ReNature

Training Course
Nature-based Solutions in Urban Planning

Designing NbS in cities: What do planners need to know?

Davide Geneletti and Chiara Cortinovis
University of Trento, Italy

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 809988.

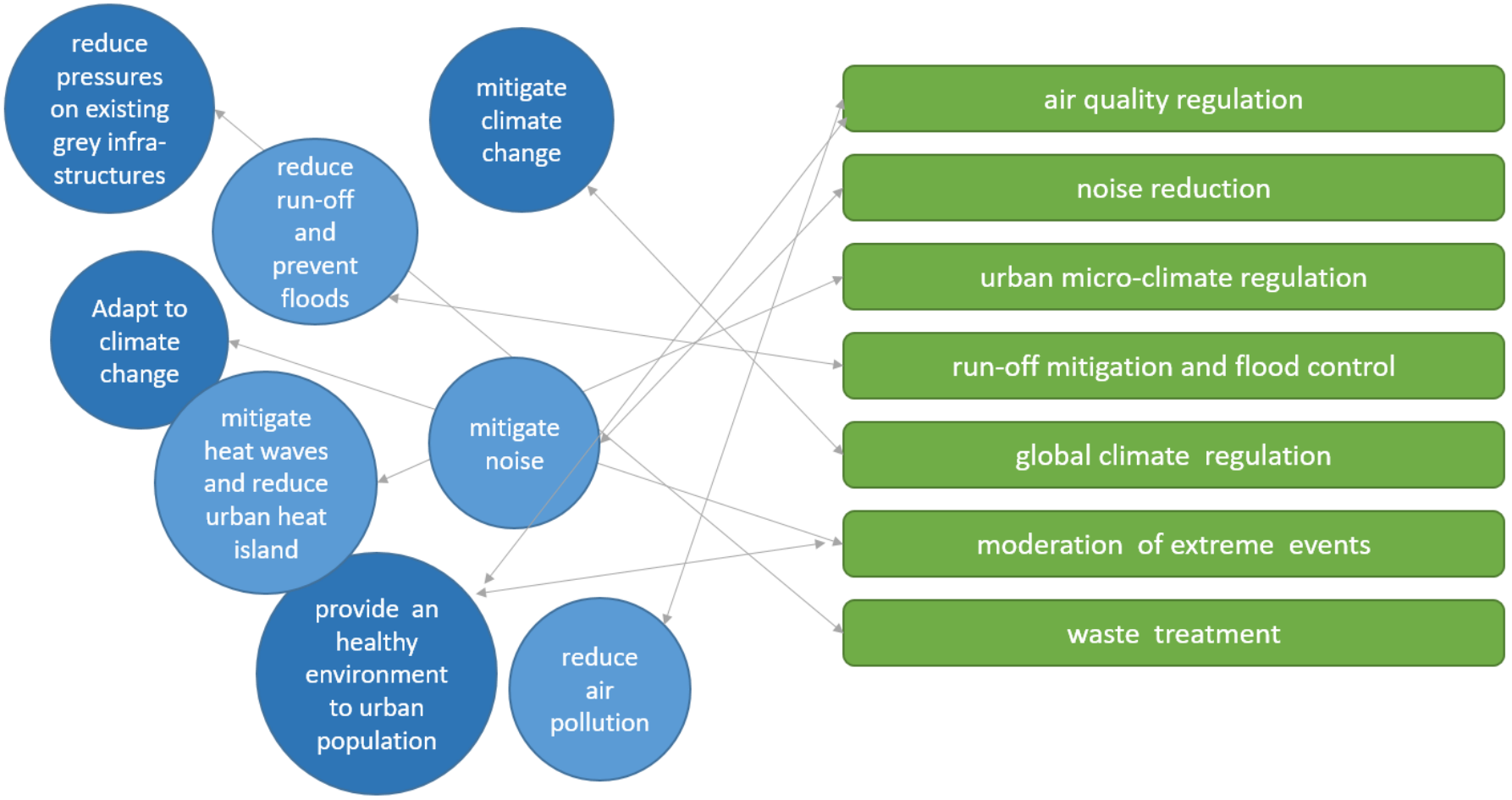
ReNature

Picture by D. Geneletti

ReNature

ReNature

Regulating ecosystem services



ReNature

Knowledge needs for planners

What planners need to know about regulating ecosystem services to design suitable NbS?

Picture by C. Cortinovis

1. Components of NbS

ReNature

Picture from Google Maps

Functionality of components for different ES

URBAN REGULATING SERVICES	GREEN SPACE COMPONENTS							
	trees	shrubs	herbaceous vegetation	permeable surfaces	wetlands	water courses	water bodies	soil
air purification	X	X						
urban micro-climate regulation	X	X	X		X	X	X	
global climate regulation	X	X						X
run-off mitigation and flood control	X	X		X	X			
noise reduction	X	X	X					
moderation of extreme events	X				X			
waste treatment				X	X		X	

Multiple components involved in the supply of a given ecosystem service

Functionality of components for different ES

URBAN REGULATING SERVICES	GREEN SPACE COMPONENTS							
	trees	shrubs	herbaceous vegetation	permeable surfaces	wetlands	water courses	water bodies	soil
air purification	X	X						
urban micro-climate regulation	X	X	X		X	X	X	
global climate regulation	X	X						X
run-off mitigation and flood control	X	X		X	X			
noise reduction	X	X	X					
moderation of extreme events	X				X			
waste treatment				X	X		X	

multi-functionality

(synergies among services)

