

The background of the slide is a composite image. On the left, there are architectural drawings: a floor plan at the top, a perspective view of a city street with buildings in the middle, and a cross-section of a building with a car and a tree at the bottom. On the right, there is a watercolor illustration of a city street with tall buildings, a road with a crosswalk, and lush green trees with some autumn-colored leaves. The title text is overlaid on a semi-transparent green rectangular background.

A Social-Ecological Perspective on Urban Nature and its Benefits

Filipa Grilo

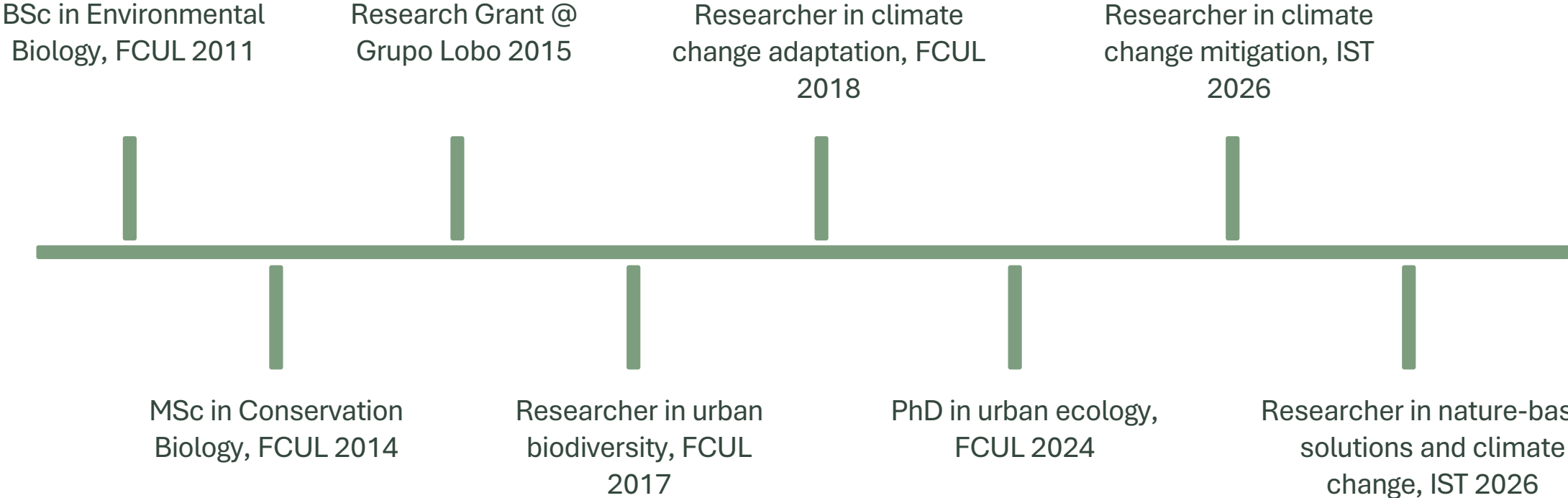
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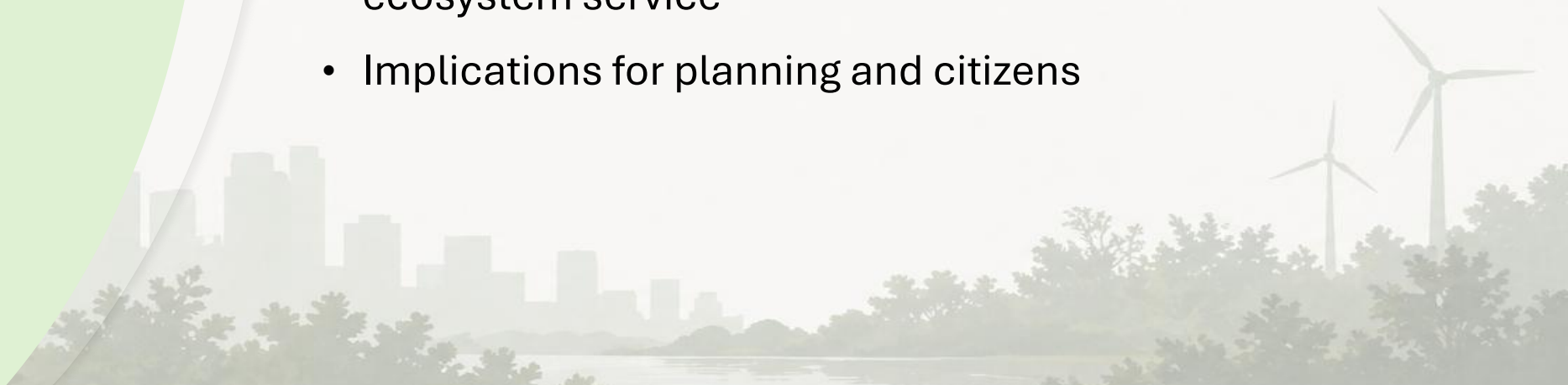
12th May 2026

Professional background



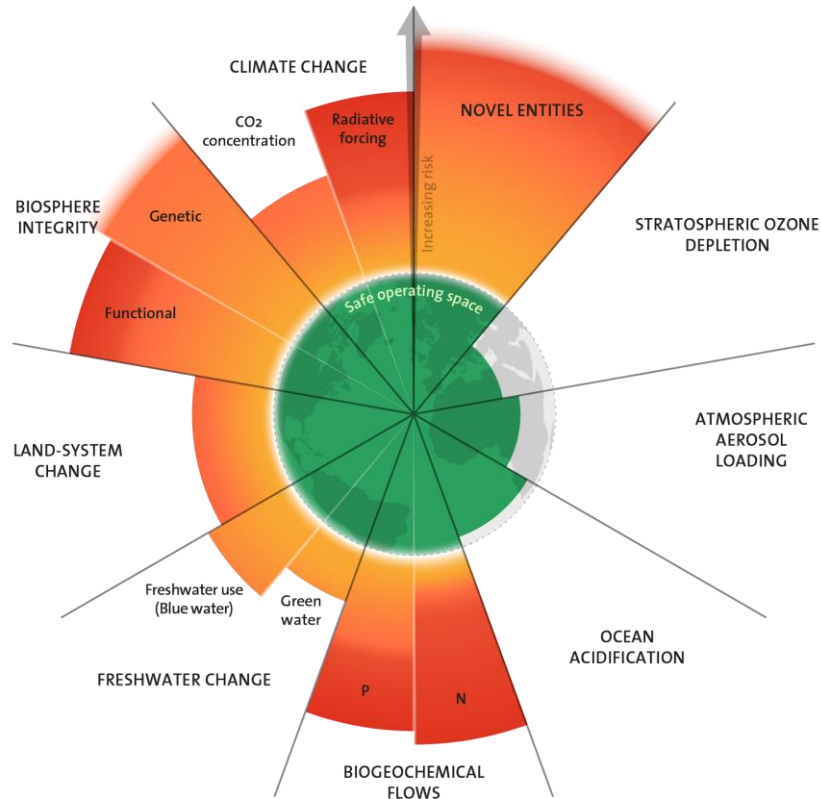
Today's talk

- Planetary boundaries, urbanization at record pace
- Implications of urbanization
- Urban green infrastructure and ecosystem services
- Functional traits and socio-ecological filters
- The Socio-Ecological Traits Framework
- The distribution of biodiversity across a city
- Functional groups of urban trees
- High-resolution models of temperature regulation as an ecosystem service
- Implications for planning and citizens

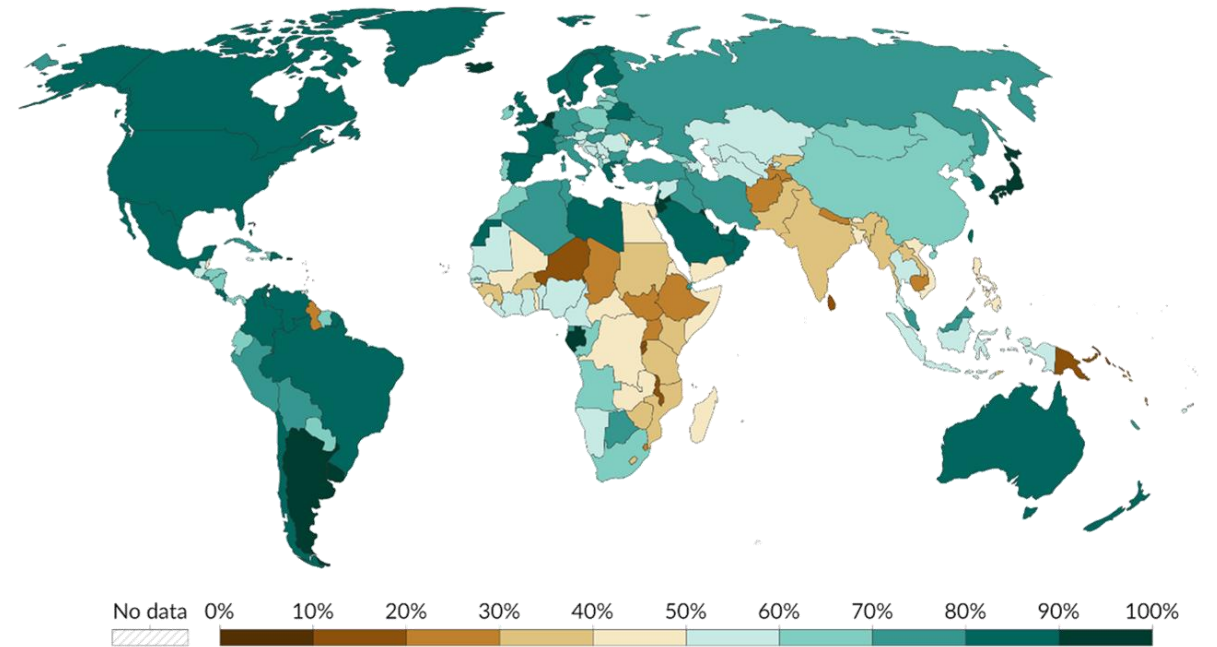


The Anthropocene and rise of urbanization – Why does this matter?

Planetary boundaries



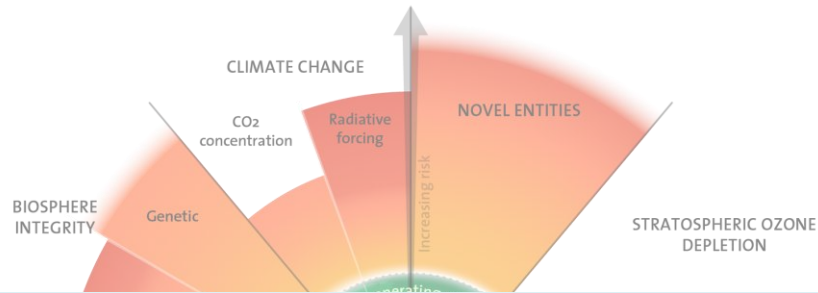
Share of the population living in urban areas in 2023



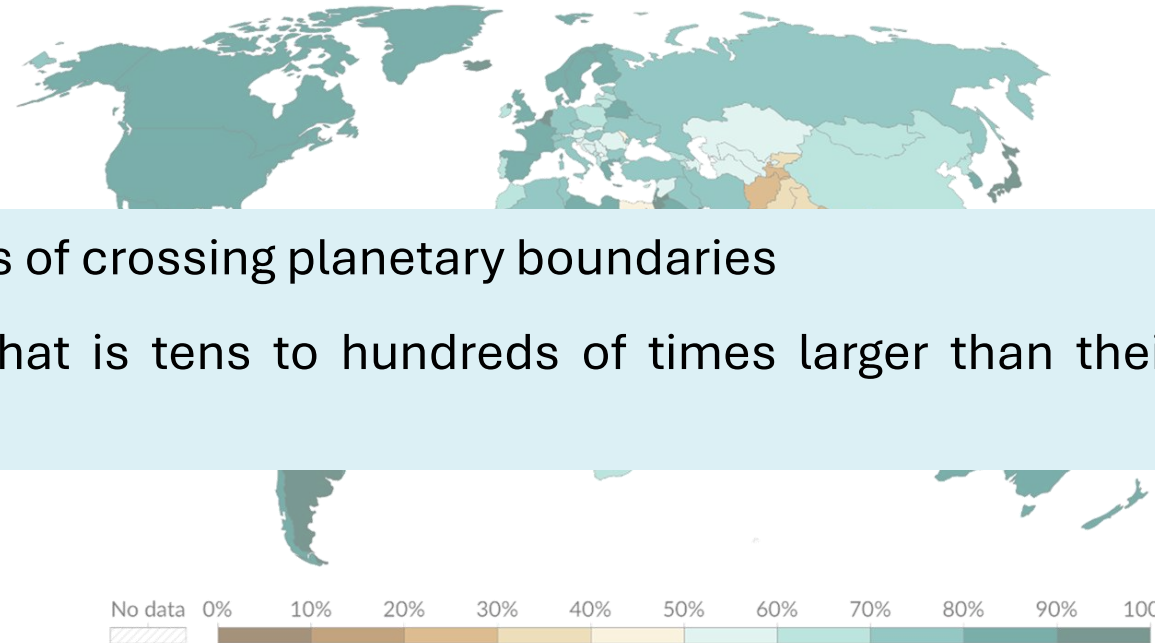
57% of the world's population lived in cities in 2022;
By 2050: ~68%

The Anthropocene and rise of urbanization – Why does this matter?

