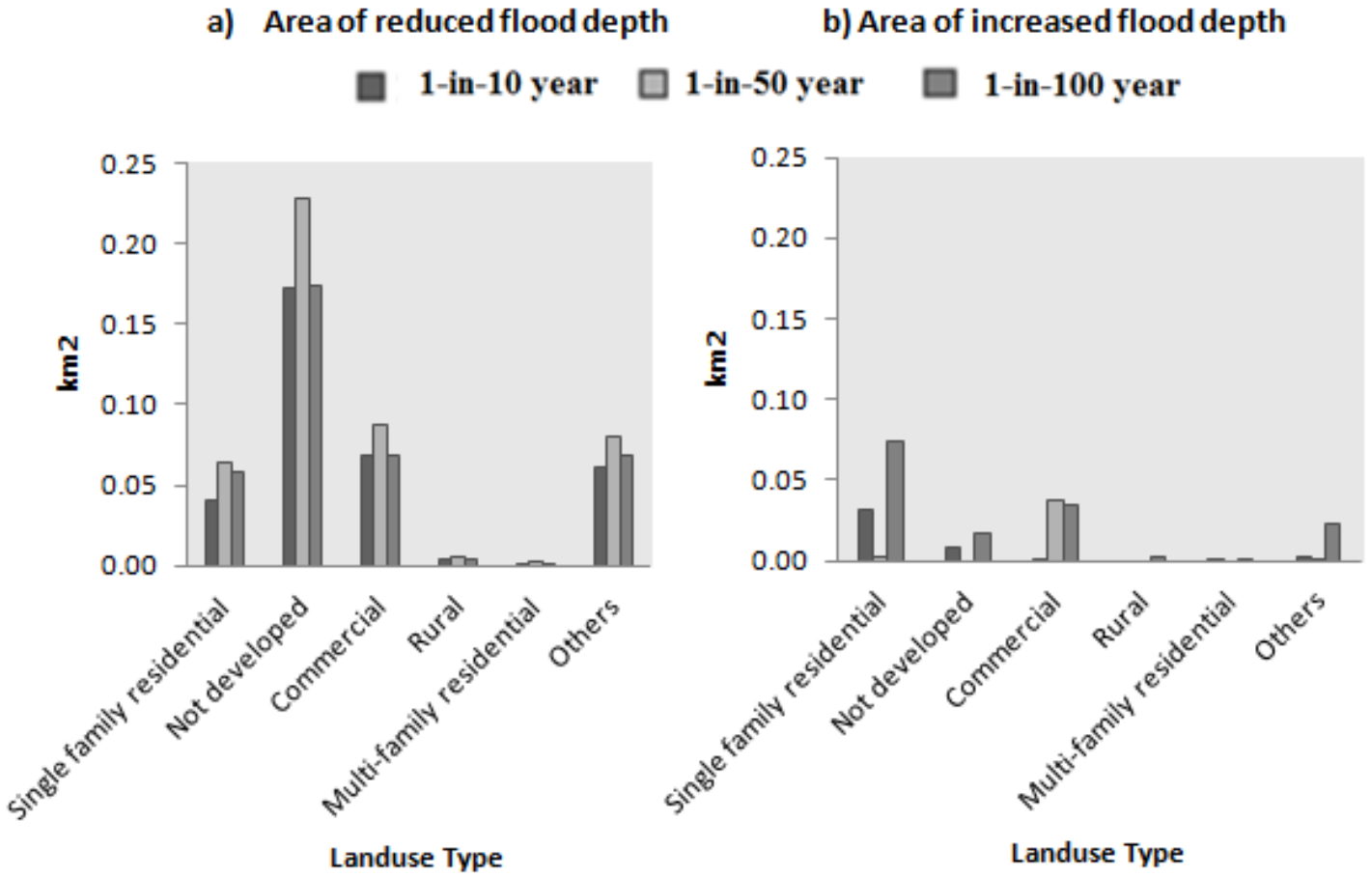


1-in-10 year Flood condition



Flood Benefits

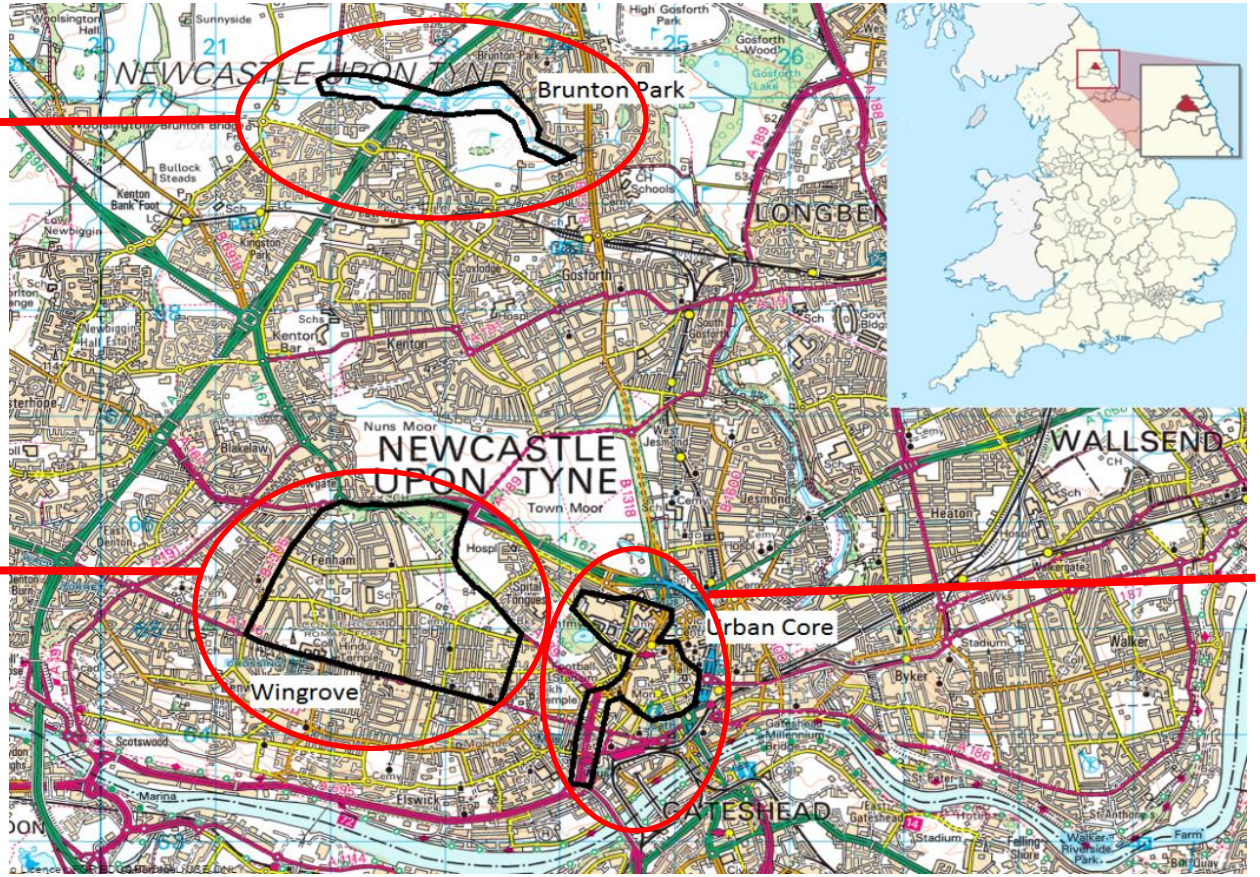
Portland , Oregon



Multiple benefit evaluation of 3 Newcastle sites

Multiple benefit evaluation of 3 Newcastle sites

Newcastle Great Park



Wingrove

Urban Core

Benefit categories considered

Flood damage mitigation

Access to green space (recreation and amenity)

Air quality (as PM_{10})