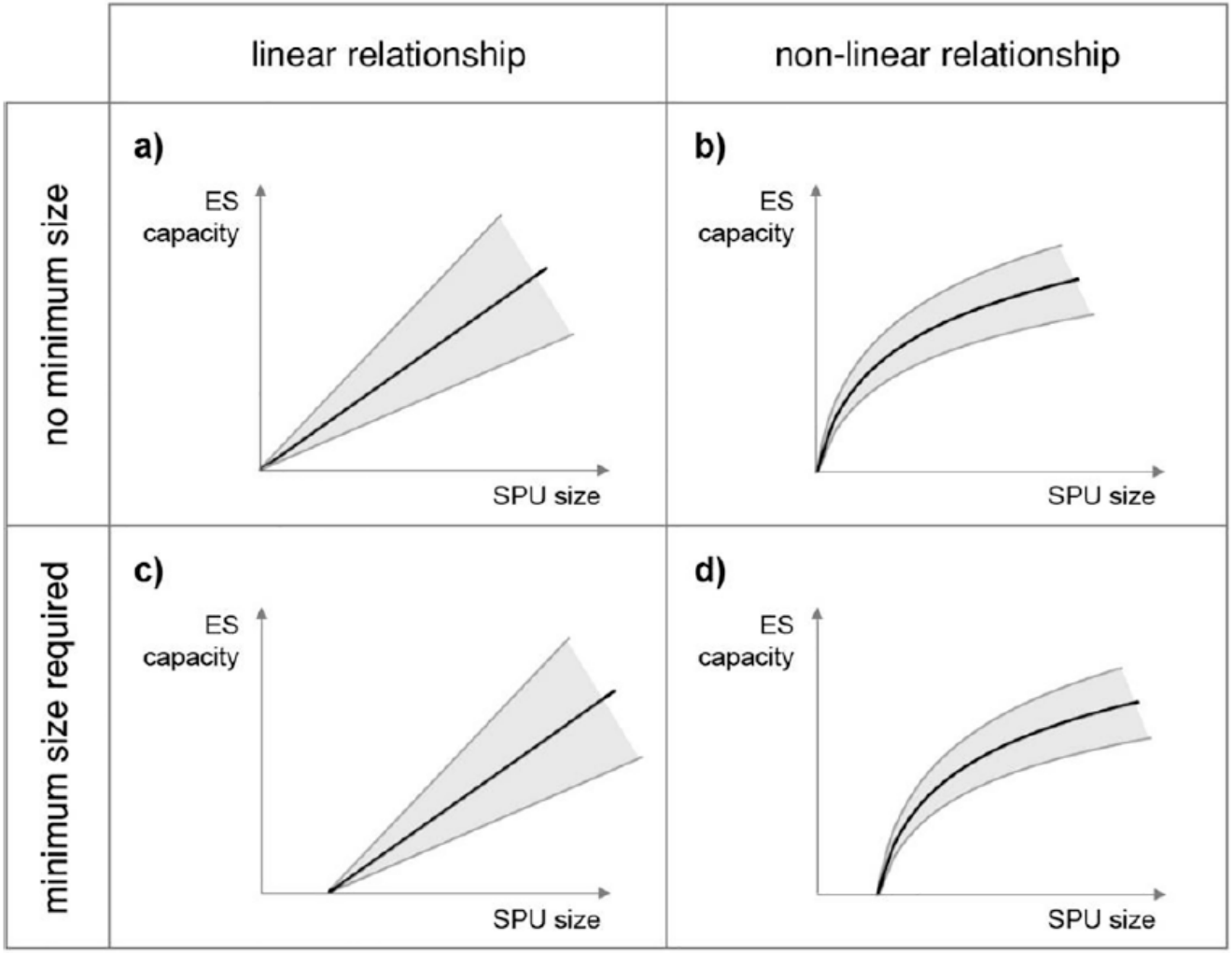
ES, ecosystem function, components

urban regulating ES	ecosystem function	biophysical structure (process)	key Refs.
air purification	uptake of gaseous air pollutants	leaves	Nowak et al. (2006)
	deposition of particles	vegetation	Nowak et al. (2006)
global climate regulation	carbon sequestration	vegetation (photosynthesis) and soil	Jo and McPherson (1995), Nowak et al. (2013)
	carbon storage	vegetation and soil	Pouyat et al. (2006), Strohbach and Haase (2012)
moderation of extreme events	physical barrier (absorption of kinetic energy)	trees	Danielsen (2005), Dobbs et al. (2011)
noise reduction	reflection and diffraction of noise	vegetation and soil	Van Renterghem et al. (2012)
	noise absorption	vegetation (mechanical vibration) and soft soil	Van Renterghem et al. (2012)
runoff mitigation and flood control	water infiltration	permeable surfaces	Yang et al. (2015)
	rainfall interception	tree canopies	Xiao and McPherson (2002)
	reduction of flood velocities	vegetation	Nisbet and Thomas (2006)
	water storage	floodplains	Blackwell and Maltby (2006)
urban temperature regulation	evapotranspiration	vegetation	Coutts et al. (2012)
	shading	tree canopies	Shashua-Bar and Hoffman (2000)
	evaporation	water	Saaroni and Ziv (2003)
	heat transfer (storage and release)	*water bodies*	Saaroni and Ziv (2003)
	wind blocking	*trees*	Huang et al. (1990)
waste treatment*	removal of storm water pollutants (sedimentation, filtration, sorption, assimilation and degradation)	ponds, wetlands, vegetated surfaces	Clar et al. (2004), Hemond and Benoit (1988)
	decomposition of solid organic litter	*soil*	Vauramo and Setälä (2011)

ReNature

Cortinovis and Geneletti, 2019

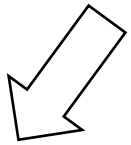
Spatial configuration and ecosystem service supply



Cortinovis and Geneletti, 2019

Spatial configuration and ecosystem service supply

Key spatial elements to inform the design of NbS



	AREA	LENGHT	WIDTH
water flow regulation	C		
urban temperature regulation	B		
noise reduction			D
air purification	A		
moderation of extreme events			D
waste treatment	D	D	
global climate regulation	A		