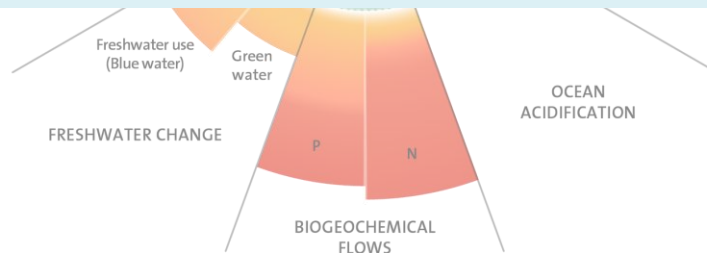
Planetary boundaries



Share of the population living in urban areas in 2023



- Urbanization is one of the main drivers of crossing planetary boundaries
- Cities have an ecological footprint that is tens to hundreds of times larger than their actual boundaries

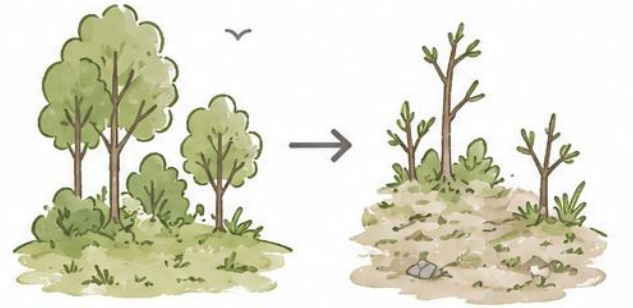
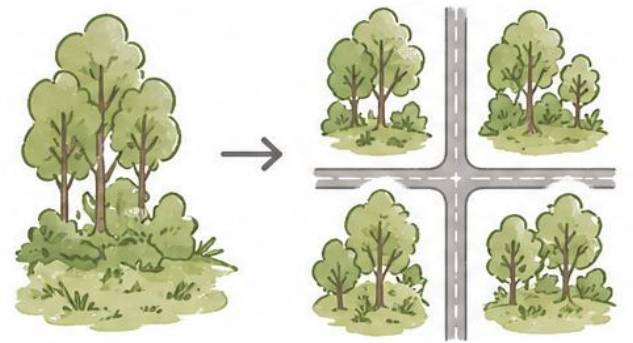
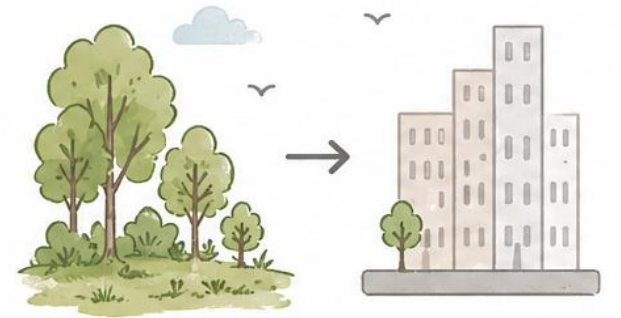


In your opinion, what is the biggest challenge cities face today?



Implications of an urbanized world

Loss, fragmentation, deterioration of (semi)natural habitats



Implications of an urbanized world

Loss, fragmentation, deterioration of (semi)natural habitats

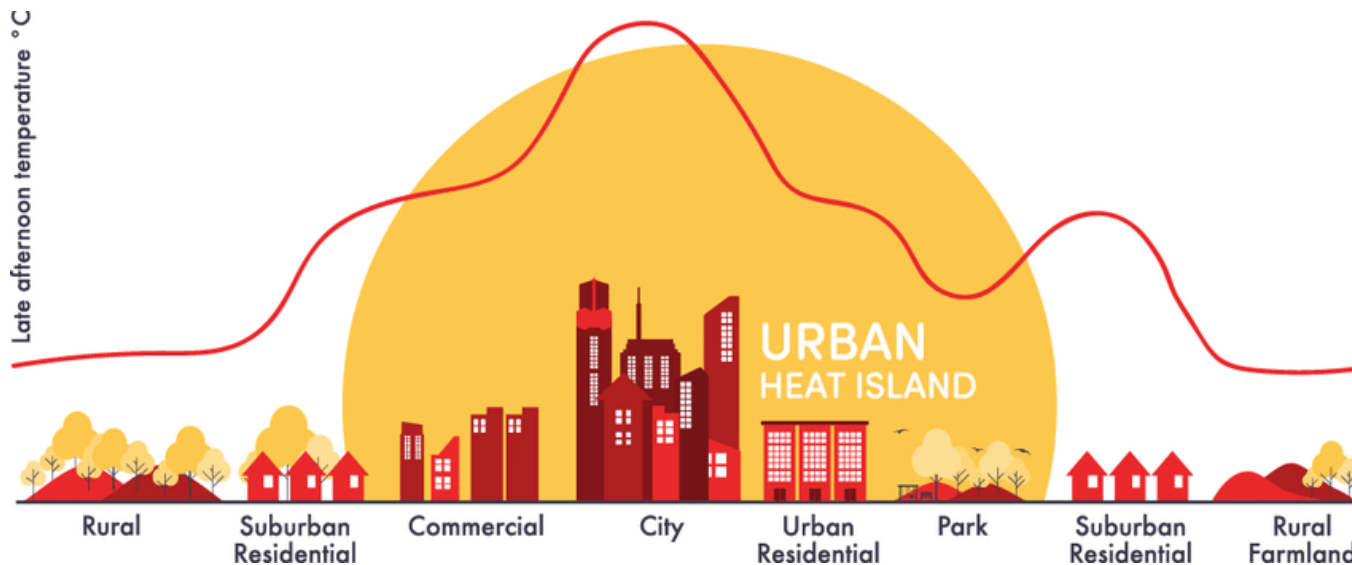
Decreased air and water quality and changes in natural water drainage patterns

Implications of an urbanized world

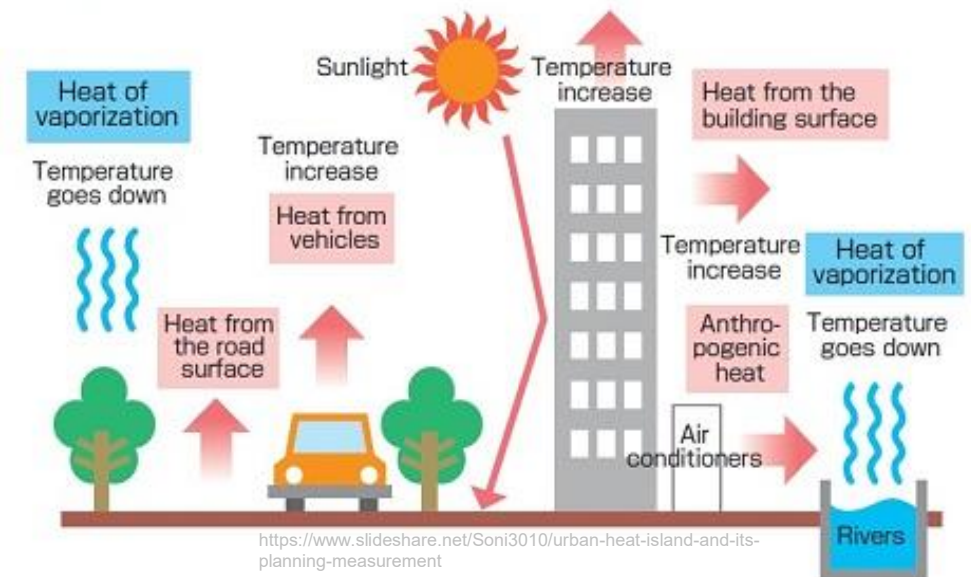
Loss, fragmentation, deterioration of (semi)natural habitats

Decreased air and water quality and changes in natural water drainage patterns

Alterations in microclimate



● How the Heat Island Phenomenon occurs



Implications of an urbanized world



Direct and indirect impacts on ecosystems, biodiversity and humans

Limits species pools and leads to biotic homogenization 🌱

Accelerates the pace of global environmental changes 🌍

Impacts human well-being, and mental and physical health 😞

BUT:

with proper planning, cities can also become **reservoirs of regional biodiversity**

Green infrastructure provides important ecosystem services

It's not just parks, it's a *system*

Neighborhood trees

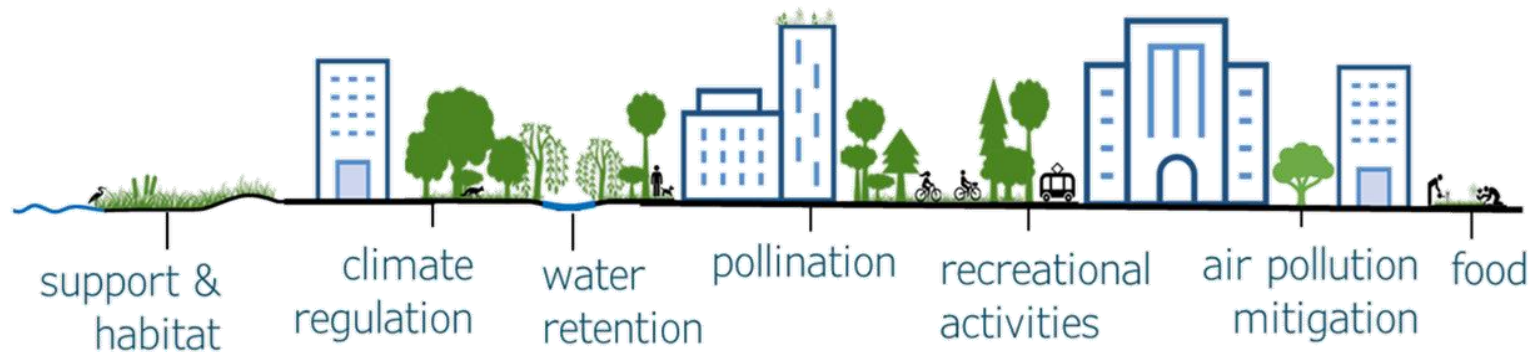
Pocket parks and trees in streets, squares and avenues are the most abundant public green element in dense urban matrices

Green roofs & walls

Hybrid ecological-technological systems that extend nature into the built environment

Parks & corridors

Larger green spaces and ecological corridors enabling fauna dispersal across the urban matrix

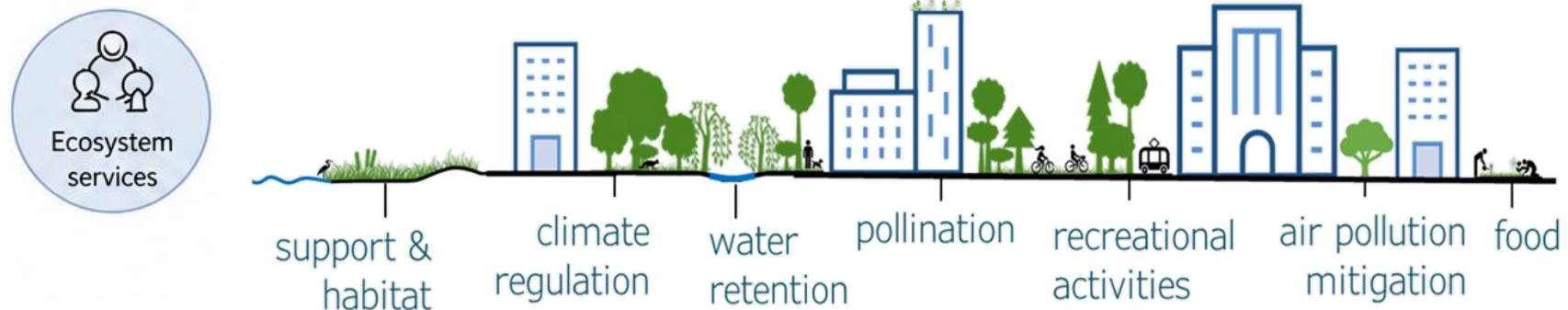


Green infrastructure provides important ecosystem services

- **Provisioning** — food (allotment gardens)
- **Regulating** — climate regulation, air quality, stormwater management, carbon capture, biodiversity habitat
- **Cultural** — sense of place, recreation, social cohesion, mental & physical health

Neighborhood trees - element most experienced by city dwellers daily.

Their role has shifted from **aesthetic** to **multifunctional**, but this potential is often underutilized.





Think of a green space near where you live.
What services does it provide?
Who benefits from it?

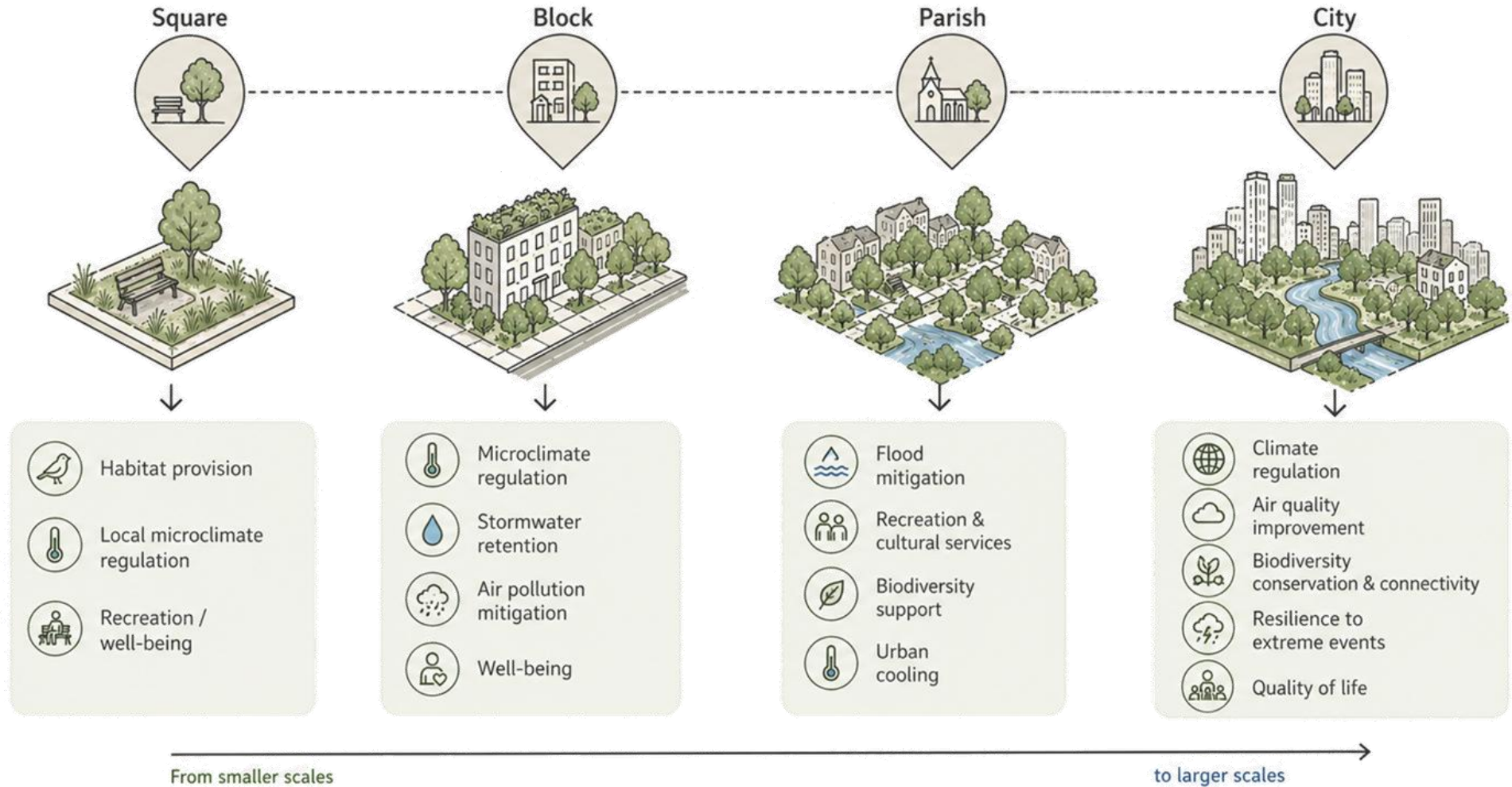
Green infrastructure provides important ecosystem services