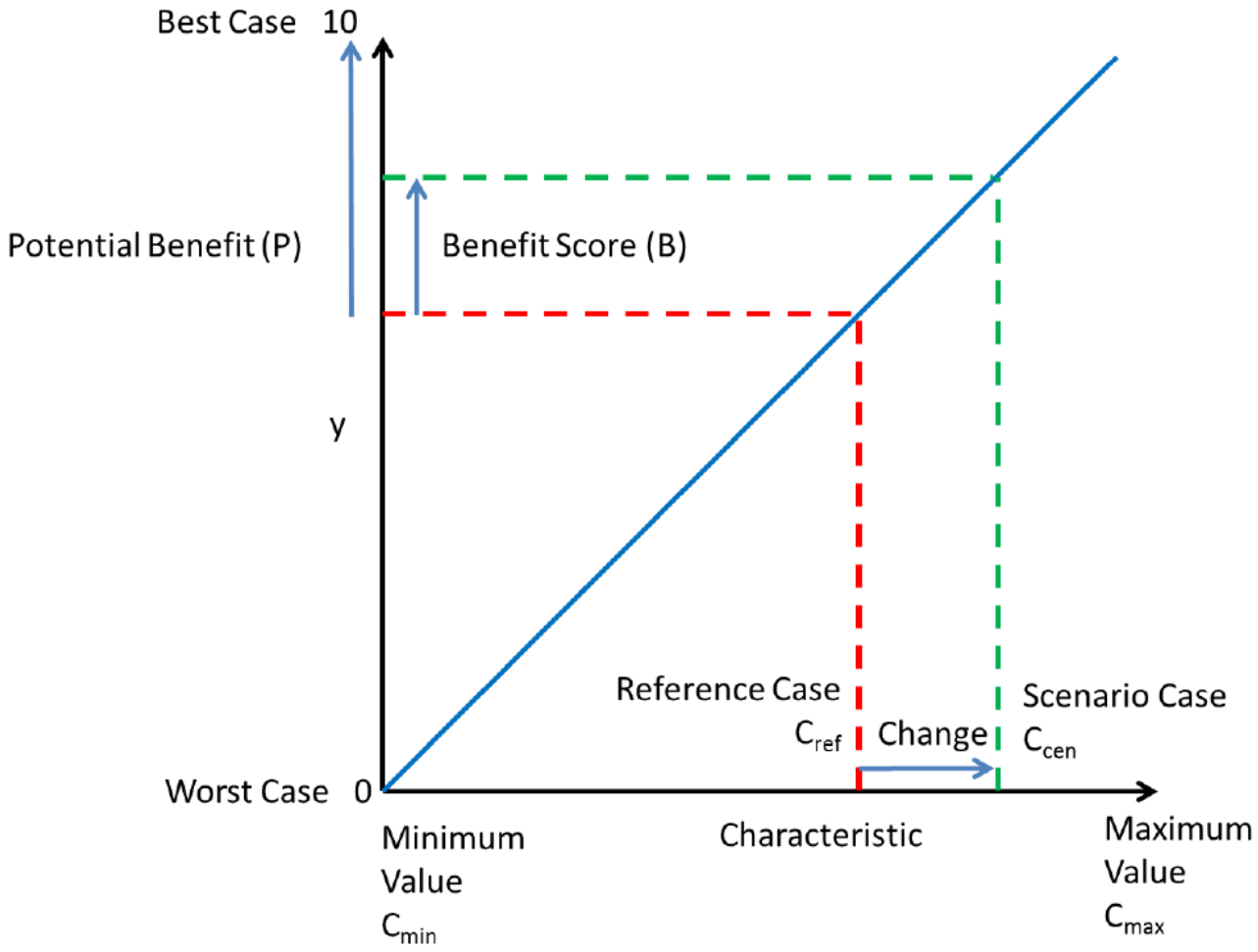
Habitat size

Noise reduction

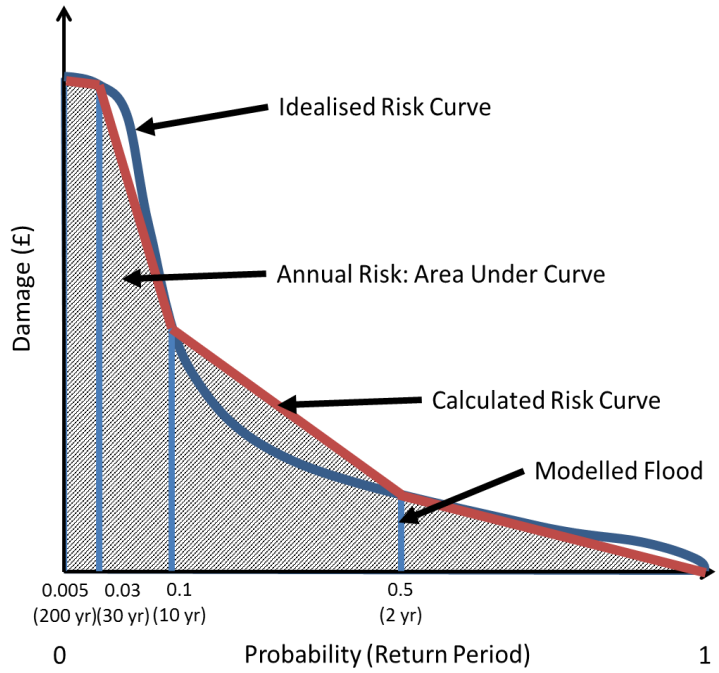
Carbon sequestration

Potential to link more layers e.g. from ecosystem services evaluation

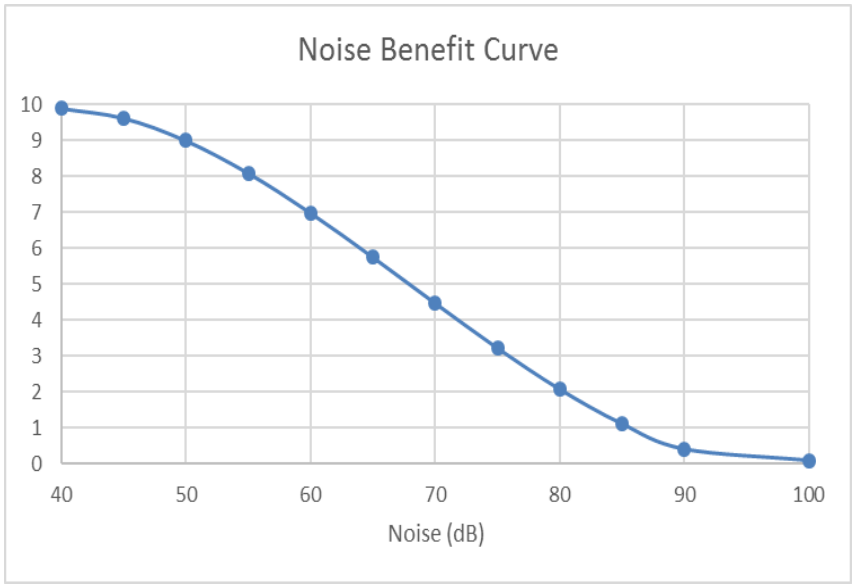
Benefit calculations



Benefit calculations