Key spatial elements

urban regulating ES	ES capacity/flow indicator [unit]
air purification	pollution removal [t/yr]
global climate regulation	carbon storage [t], carbon sequestration [t/yr]
moderation of extreme events	wave height reduction [%]
noise reduction	excess noise attenuation [dBA]
runoff mitigation and flood control	avoided runoff
urban temperature regulation	Δt [°C]
waste treatment	pollution removal efficiency [%]

Cortinovis and Geneletti, 2019

Key spatial elements

UGI typologies and level of ecological organisation *	relevant UGI size and relation with ES capacity **
trees (I), shrubs (I)	area (a)
trees (I), shrubs (I), soil (E)	area (a)
trees (P), wetlands (E)	width of the buffer zone (d)
trees (P), shrubs (P), soft soil (E)	width of the buffer zone (c/d)
trees (P), shrubs (P), permeable soil (E), wetlands (E)	area (interception and infiltration), volume (storage) (a/c)
trees (I), shrublands and grasslands (E), permeable areas (E), wetlands (E), water courses (E), water bodies (E)	area and shape index (b)
herbaceous vegetation (E), soil (E), wetlands (E)	wetland-to-watershed area / length of the vegetation strip (d)

Cortinovis and Geneletti, 2019

Key spatial elements

urban regulating ES	ES capacity/flow indicator [unit]
air purification	pollution removal [t/yr]
global climate regulation	carbon storage [t], carbon sequestration [t/yr]
moderation of extreme events	wave height reduction [%]
noise reduction	excess noise attenuation [dBA]
runoff mitigation and flood control	avoided runoff
urban temperature regulation	Δt [°C]
waste treatment	pollution removal efficiency [%]

Key spatial elements

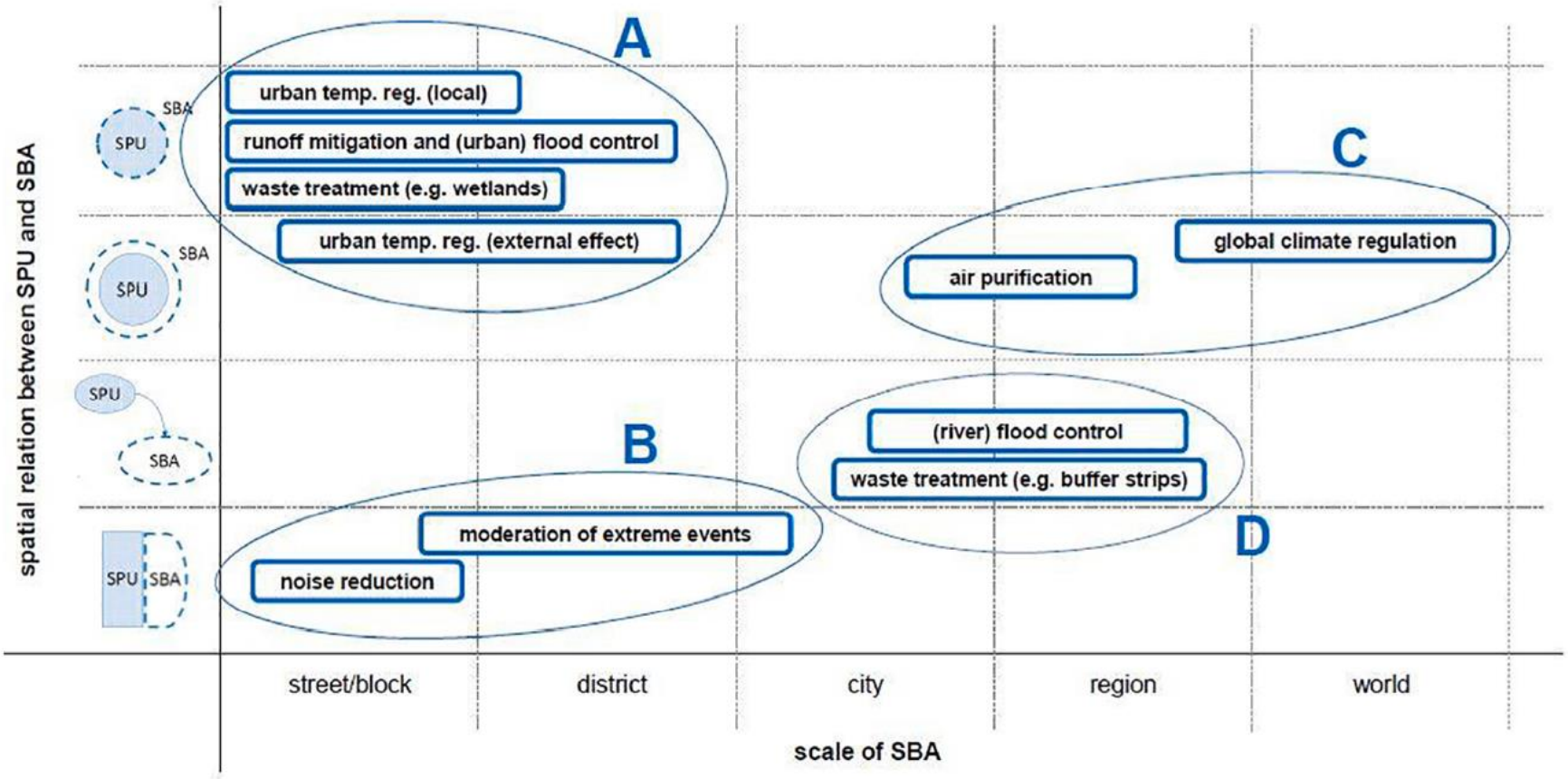
UGI typologies and level of ecological organisation *	relevant UGI size and relation with ES capacity **
trees (I), shrubs (I)	area (a)
trees (I), shrubs (I), soil (E)	area (a)
trees (P), wetlands (E)	width of the buffer zone (d)
trees (P), shrubs (P), soft soil (E)	width of the buffer zone (c/d)
trees (P), shrubs (P), permeable soil (E), wetlands (E)	area (interception and infiltration), volume (storage) (a/c)
trees (I), shrublands and grasslands (E), permeable areas (E), wetlands (E), water courses (E), water bodies (E)	area and shape index (b)
herbaceous vegetation (E), soil (E), wetlands (E)	wetland-to-watershed area / length of the vegetation strip (d)