From broader to finer scales

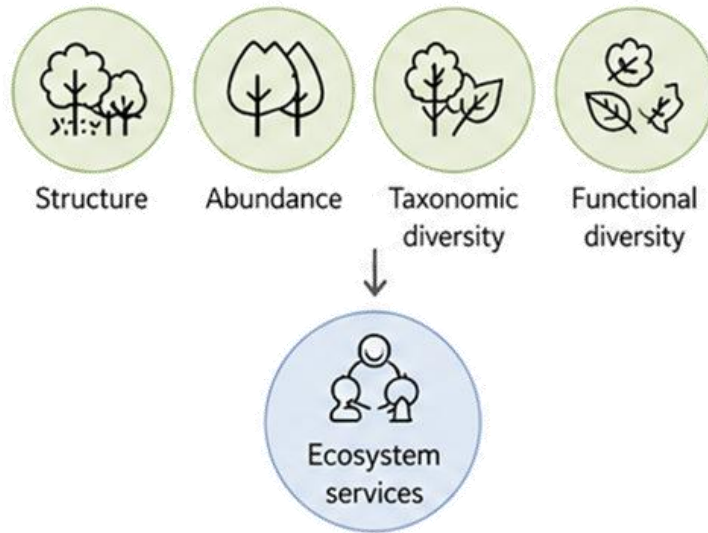


Green infrastructure provides important ecosystem services



Green infrastructure provides important ecosystem services

Through different biodiversity facets



From broader to finer scales

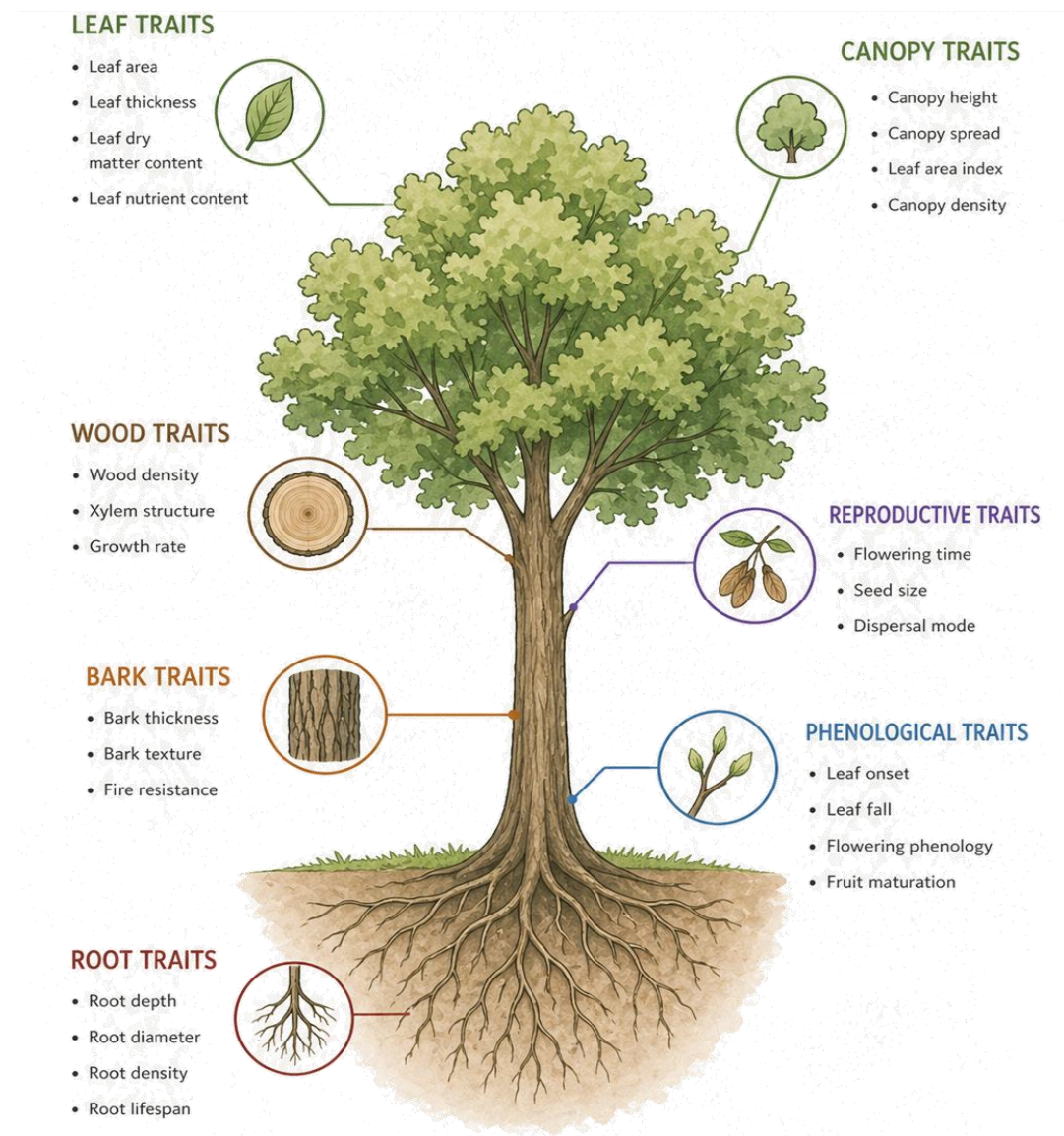


Traits: a toolkit of ecological functions

Taxonomic tell us which tree was planted, functional traits tells us their functions

Urban biodiversity needs to be seen as a “toolkit of functions”

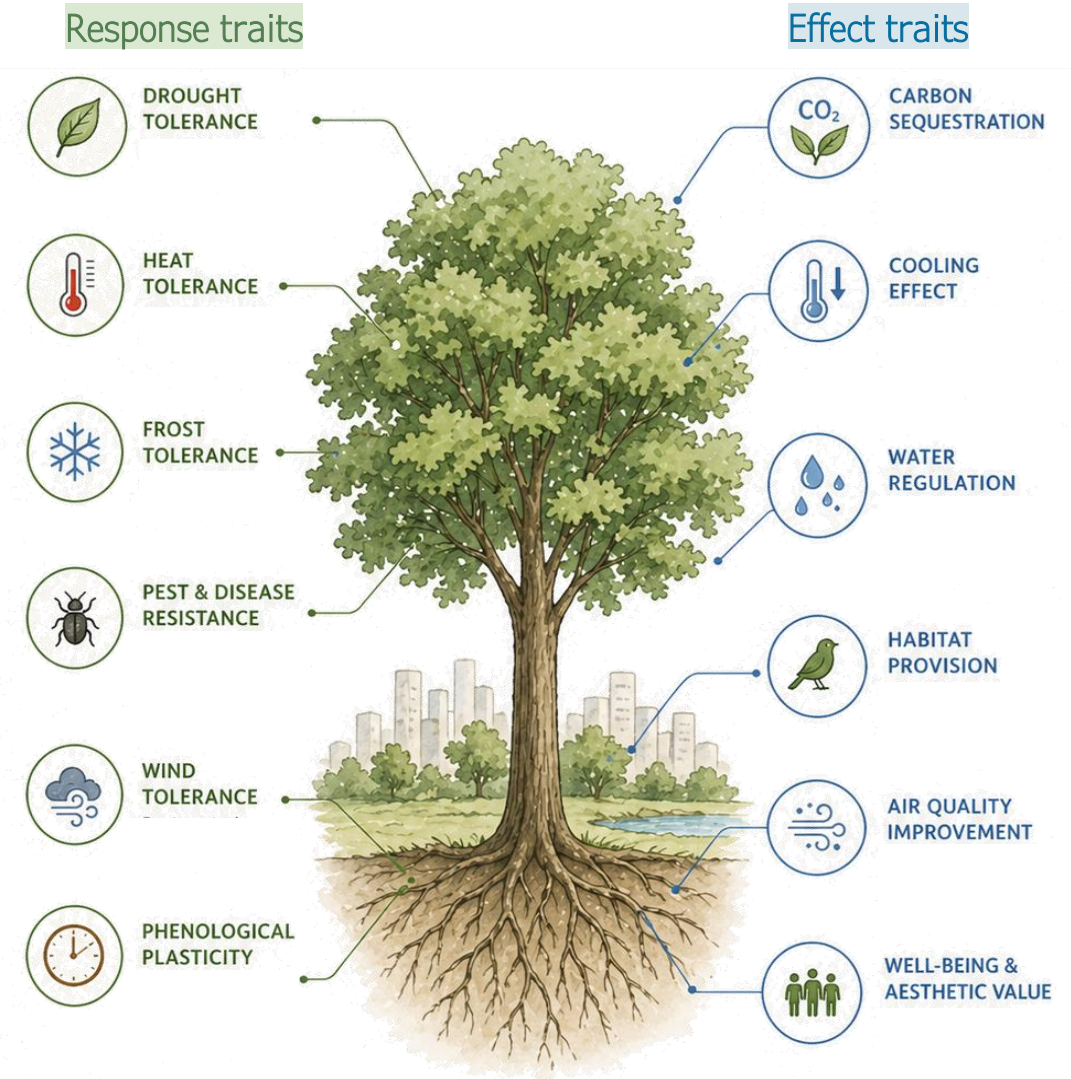
Traits are linked to spread, regeneration, tolerances to disturbances, and the delivery of ecosystem services



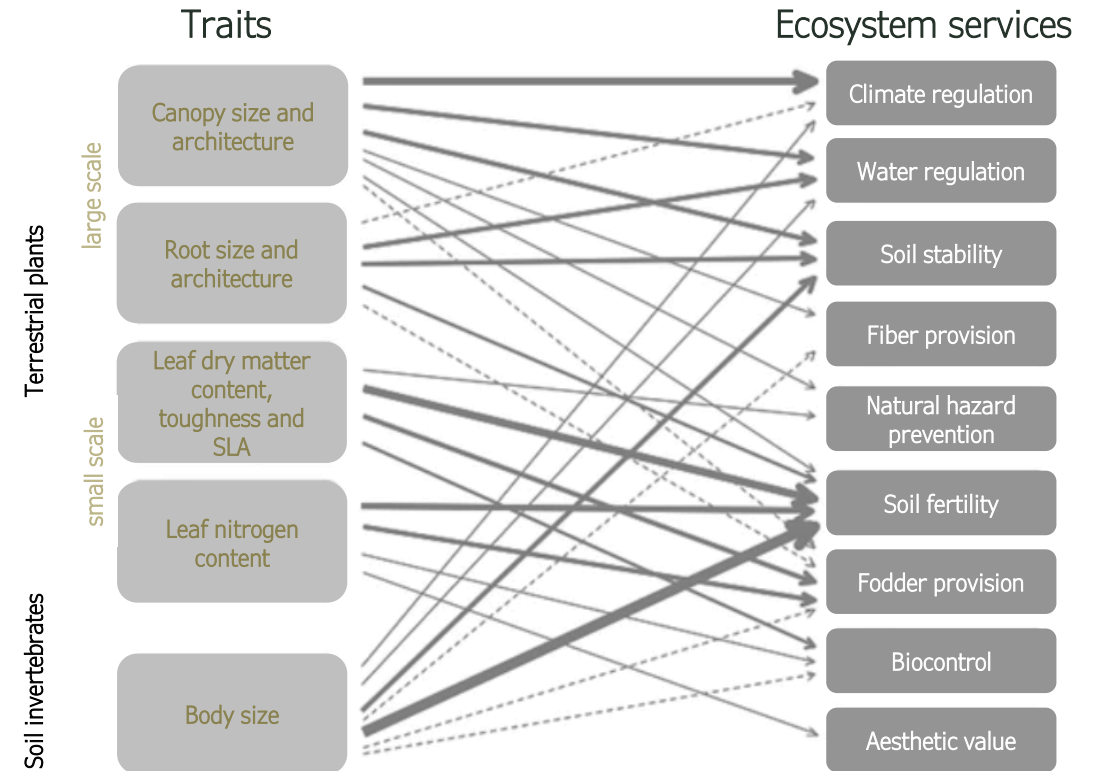
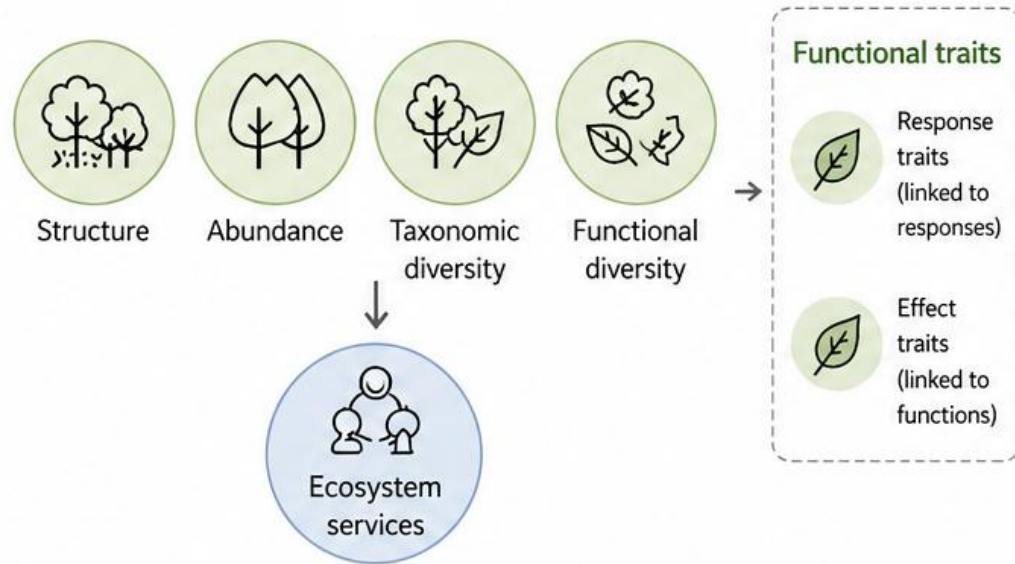
Traits: a toolkit of ecological functions