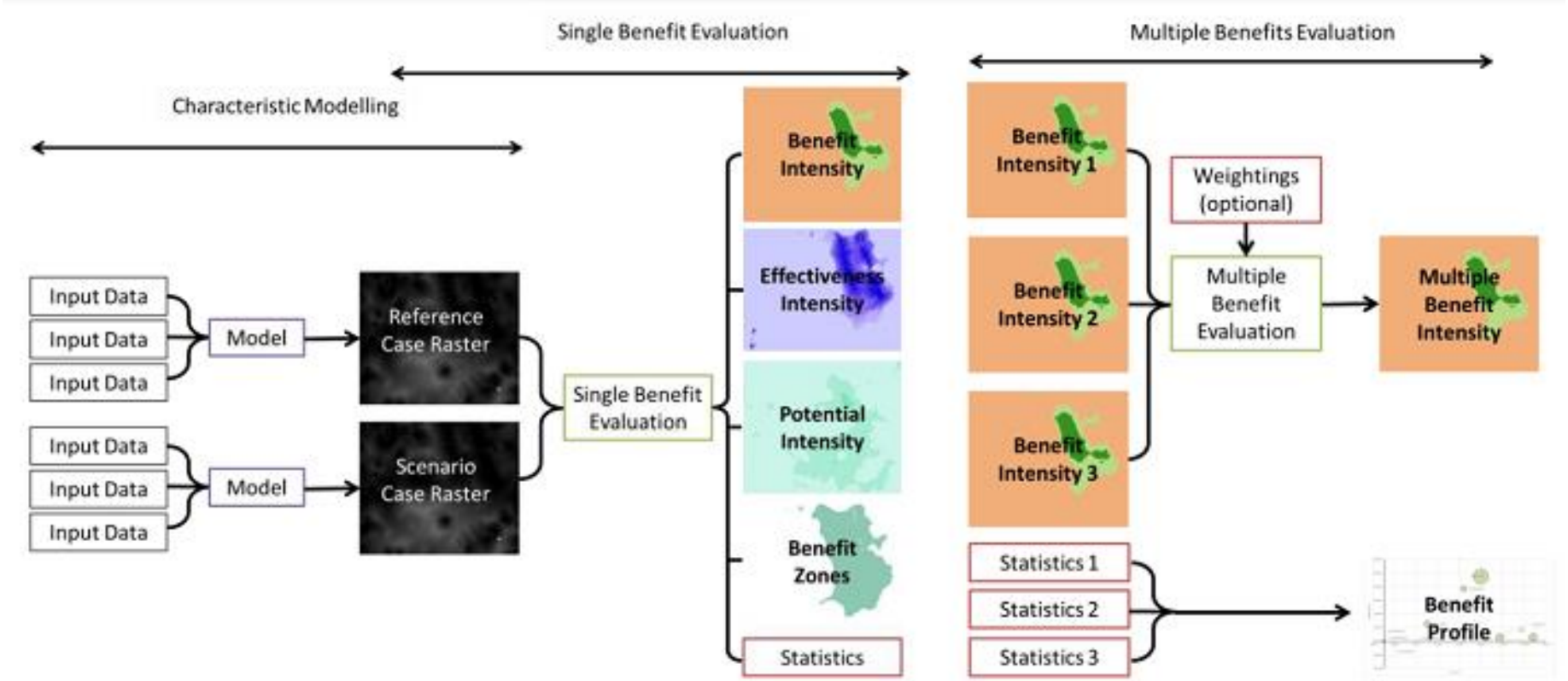


Depth damage curves

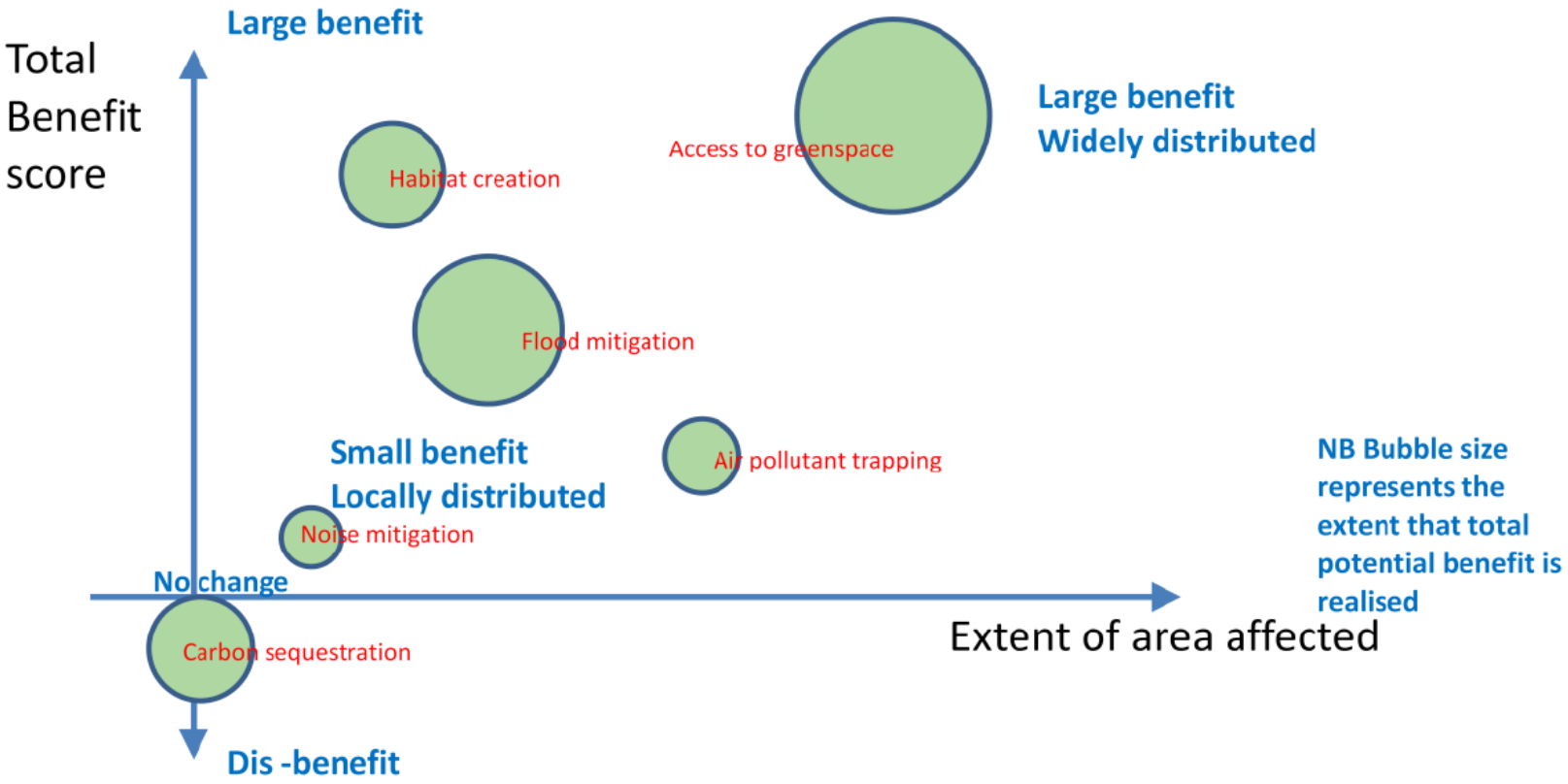


Noise benefit curves

GIS Toolbox


Single Benefit Evaluation
Multiple Benefits Evaluation
Characteristic Modelling
Input Data
Input Data
Input Data
Model
Reference Case Raster
Input Data
Input Data
Input Data
Model
Scenario Case Raster
Single Benefit Evaluation
Benefit Intensity
Effectiveness Intensity
Potential Intensity
Benefit Zones
Statistics
Benefit Intensity 1
Benefit Intensity 2
Benefit Intensity 3
Weightings (optional)
Multiple Benefit Evaluation
Multiple Benefit Intensity
Statistics 1
Statistics 2
Statistics 3
Benefit Profile