Cortinovis and Geneletti, 2019

3. Spatial relation between supply and benefits

Picture by C. Cortinovis

scale of benefitting areas for different ES



Cortinovis and Geneletti, 2019

ReNature

The role of existing ecological pressures

- For some ES, the intensity of ecological pressures (eg, air pollution) has a direct effect on the ecosystem functions performed by the NbS, ultimately increasing or decreasing ES capacity.

- Ecological pressures play also a key role in the definition of ES demand.

Some examples

urban regulating ES	ecological pressure	main effects on urban population and physical assets	main effects on urban green infrastructure
air purification	concentration of air pollutants (PM_{10}, $PM_{2.5}$, NO_2, O_3, CO, SO_2)	Ambient air pollution is responsible for 14% of the disease burden of lung cancer, 23% of ischemic heart disease, 25% of stroke and 9% of chronic obstructive pulmonary disease worldwide. (Prüss-Üstün, Wolf, Corvalán, Bos, & Neira, 2016)	Elevated ozone concentrations reduce tree biomass and leaf area. (Wittig, Ainsworth, Naidu, Karnosky, & Long, 2009) Concentrations of air pollutants delays spring phenology. (Jochner et al., 2015)
noise reduction	noise	Traffic noise induces annoyance, stress, and sleep disturbances, and increase the risk for ischaemic heart disease, stroke, and hypertensive diseases. Noise disturbance also produces a significant decrease in housing and renting prices. (Vienneau et al., 2015)	-
urban temperature regulation	urban heat island and heat waves	Mortality rates and hospital admissions for heat-related, cardiovascular, and respiratory diseases increase during heat waves. (D'Ippoliti et al., 2010; Mastrangelo et al., 2007) Urban heat island exacerbates the negative effects of heat waves in urban areas. (Tan et al., 2010)	Droughts and limited water availability may lead to leaf senescence, reduced transpiration, loss of canopy cover, and vegetation death. (Coutts, Tapper, Beringer, Loughnan, & Demuzere, 2012)

Cortinovis and Geneletti, 2019

The role of existing ecological pressures

urban regulating ES	effect of ecological pressure on ES capacity ***
air purification	↑
global climate regulation	↑
moderation of extreme events	↔
noise reduction	↔
runoff mitigation and flood control	↓
urban temperature regulation	↓evapotranspiration, ↑ shading
waste treatment	↓

The role of existing ecological pressures

- For some ES, the intensity of ecological pressures (eg, air pollution) has a direct effect on the ecosystem functions performed by the NbS, ultimately increasing or decreasing ES capacity.

- Ecological pressures play also a key role in the definition of ES demand.

Indicators to measure ES demand

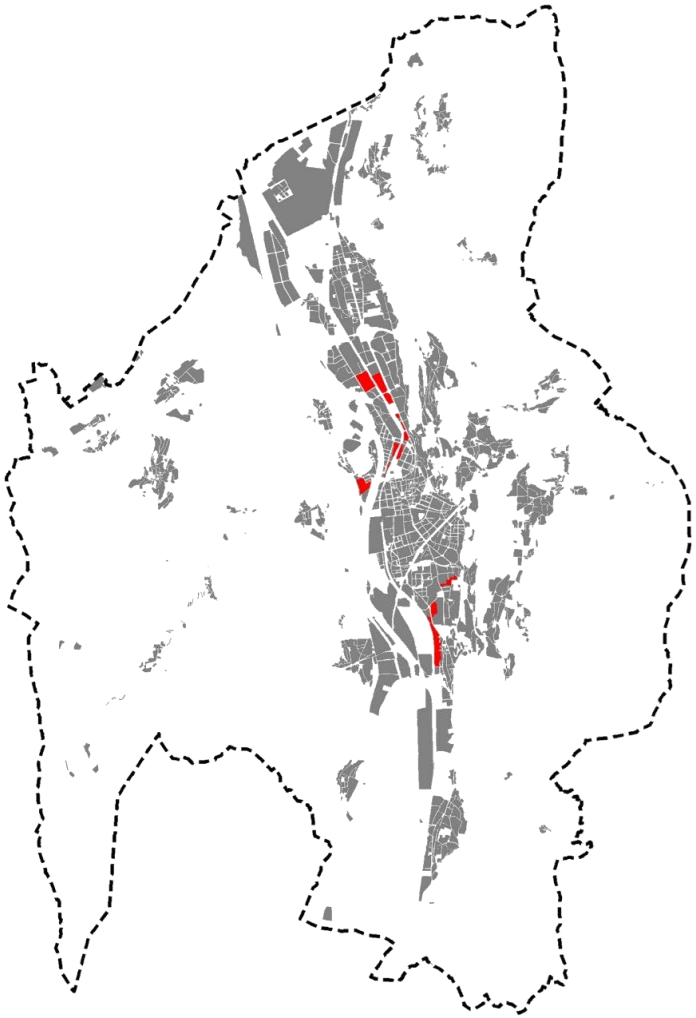
urban regulating ES	spatial distribution of population and physical assets (ES demand areas and high exposure)	highly vulnerable population groups and urban areas (high sensitivity and/or low resilience)
air purification	• population density Baró et al. (2016), Morani et al. (2011)	• foetuses and children, elderlies, and persons with pre-existing cardiorespiratory diseases, diabetes, or asthma (Makri and Stilianakis, 2008)
global climate regulation	• census population; transportation, agricultural and industrial intensity per census tract Zhao et al. (2015)* • spatially-normalized annual CO_2 emissions per person Larondelle and Lauf (2016)*	-
moderation of extreme events	• population density, road density, percentage of artificial surfaces, number of historical and cultural sites Liquete et al. (2013)	• vulnerable areas based on the number of people and the total cost of damage (Wei et al., 2004)
noise reduction	• presence of residential and recreational areas Syrbe and Walz (2012)	• children, elderly, chronically ill (WHO, 2009)
runoff mitigation and flood control	• presence of flood-vulnerable properties Bagstad et al. (2014) density of built areas, density of households Syrbe and Walz (2012)	• vulnerable areas based on damage cost (Olsen et al., 2015)
urban temperature regulation	• census population Geneletti et al. (2016) population density Larondelle and Lauf (2016)	• infants; elderlies; people with obesity, hypertension, pulmonary, or cardiovascular disease; people with restricted mobility; people living alone and lacking social contacts; low-income groups (Basu and Samet, 2002; Kenny et al., 2010) • urban areas with more intense heat island effect based on density and lack of green spaces (EEA, 2012) • amount of elderly people (Larondelle and Lauf, 2016) • impervious cover density, children under the age of 5, adults above the age of 65 (Zidar et al., 2017)
waste treatment	• traffic load and proportion of impervious areas Nordeidet et al. (2004)*	• critical conditions of the sewage system (e.g., based on overflows and diffuse losses) (Nordeidet et al., 2004)