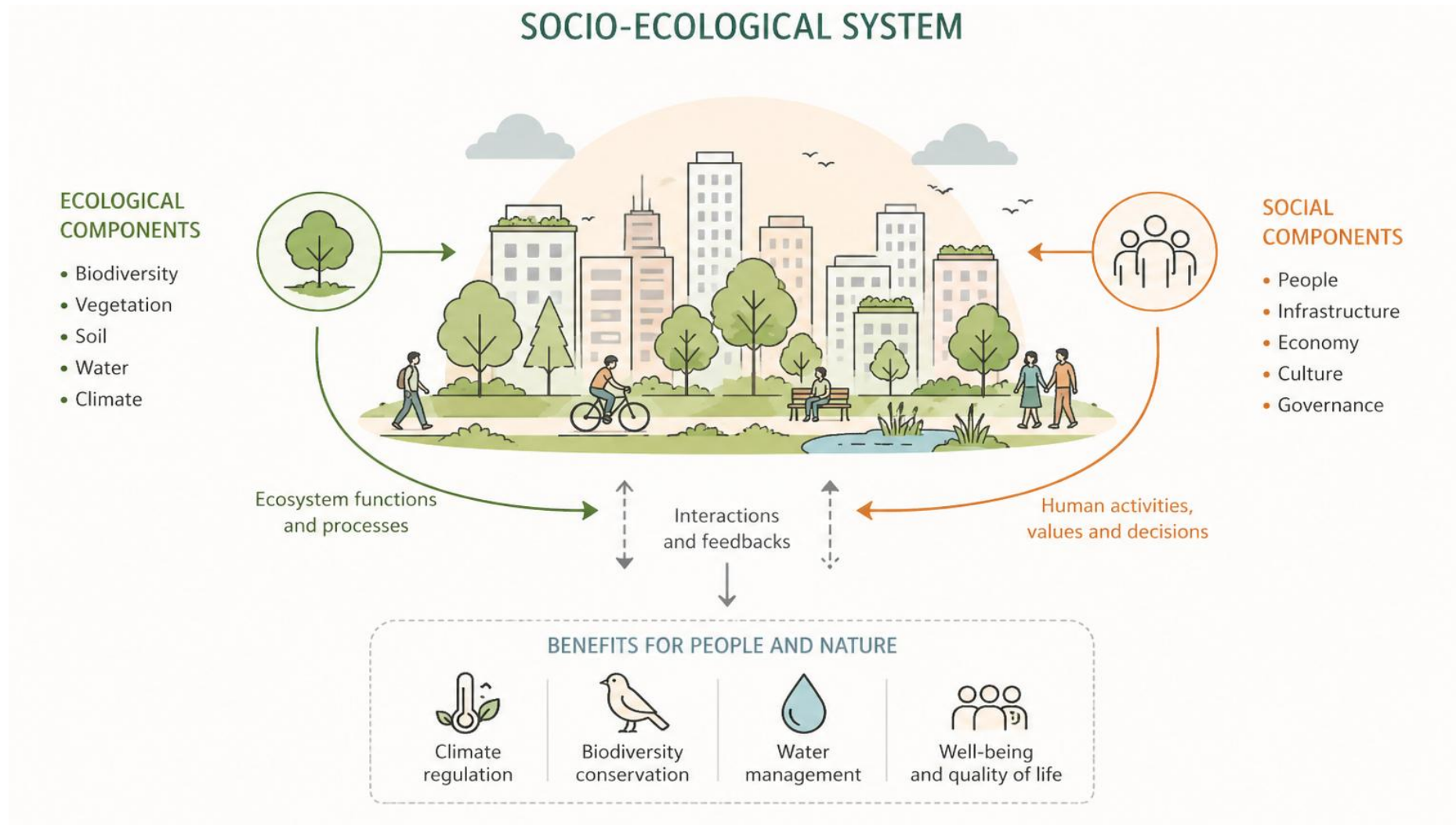
- Response and effect traits can overlap, diverge, conflict
- When response and effect traits **overlap**, a stress event can simultaneously reduce the species' tolerance AND its service delivery
- Example: high temperatures cause early leaf shedding (response) which reduces shading and evapotranspiration (effect) → less cooling → more heat stress → human well-being is affected



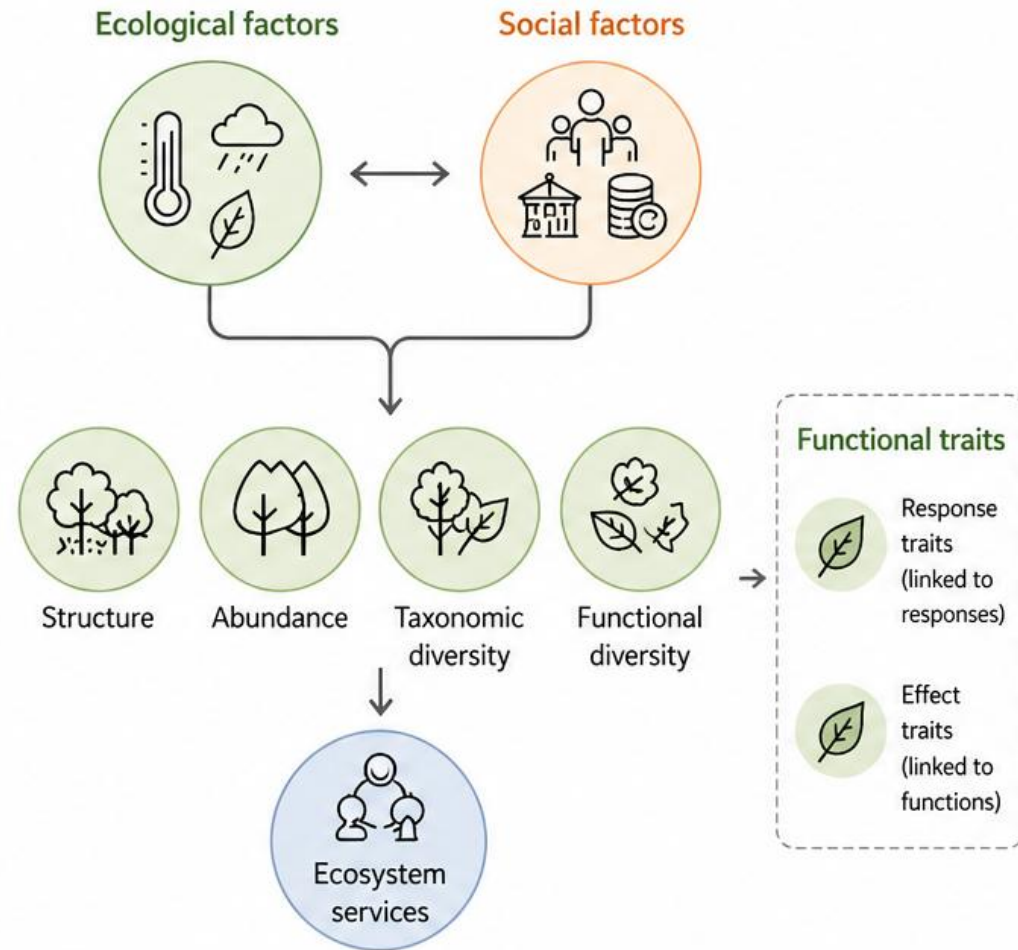
Green infrastructure provides important ecosystem services



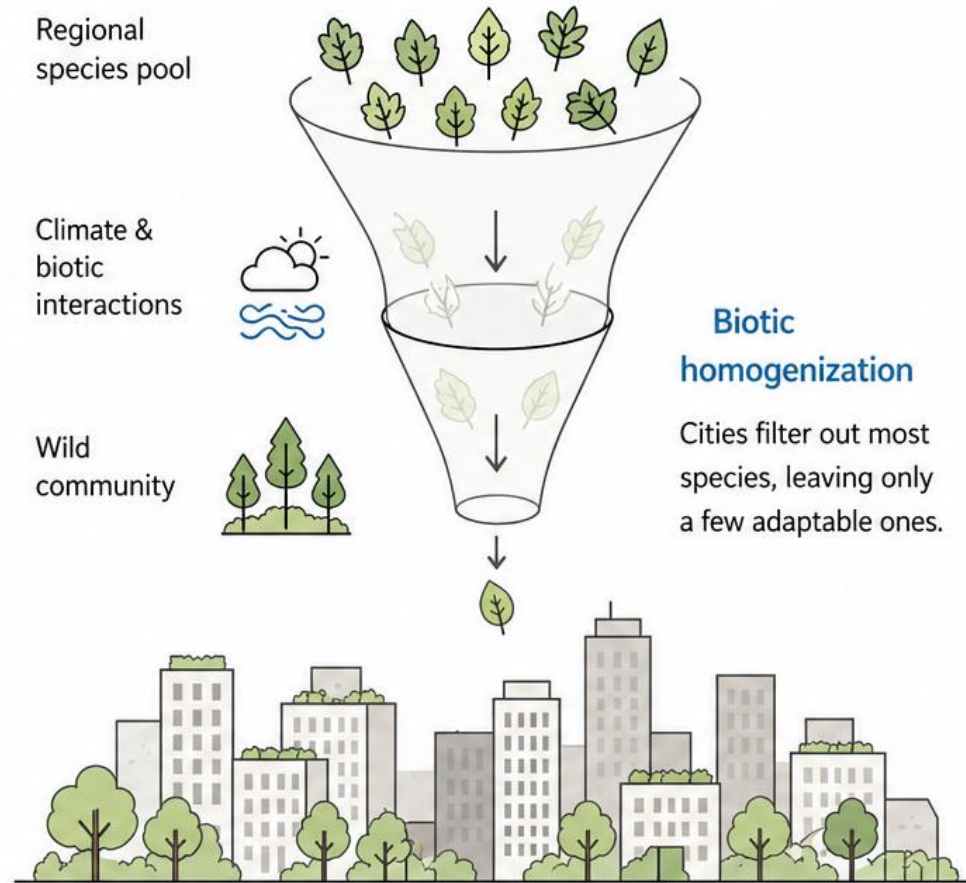
Urban biodiversity's services delivery is influenced by **social** and **ecological** factors



Urban biodiversity's services delivery is influenced by **social** and **ecological** factors



Urban biodiversity's services delivery is influenced by **social** and **ecological** factors



Ecosystem services in cities result from the filtering of biodiversity through ecological processes and **social** contexts.