Modified benefit profile



SUDS Locations in Wingrove

Wingrove

Access to Greenspace

Air Pollution

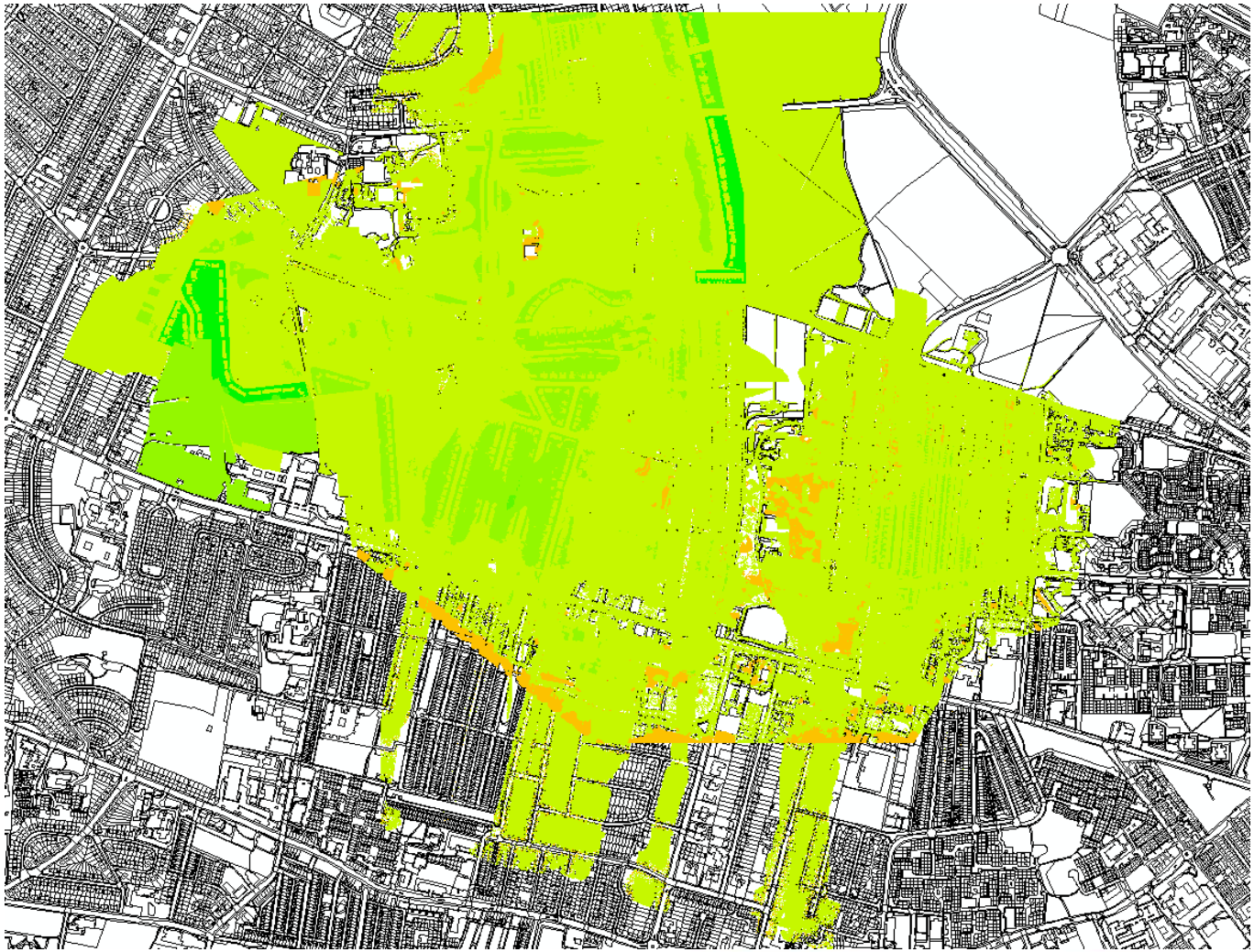
Carbon Sequestration

Flood Damage

Habitat Size

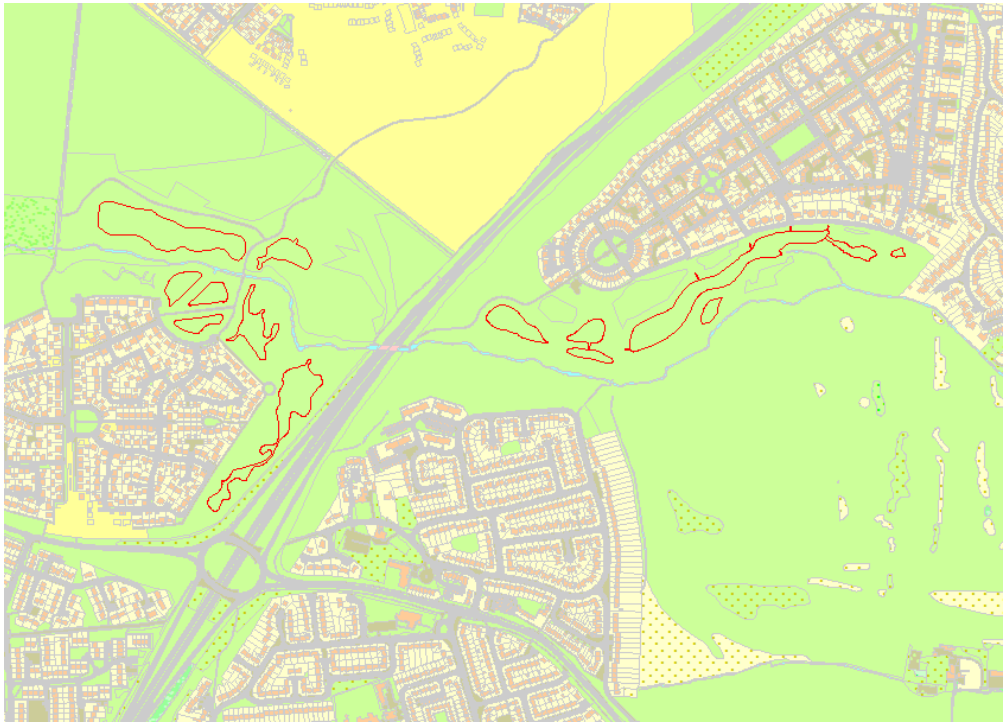
Noise Attenuation

Benefit Intensity: Wingrove



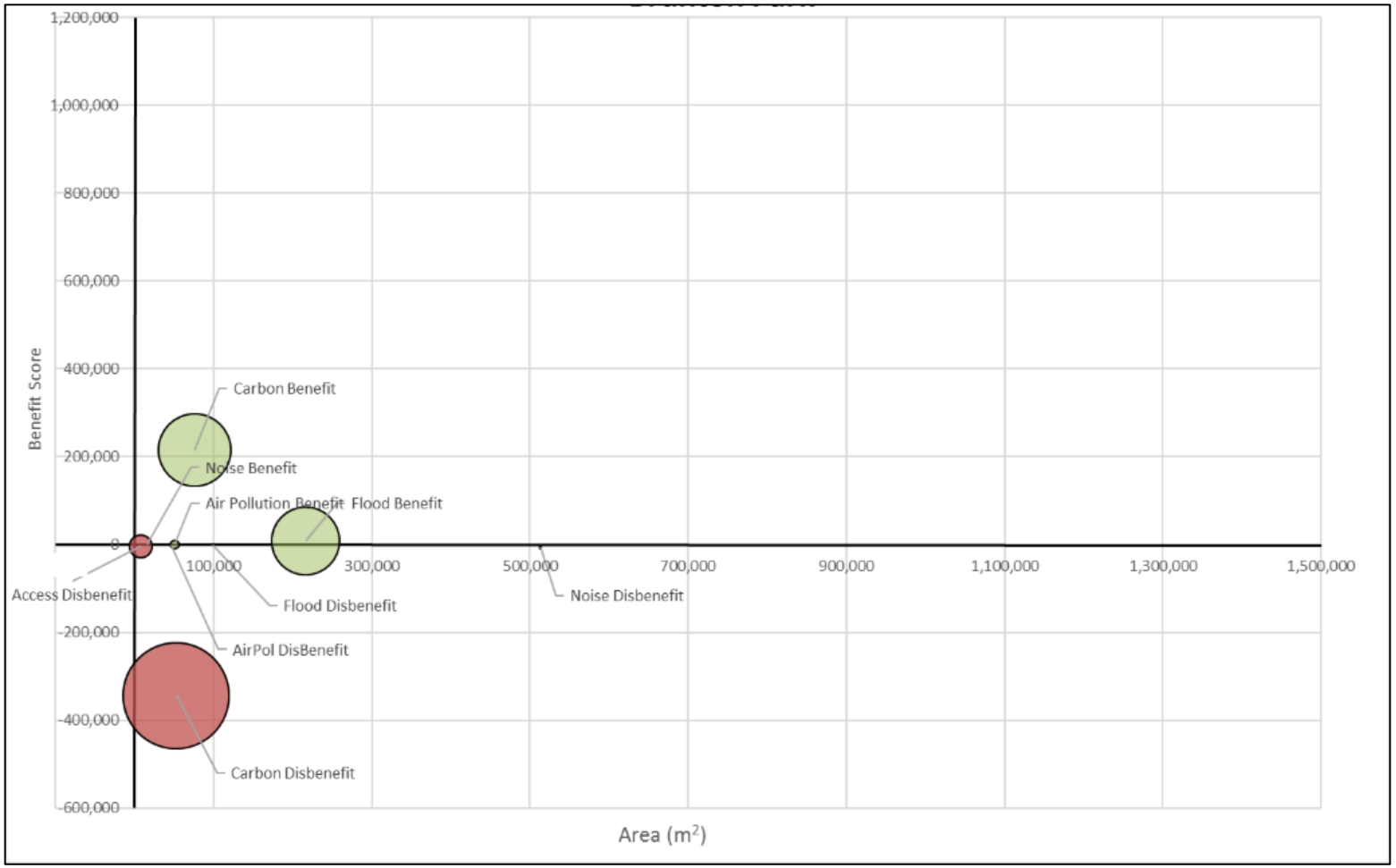
Benefit Profile: Wingrove

SUDS Locations in Newcastle Great Park



Benefit Intensity: Newcastle Great Park

Benefit Profile: Newcastle Great Park

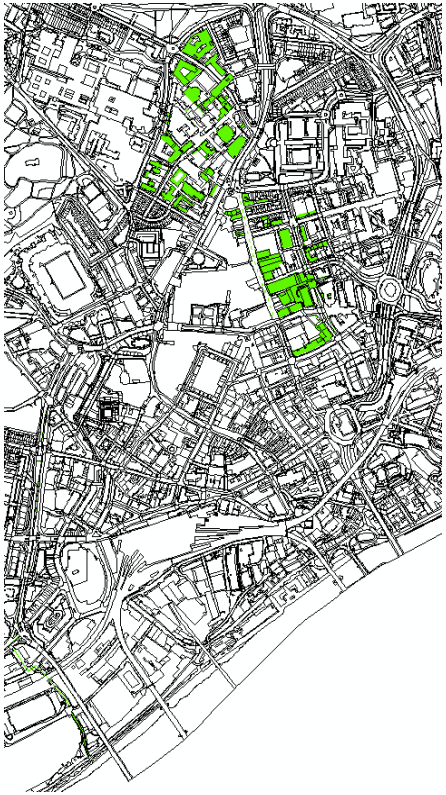


SUDS Locations in Urban Core

Urban Core

Access to Greenspace

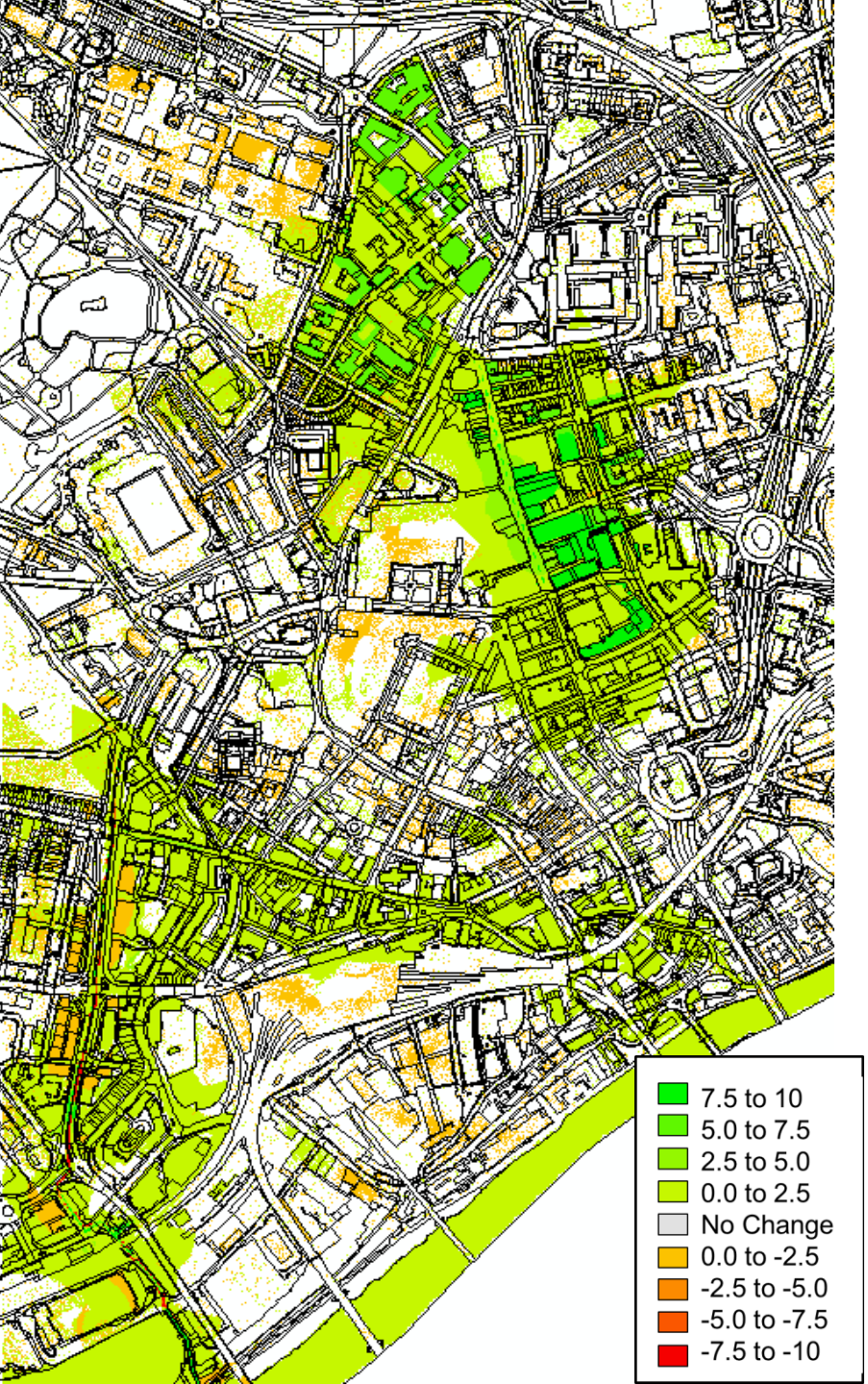
Noise Pollution



Carbon Sequestration