case study: the city of Trento

Picture source: Wikipedia (https://it.wikipedia.org/wiki/Trento)

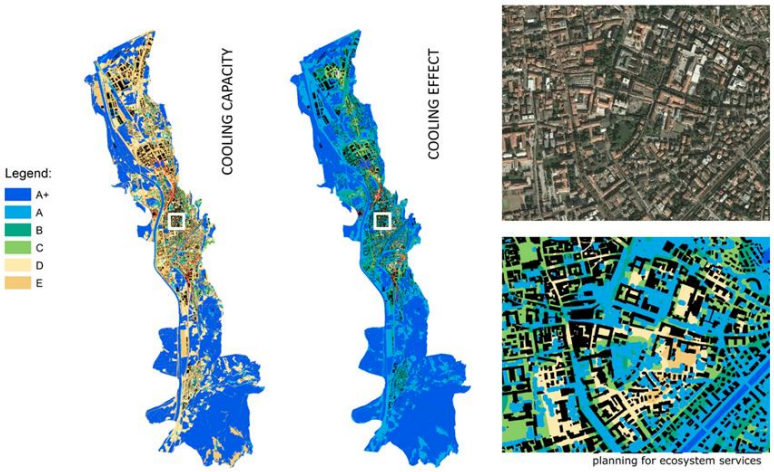
ReNature

NbS for brownfield redevelopment: 13 possible sites



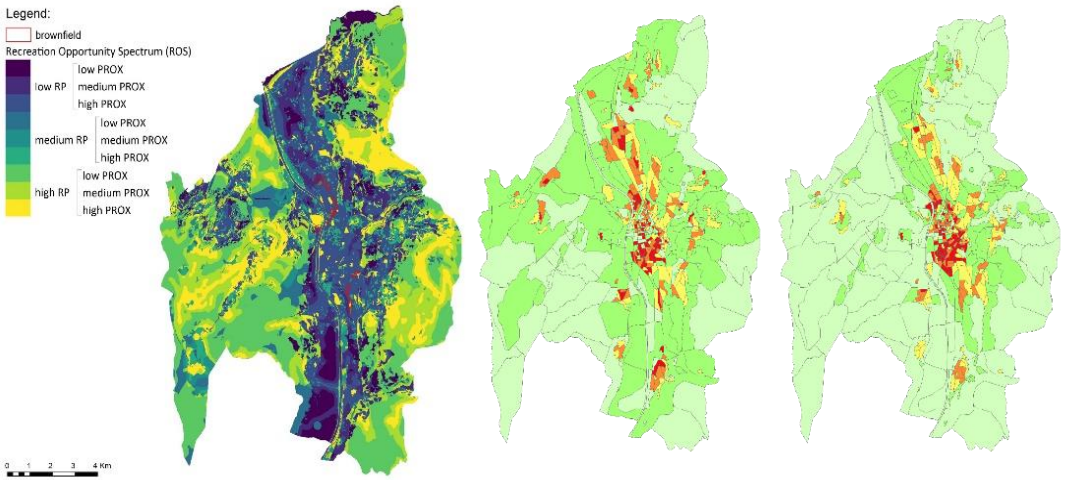
ReNature

NbS for two main challenges:



1. Reducing urban heat islands

2. Enhancing nature-based recreation



ReNature

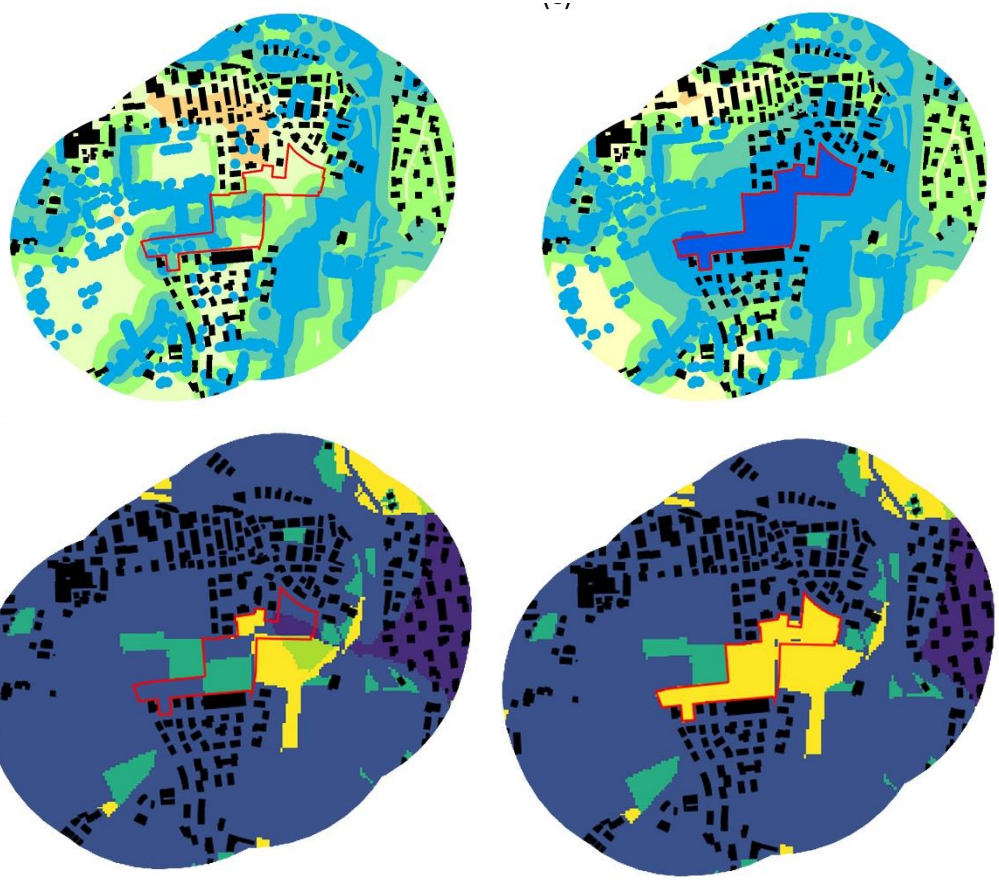
Geneletti et al., 2016; Cortinovs and Geneletti, 2018

Predicting the effects of different NbS

Effects of redevelopment options

COOLING

RECREATION



bare soil with scattered trees

homogeneous grassy area with tree coverage > 80% (e.g., intensely planted urban park)

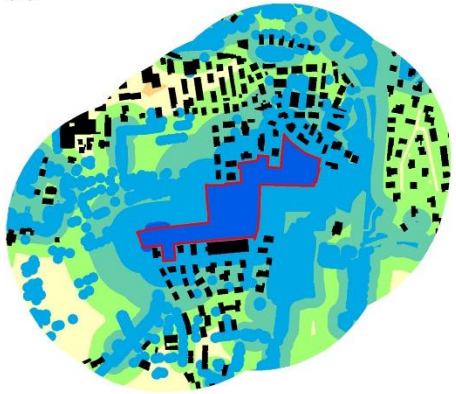
Geneletti et al., 2020; Cortinovs and Geneletti, 2018

ReNature

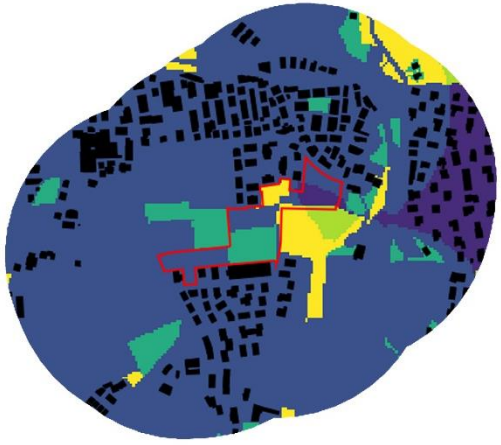
Predicting the effects of different NbS

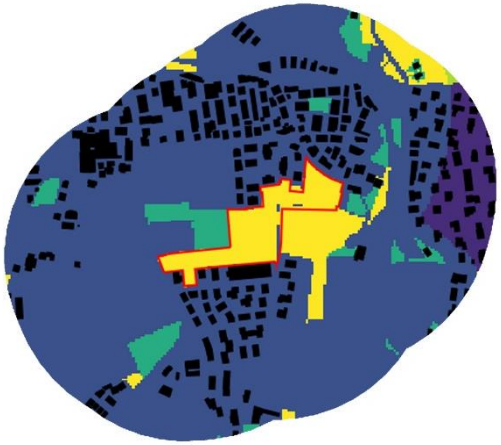
Effects of redevelopment options

COOLING



RECREATION





bare soil with scattered trees

homogeneous grassy area with tree coverage > 80% (e.g., intensely planted urban park)