Climate regulation



Biodiversity support

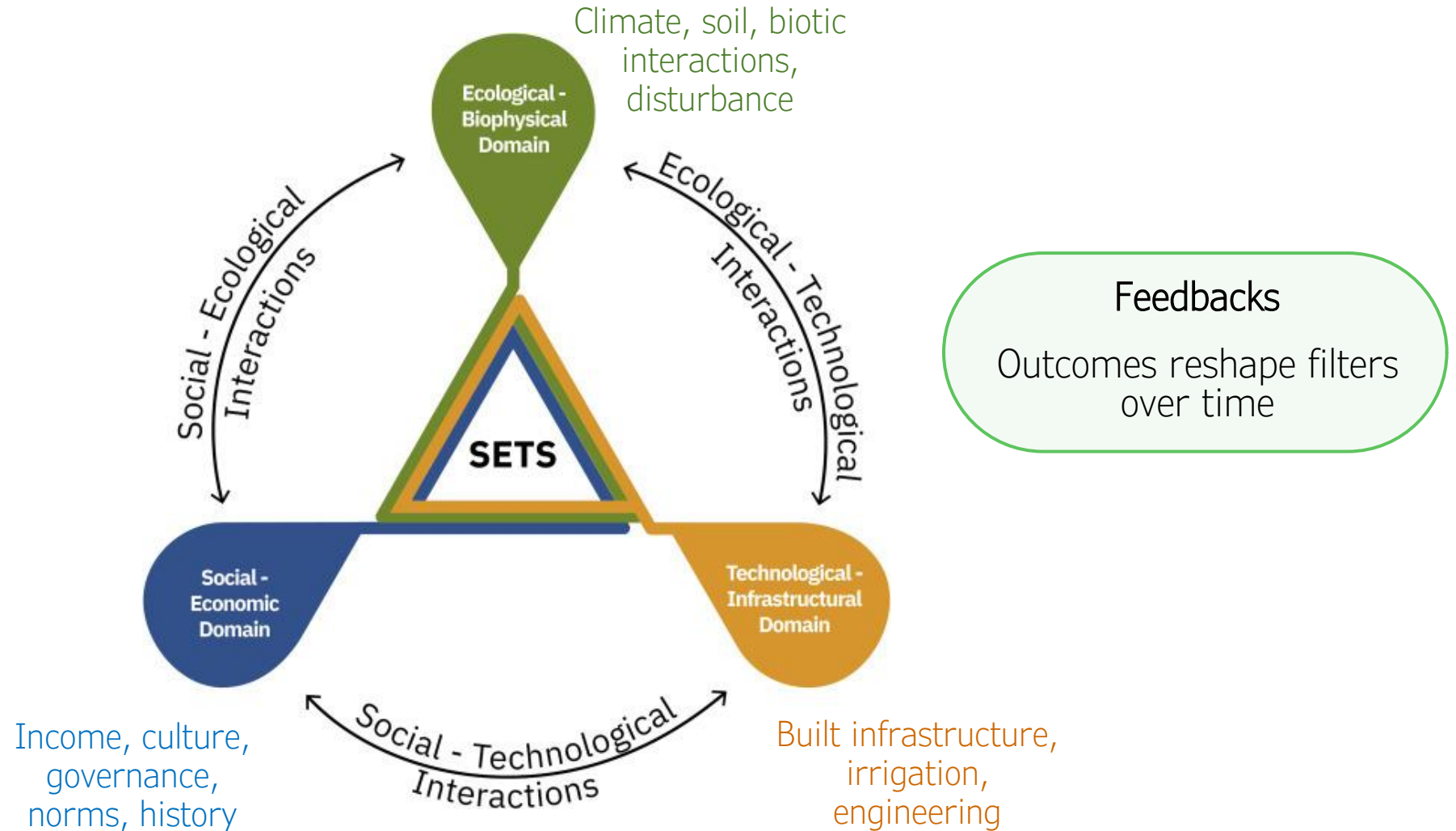


Water regulation



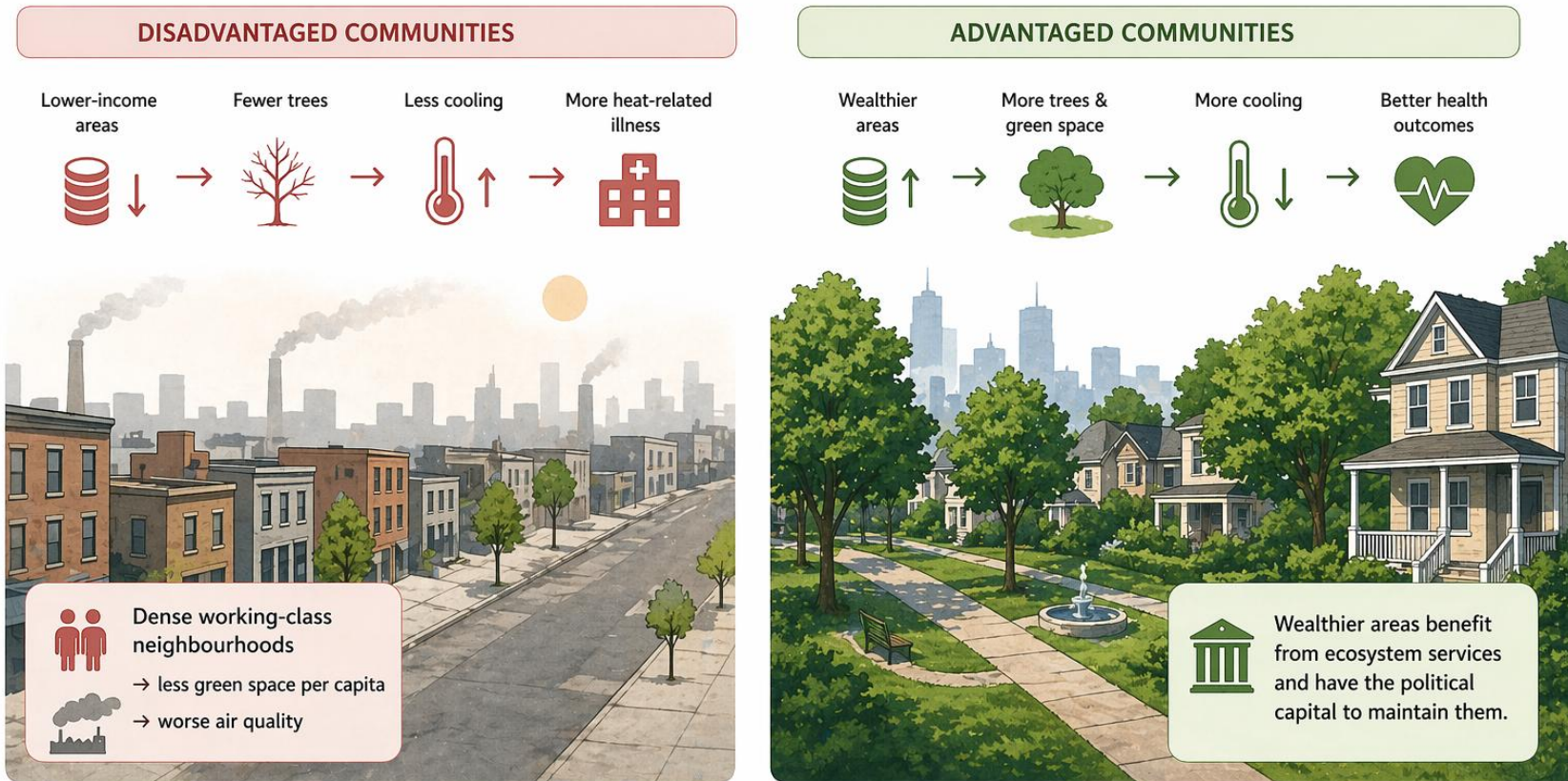
Human well-being

Urban areas as Socio-Ecological-Technological Systems

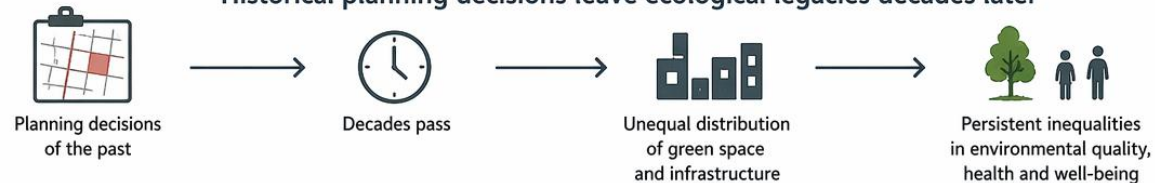


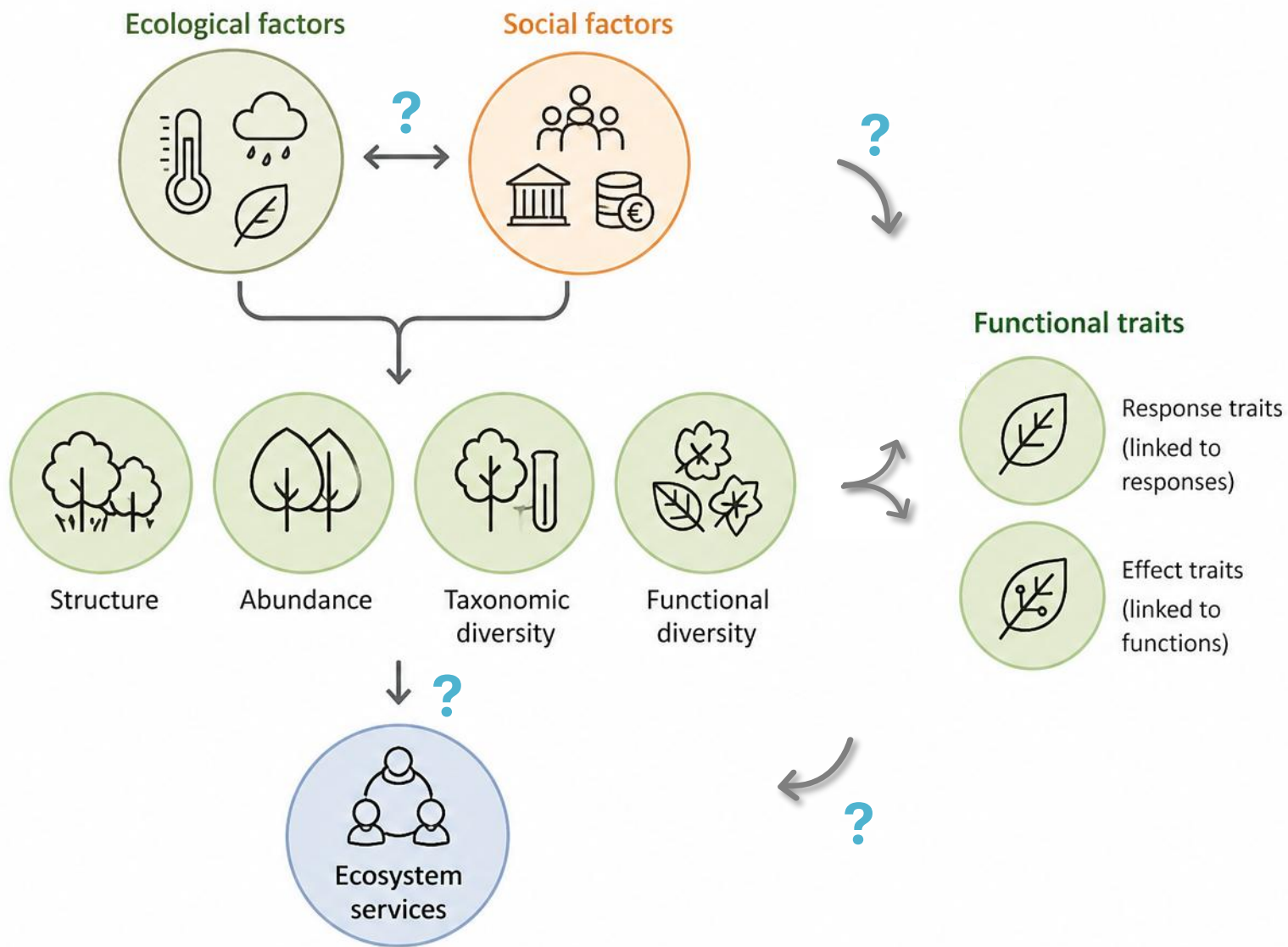
Urban biodiversity's services delivery is influenced by social and ecological factors

Social filters ≠ neutral - can encode historical inequalities



Historical planning decisions leave ecological legacies decades later





What is the gap?

Need for urban studies that integrate social and ecological dimensions, emphasizing their connections to different biodiversity facets and ecosystem services delivery

Rationale

Conceptual framework

- 1 How are species traits, social and ecological filters, and ecosystem services linked in urban systems?

Theoretical application of the framework rationale

- 2 How are trees' biodiversity facets distributed across a historical Mediterranean city?
- 3 How is tree abundance and diversity associated with social and ecological factors?

Nature-based solutions put into practice

- 4 What factors influence microclimate at a high spatial resolution?

biological facets



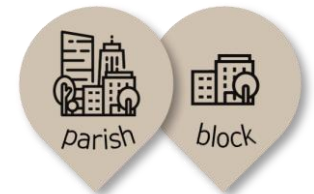
spatial scale



tree level



tree level



green space level tree level



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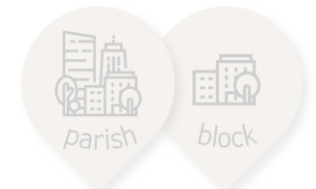
biological facets



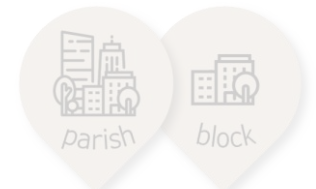
spatial scale



tree level



tree level



green space level tree level



What are the linkages between species traits, social-ecological filters, and ecosystem services in urban systems?

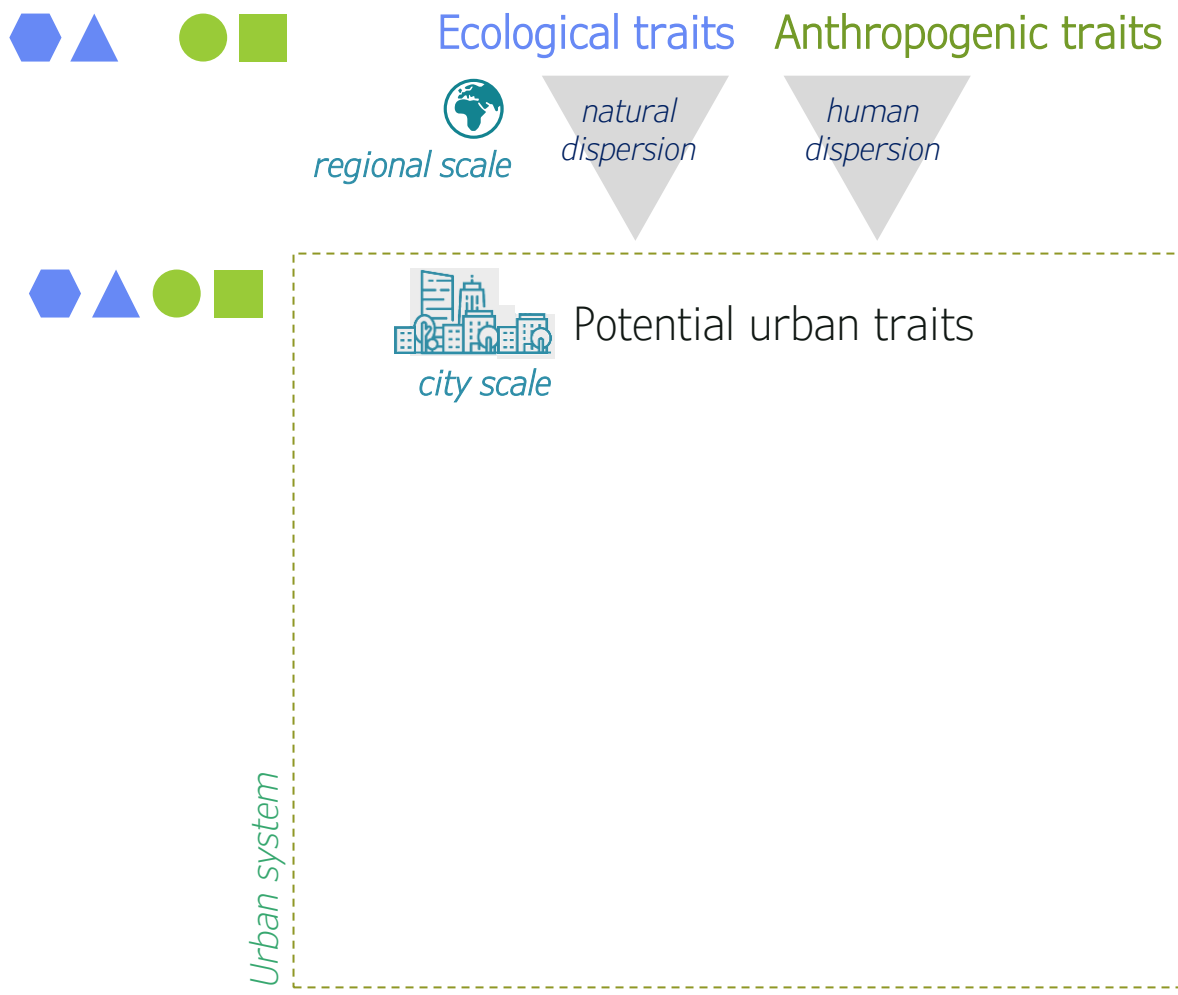
Social-Ecological Traits Framework

Urban biodiversity is not just shaped by **which species are present**, but by **how traits are expressed** under social and ecological filtering.

The framework shows not just **which** filters act, but **how** they alter the phenotypic expression of traits, with downstream consequences for ecosystem services and human well-being.

What are the linkages between species traits, social-ecological filters, and ecosystem services in urban systems?

Social-Ecological Traits Framework

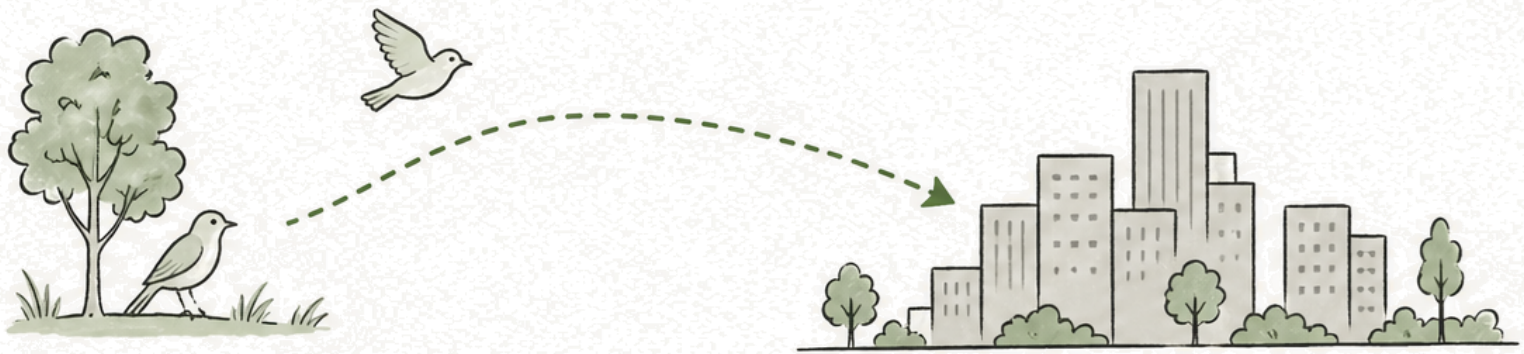


What are the linkages between species traits, social-ecological filters, and ecosystem services in urban systems?