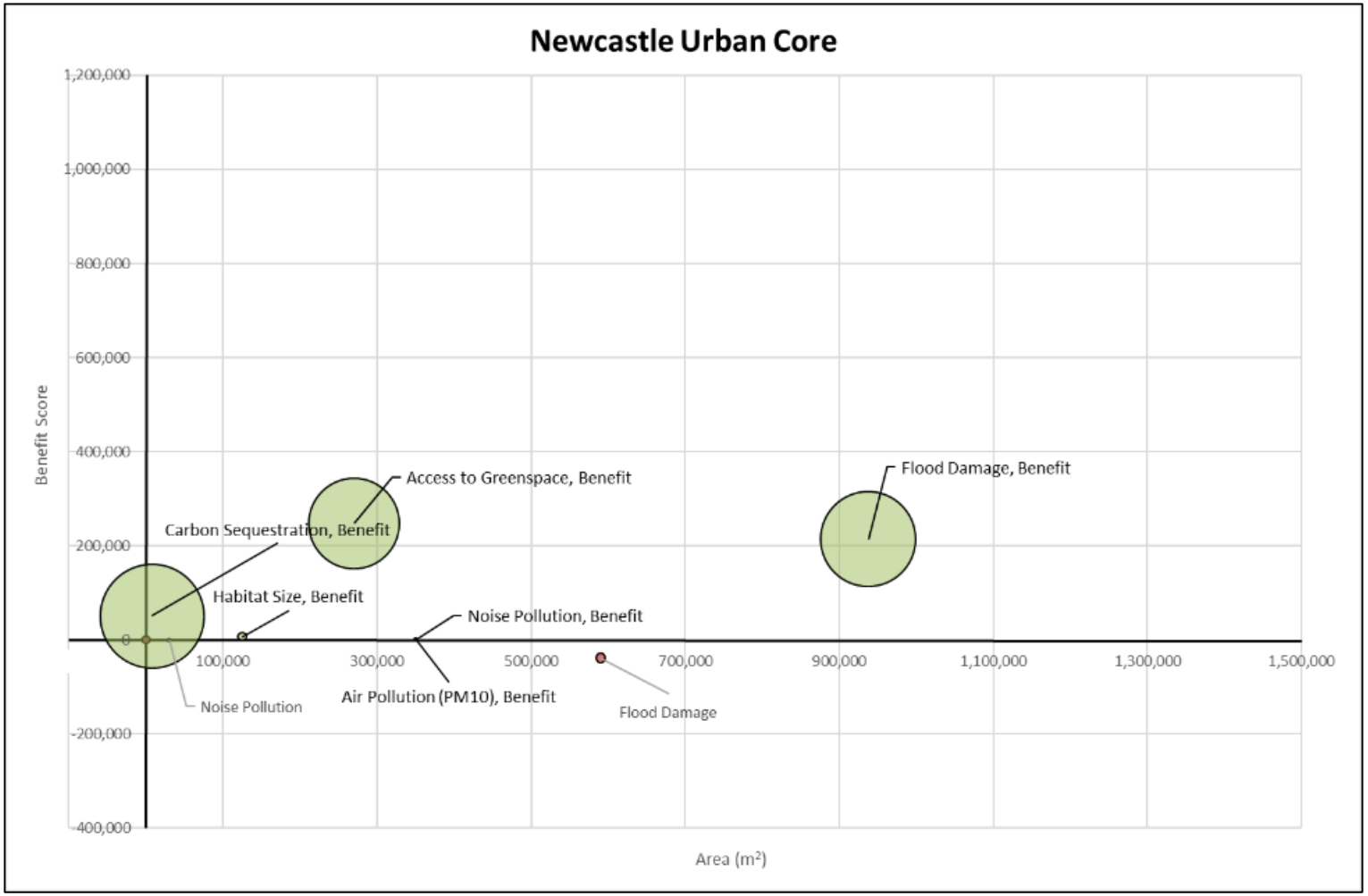
Flood Damage

Benefit Intensity Urban Core



blue green CITIES

Benefit Profile: Urban Core



Overall comparison

SWITCH criteria	NGP	Wingrove	Urban Core
	existing	proposed	proposed
Water sensitivity (Urban water brought closer to natural water cycles)	+	+	++
Aesthetics (flood water visible- integration into surrounding area)	++	+++	++
Functionality (Appropriate design; adaptable to climate and population)	+	++	+
Public perception and acceptance (public involvement)	++	(+)	(+)
Usability (for recreation and conservation)	+++	+++	++
Integrative planning (combining function, aesthetics & use through interdisciplinary planning)	+	(+++)	(++)

Conclusion

A Method for contextualising the multiple benefits from Blue Green infrastructure
- in terms of the specific uplift an area receives in each benefit category

Visualisation of the spatial distribution of benefits

Three new terms defined :

Benefit profile
Benefit intensity
Benefit dependency

A Blue Green Cities Multiple benefit toolbox (ArcGIS 10)

Key messages:

• Spatial distribution of multiple benefit intensity can usefully inform urban planning

• Wider benefit performance of SuDS/GI installations depends on the initial conditions of each site location

• Tradeoffs may occur between benefit categories,

• Many benefits are incremental and to be assessed in relation to the rate they develop over time, so concepts of realised and potential benefit are important

Discussion

- **How can the temporal dimension be addressed (as benefits accrue over time?**
- **How are multiple benefits valued by the asset owner ?**

  - how is multi-functionality shared across responsible agencies?
- **What are the relational barriers between organisations / stakeholders that must be overcome to deliver a Blue Green scheme ?**
- **Should the *relevant dominant* benefits from a SuDS/GI scheme be identified at the planning stage so the subsequent design can co-optimise the flood management function AND the wider (relevant) benefits**