Disaggregated beneficiaries

Children < 5

Elderly > 65

Other beneficiaries

Children + teenagers < 20

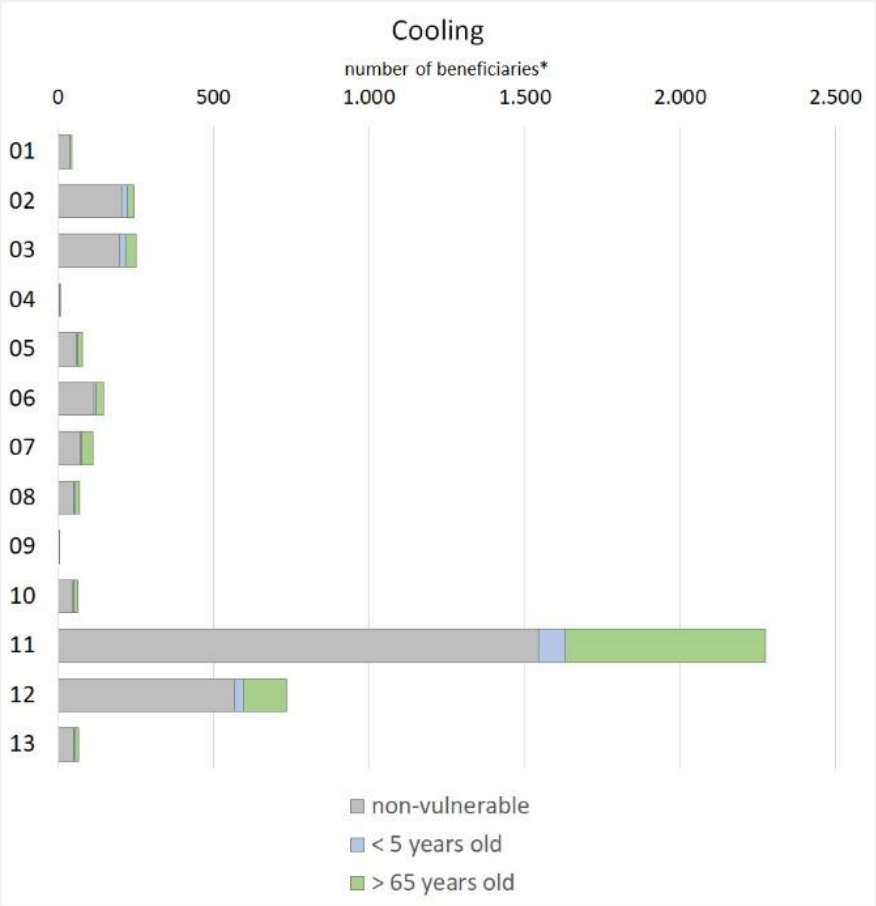
Elderly > 65

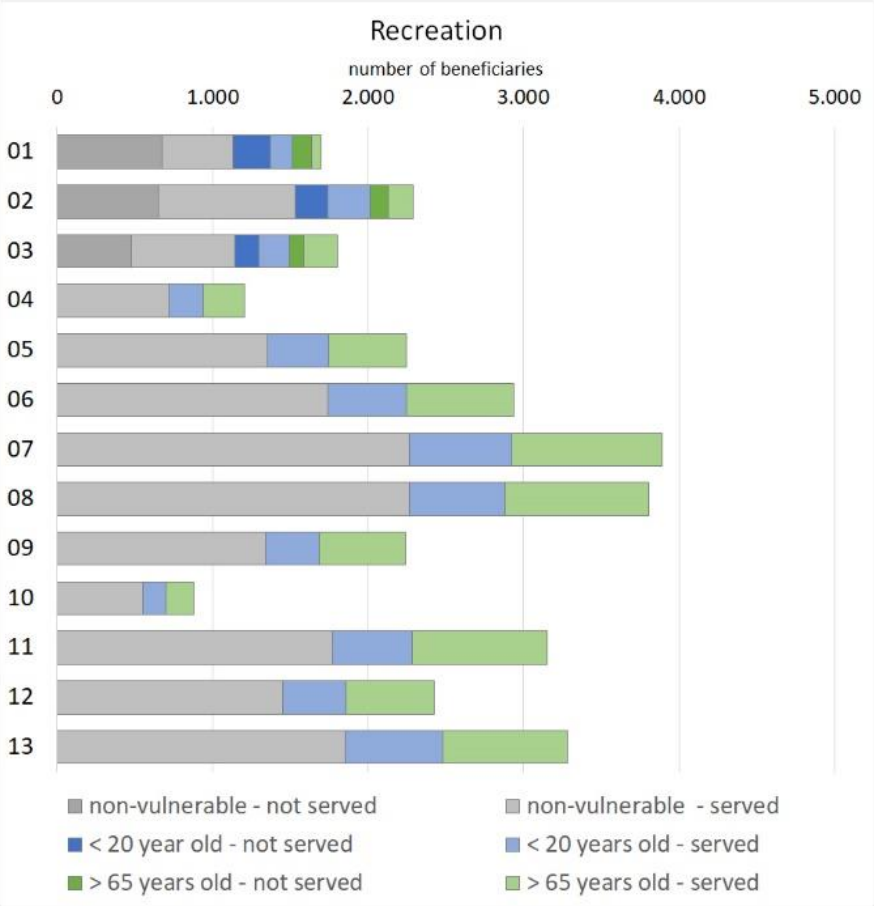
Other beneficiaries

ReNature

Geneletti et al., 2020; Cortinovs and Geneletti, 2018

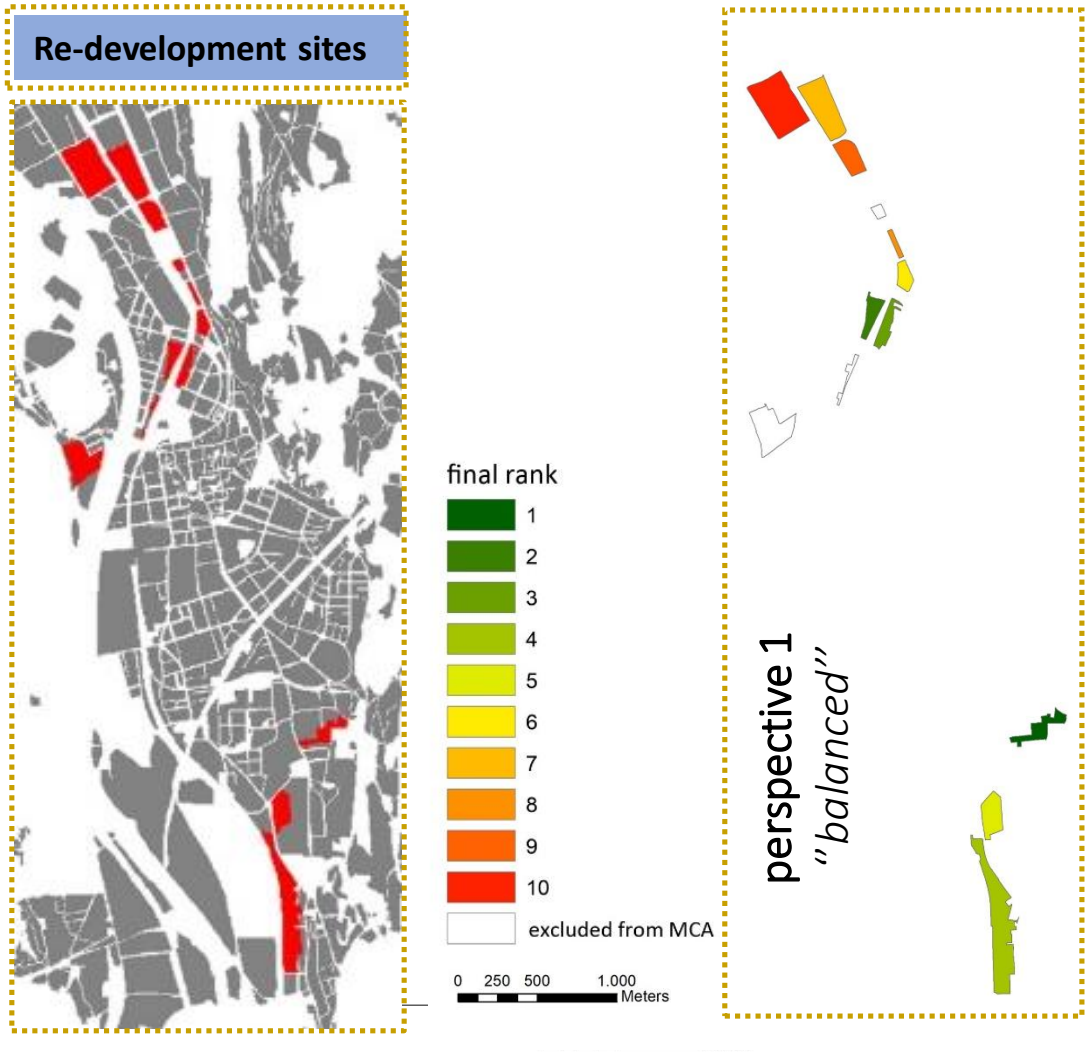
Impact assessment of NbS





ReNature

Preferred NbS siting by different perspectives



Examples of urban planning questions

Where are NbS most needed?

How should NbS be designed to maximise their benefits?

In which area the same “investment” is expected to obtain the biggest gain?

Thank you!

Planning for Ecosystem Services
@University of Trento

www.planningfores.com

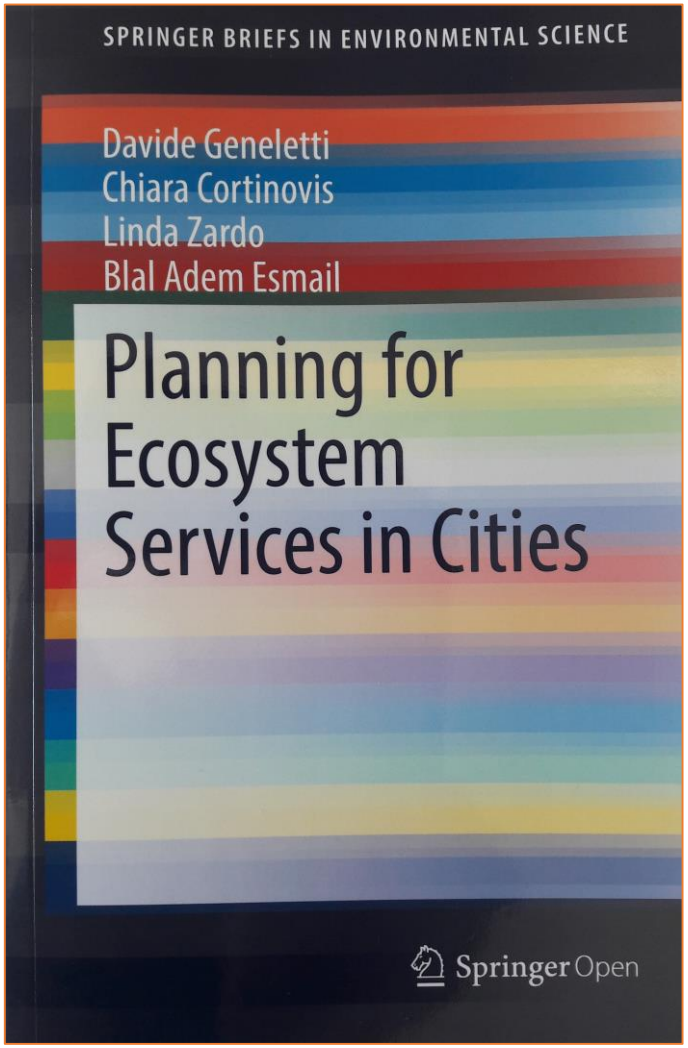







ReNature

References



Cortinovis, C., & Geneletti, D. (2019). A framework to explore the effects of urban planning decisions on regulating ecosystem services in cities. Ecosystem Services, 38, 100946. doi:10.1016/j.ecoser.2019.100946

Cortinovis C, Geneletti D (2018) Mapping and assessing ecosystem services to support urban planning: A case study on brownfield regeneration in Trento, Italy. One Ecosystem 3: e25477. doi: 10.3897/oneeco.3.e25477.

Geneletti, D, Cortinovis, C, Zardo, L, Adem Esmail, B (2020). Planning for ecosystem services in cities. Springer. https://link.springer.com/book/10.1007%2F978-3-030-20024-4

Geneletti, D., Zardo, L., Cortinovis, C. (2016) Promoting nature-based solutions for climate adaptation in cities through impact assessment. In: Geneletti, D (Ed). Handbook on biodiversity and ecosystem services in impact assessment, Edward Elgar Publishing, 428-452.