Two types of trait combinations arrive in cities:

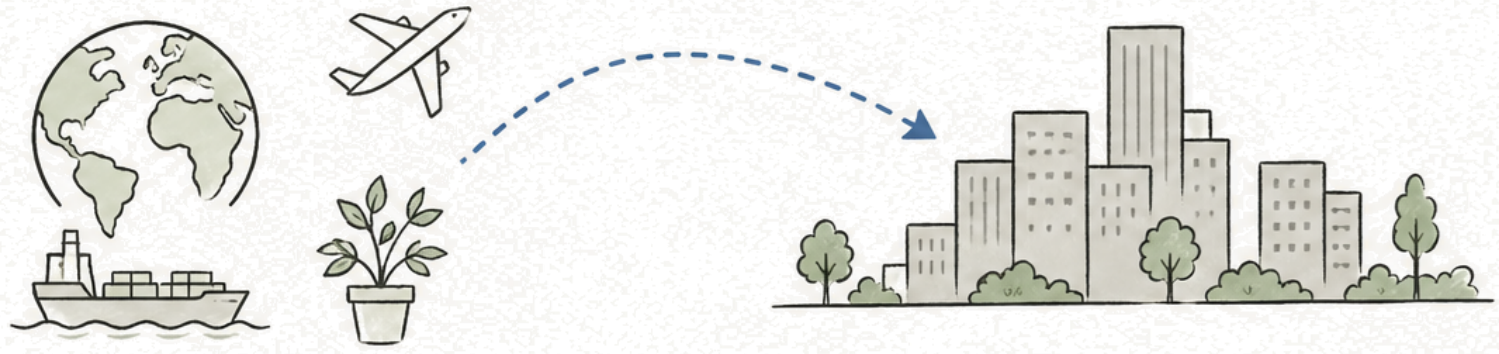
Ecological traits

from native species that naturally disperse to urban areas (e.g., opportunistic species)



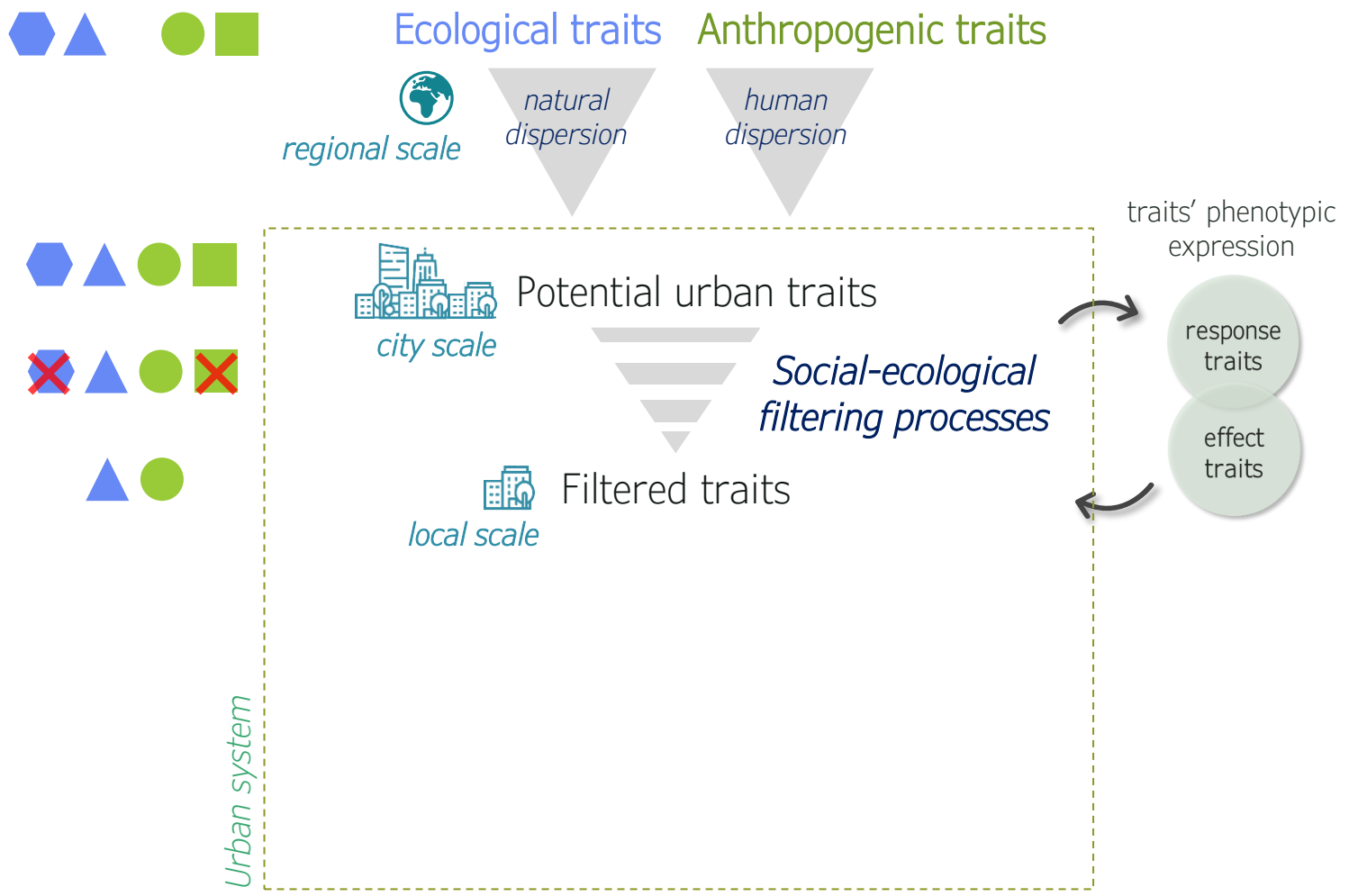
Anthropogenic traits

from species introduced through human-mediated dispersion (intentionally or unintentionally), sourced from anywhere in the world



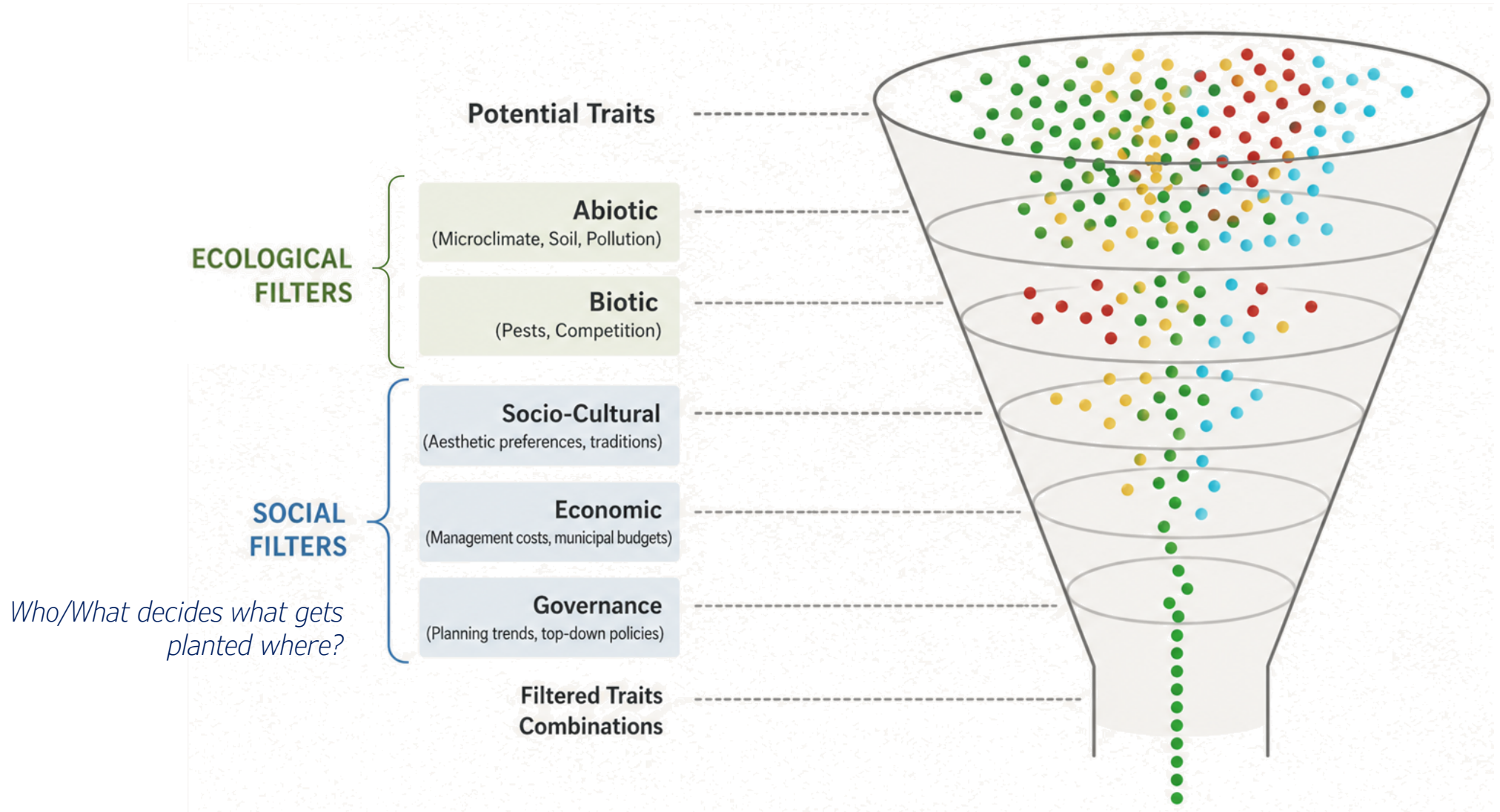
What are the linkages between species traits, social-ecological filters, and ecosystem services in urban systems?

Social-Ecological Traits Framework



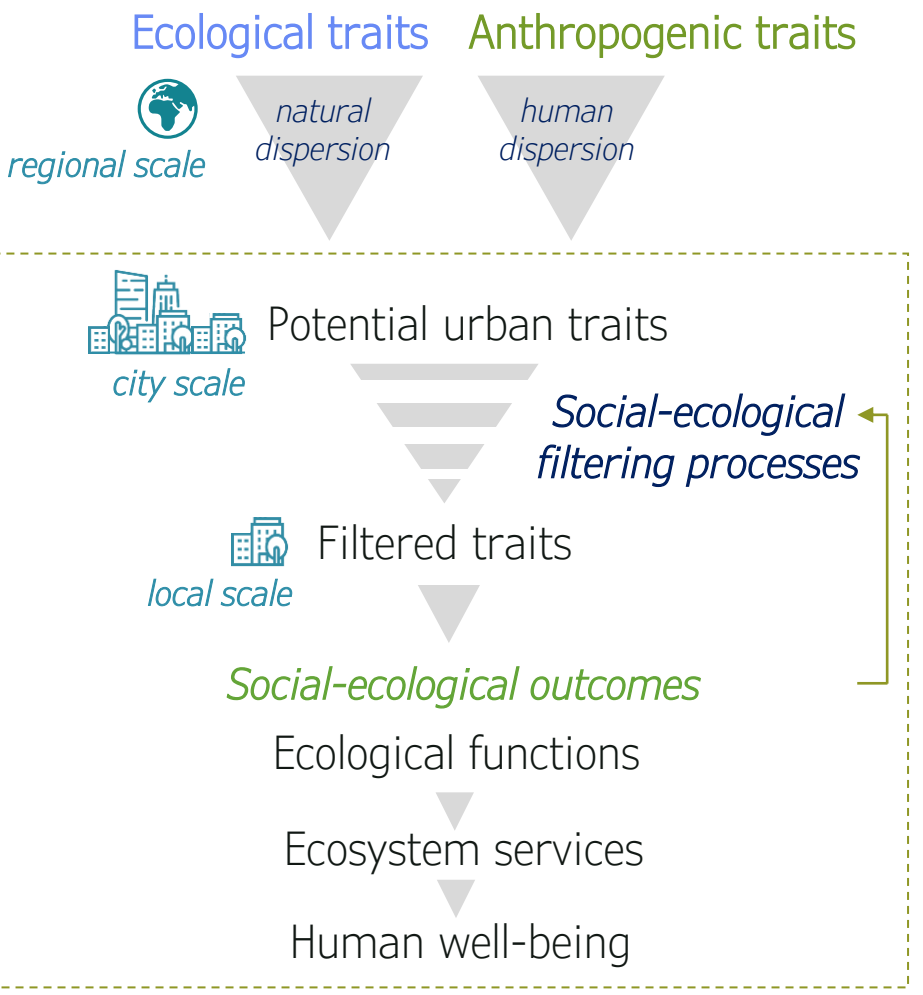
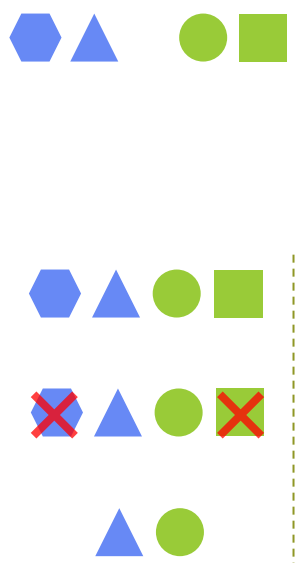
What are the linkages between species traits, social-ecological filters, and ecosystem services in urban systems?

Social-ecological filtering processes



What are the linkages between species traits, social-ecological filters, and ecosystem services in urban systems?

Social-Ecological Traits Framework



Functional approaches support the incorporation of biodiversity in urban planning for ecosystem services effectiveness

Outcomes influence the filters.
Ex: a cooler neighbourhood attracts investment, changing governance

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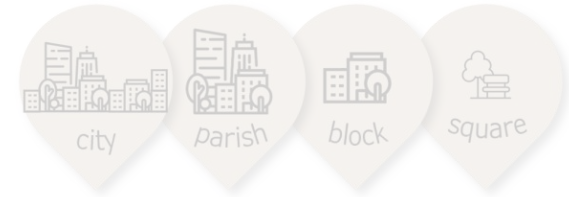
Nature-based solutions put into practice

- 4 What factors influence microclimate at a high spatial resolution?

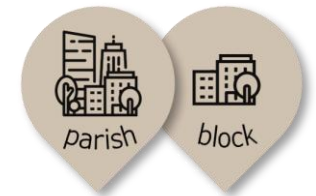
biological facets



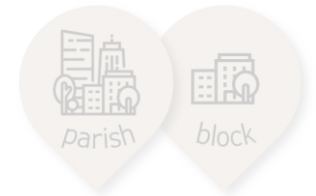
spatial scale



tree level



tree level



green space level tree level



How are the taxonomic and functional facets of trees distributed across a historical Mediterranean city?

Biodiversity Facets

all trees
(n=+-66k)

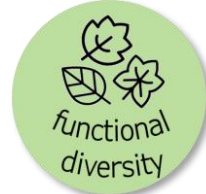


identified trees
(n=+-50k, >300spp)



species richness
Shannon index
evenness
beta diversity

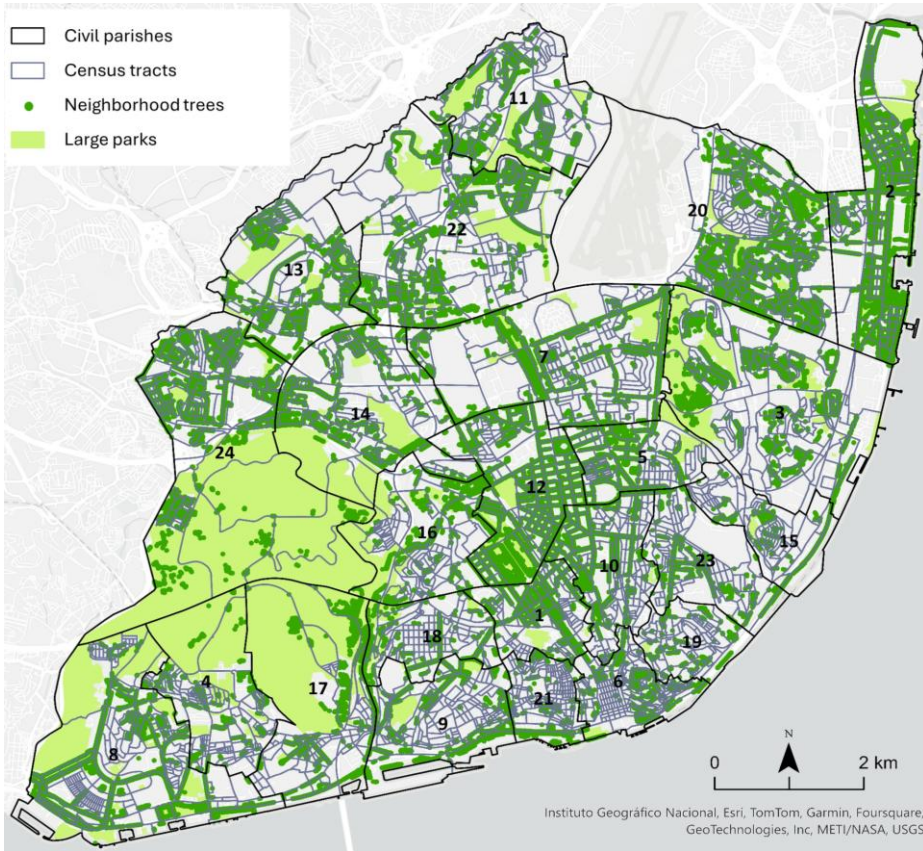
70% of identified trees
(n=+-30k, 20spp)



divergence
evenness
functional groups
(n=+-22k, 18spp)

Which traits?

- Spread & regeneration
- Tolerance to disturbances
- Ecosystem services delivery



Grilo F, et al. 2024. Where the not-so-wild things are in cities? The influence of social-ecological factors in urban trees at multiple scales. Science of the Total Environment 929, 172552.
Grilo F, et al. (in revisions). Urban trees through a functional traits' lens: Exploring the interplay between tree functional groups and social-ecological factors.

How are the taxonomic and functional facets of trees distributed across a historical Mediterranean city?

At broader scales

Abundance and diversity **unevenly distributed**
 Beta diversity and evenness indicate **dominance of few species**

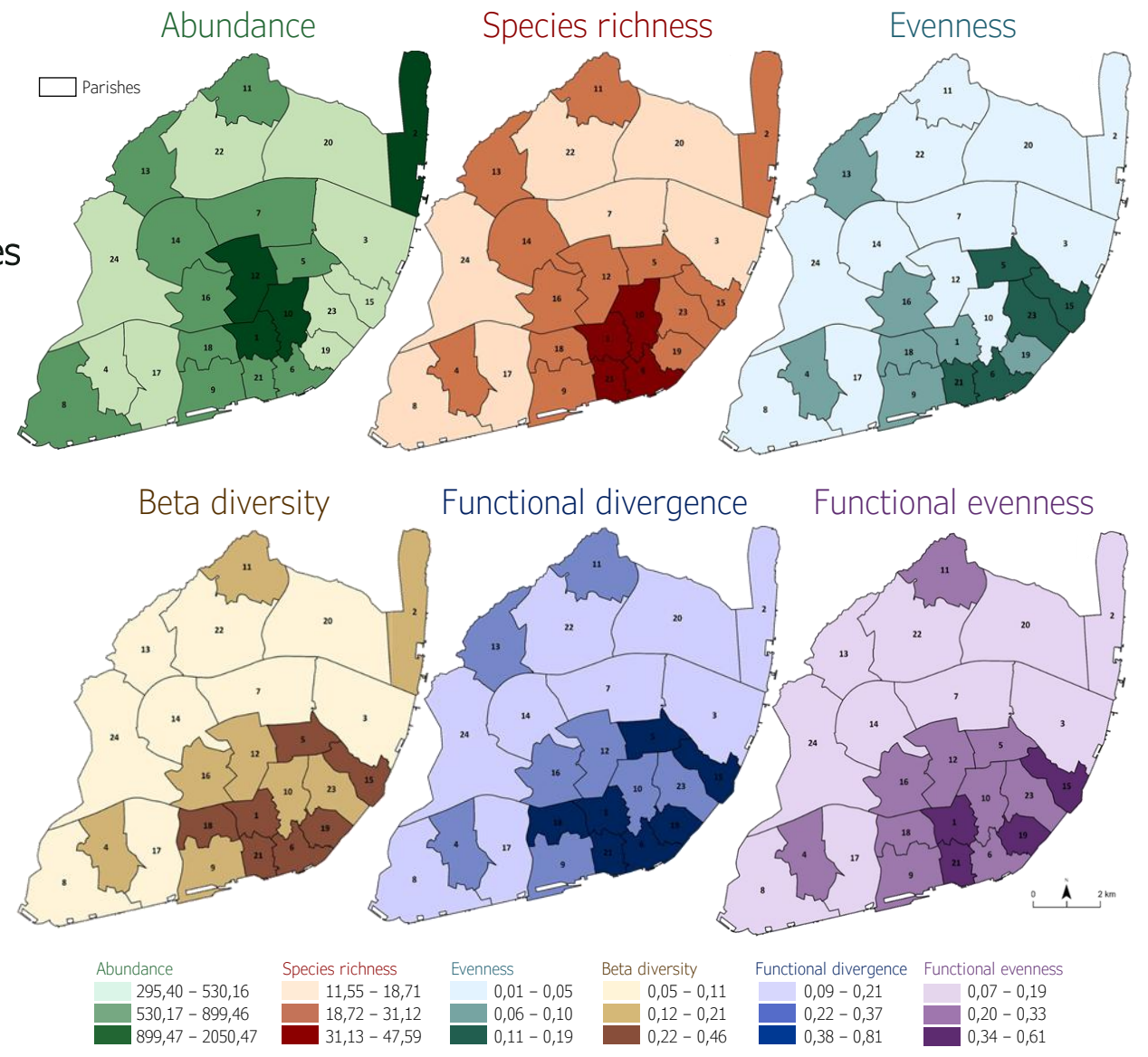
Older areas - high abundance, diversity and species replacement

Newest areas - low diversity

Different capacity to respond to changes and provide ecosystem services

Planning and management implications

- Ecological rehabilitation - reduce heat island, promote ecological corridors and well-being
- Urban planning history cumulative effect



How are the taxonomic and functional facets of trees distributed across a historical Mediterranean city?

At finer scales

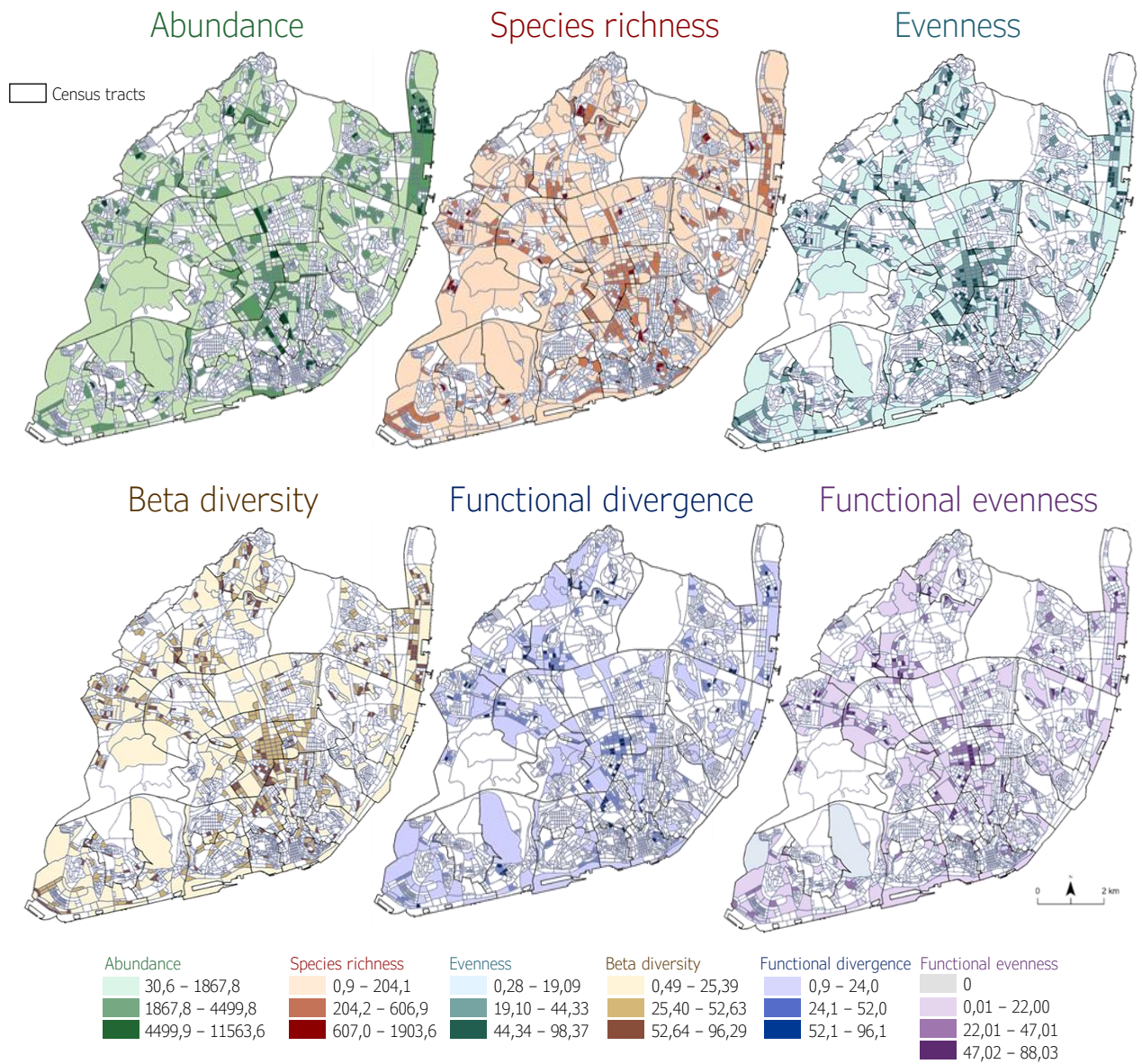
Most trees concentrated in few blocks

High local heterogeneity

Benefits provided to a small percentage of the population

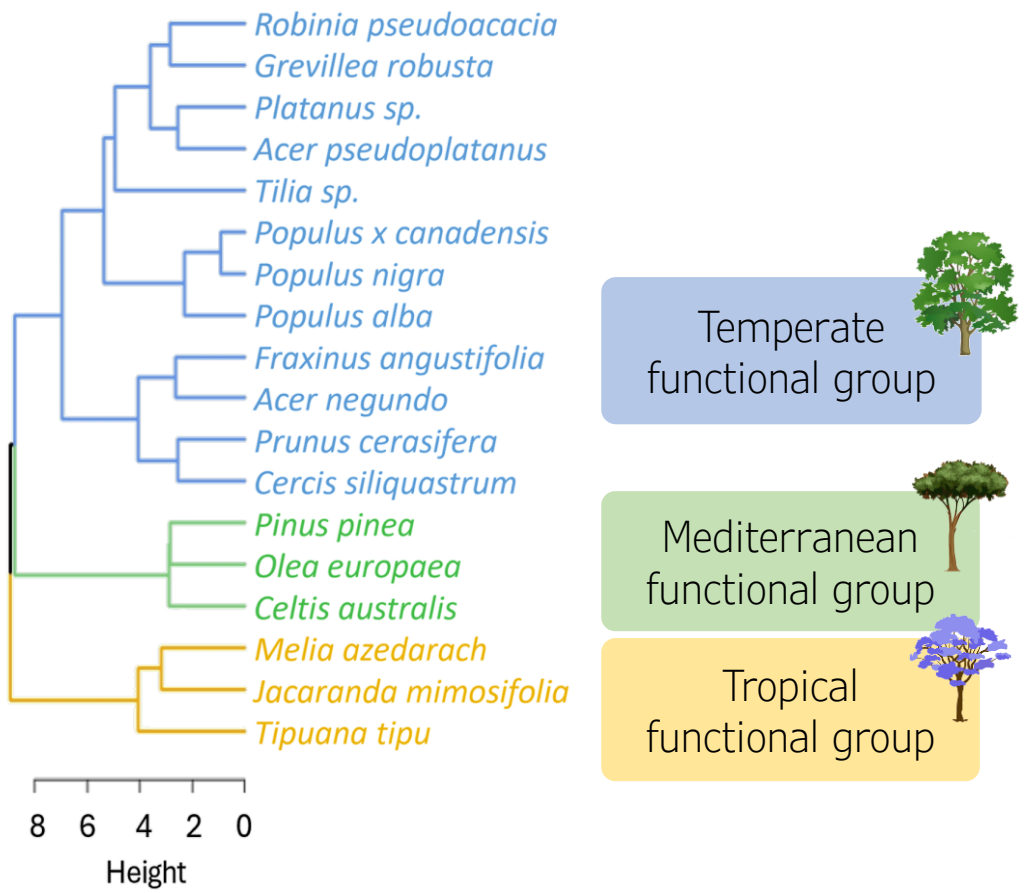
Important to not generalize results at larger scales - overestimations

- ### Planning and management implications
- Higher resolutions essential for precision management & to identify critical areas
 - Important in older cities









How are the taxonomic and functional facets of trees distributed across a historical Mediterranean city?

Species' functional grouping considering traits related to spread & regeneration, tolerance to disturbances, ecosystem services delivery



Potential for different levels of resilience to perturbation and the delivery of complementary ecosystem services

	Continental Group	Scale: ~11,167 trees (The vast majority)	Traits: Temperate climate preference, rapid growth, deciduous.	 High irrigation need. Low drought tolerance.
	Mediterranean Group	Scale: ~6,960 trees	Traits: Native to Portugal, slow growth, long life span.	 Highly tolerant to drought and wind.
	Tropical Group	Scale: ~3,185 trees	Traits: Exotic, large aesthetic leaves/flowers, deciduous	 High tolerance to pests and shade.

How are the taxonomic and functional facets of trees distributed across a historical Mediterranean city?

Species' functional grouping

Unequal patterns of abundance

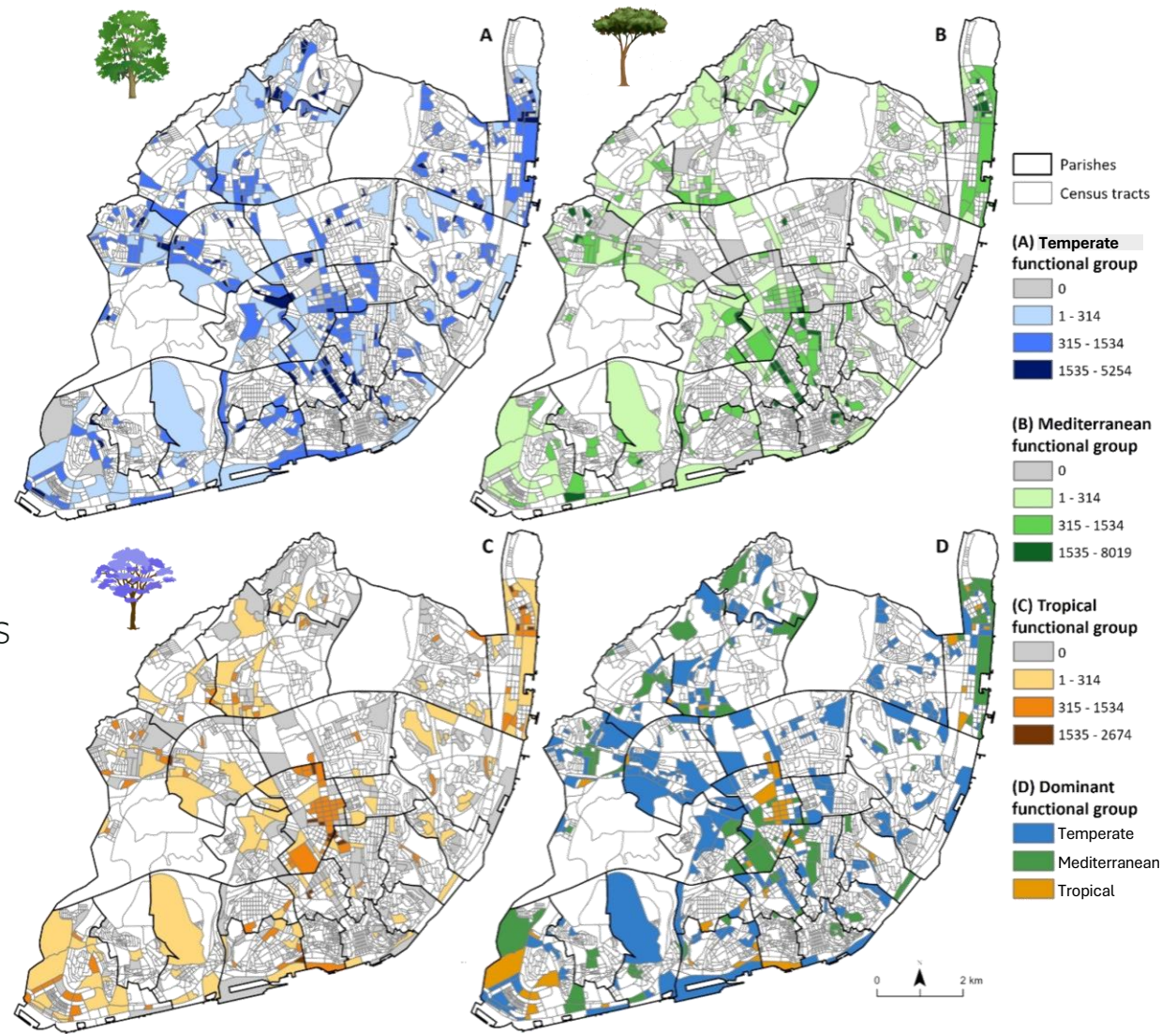
Temperate group abundant across the city, mediterranean concentrated in the city center and newest area, tropical concentrated in the city center


Different capacity to respond to changes and provide ecosystem services

Dominance of the temperate functional group in most blocks

Planning and management implications

- Enhance functional diversity
- Invest in trees with greater ecological resilience to future climate scenarios





Should cities prioritize native/Mediterranean species over non-natives that can be more resilient in future climate?

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biological facets



tree level



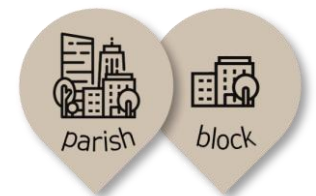
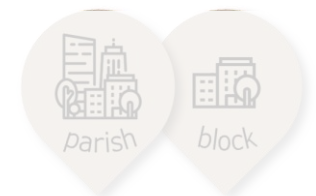
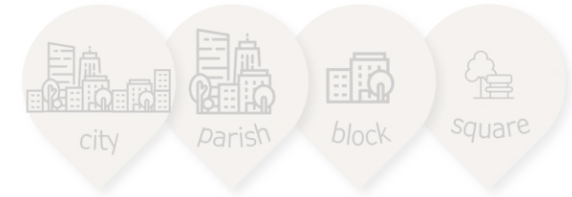
tree level



green space level tree level



spatial scale



How is tree abundance and diversity associated with social and ecological factors?

Biodiversity Facets

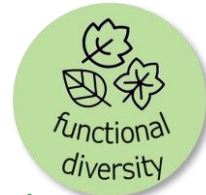
all trees



identified trees



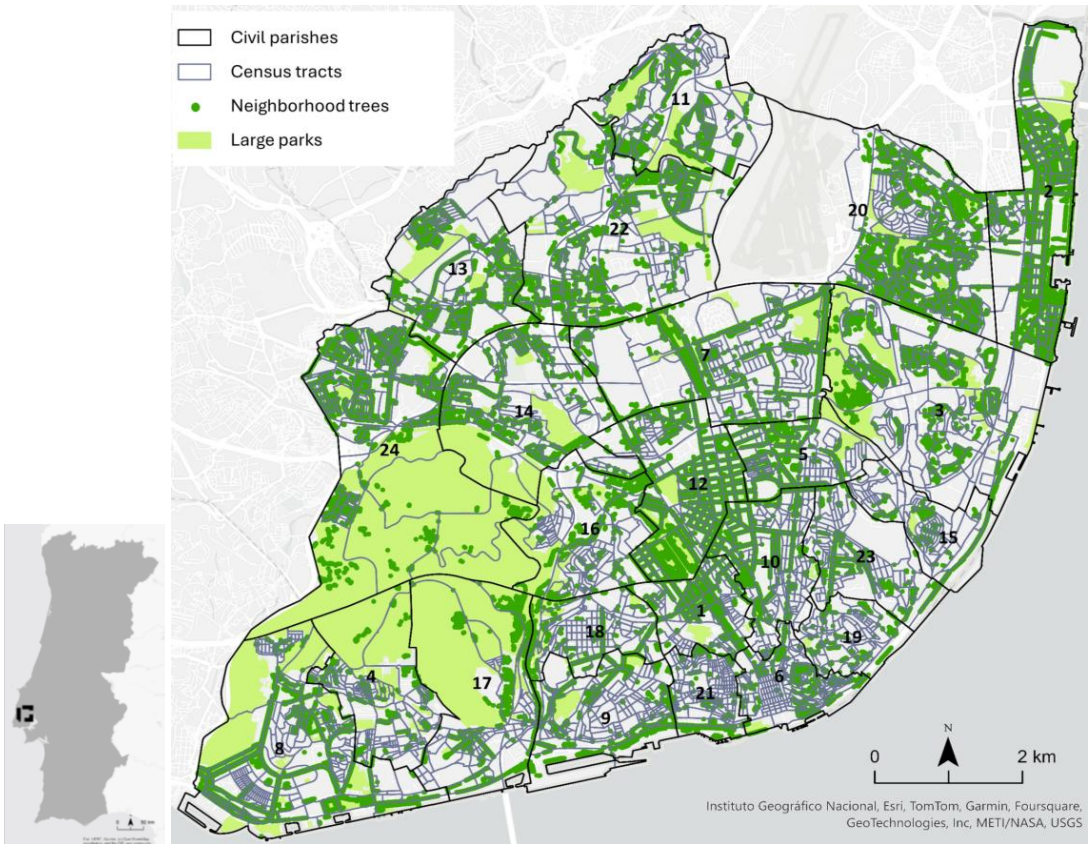
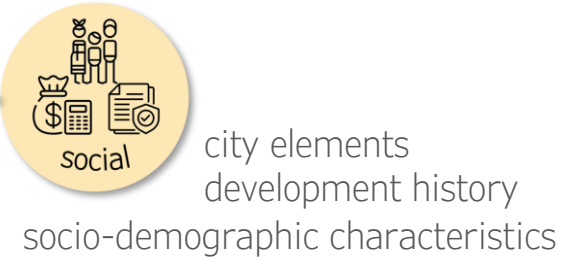
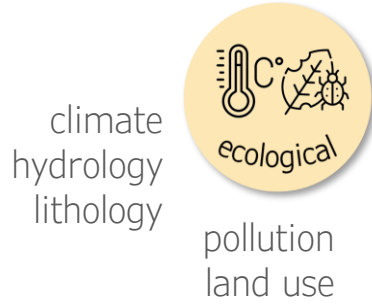
70% of identified trees



Which traits?

- Spread & regeneration
- Tolerance to disturbances
- Ecosystem services delivery

Social-Ecological Factors



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How is tree abundance and diversity associated with social and ecological factors?

Strong associations between social factors and all biological indices and spatial scales

→ Higher abundance and diversity in more urbanized areas

Ecological factors showed weaker relationships with urban trees, except for tree abundance

parish					block				
Indices	Variable type	Independent variables	Trend	Adj. R ²	Indices	Variable type	Independent variables	Trend	Adj. R ²
Abundance	Ecological	Clay soil type*	U	0.58	Abundance	Ecological	LST***	∩	0.35
	Social	NO***	-			Social	Public elements***	+	
Sp. richness	Social	Buildings' area**	+	0.80	Sp. richness	Social	Public elements***	+	0.25
		Buildings***	+				Roads***	∩	
Shannon index	Social	Buildings***	+	0.78	Shannon index	Social	Public elements***	+	0.43
Evenness	Social	Families 1-2 elements***	∩	0.45	Evenness	Social	Buildings' area ***	∩	0.58
		Buildings***	+				Roads***	+	
F. divergence	Social	Buildings<1945***	+	0.74	F. divergence	Social	Roads***	+	0.71
F. evenness	Social	Buildings***	+	0.74	F. evenness	Social	Roads***	+	0.62

* p < 0.05; ** p < 0.01; *** p < 0.001

How is tree abundance and diversity associated with social and ecological factors?

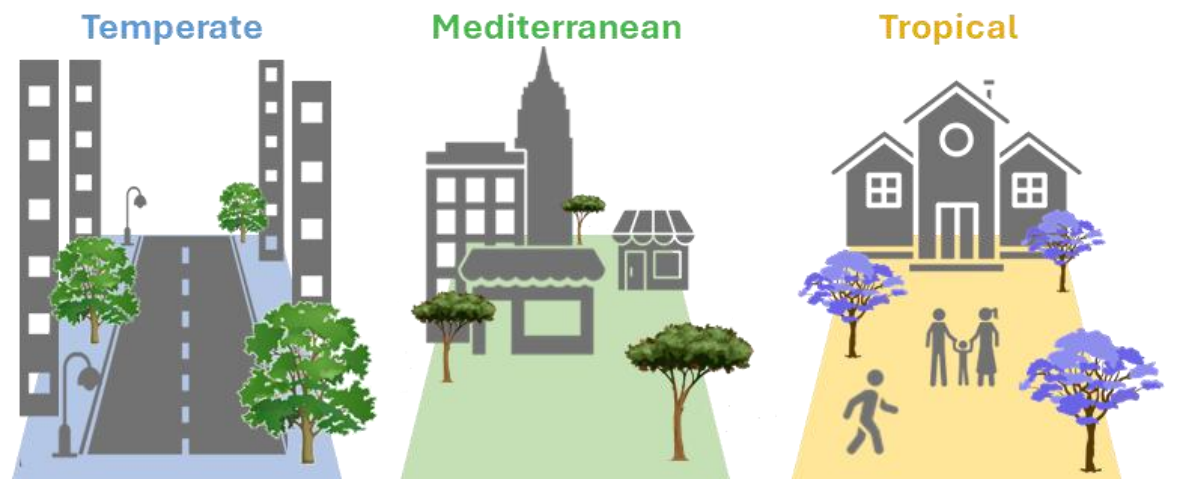
Social factors associated with **all groups**, ecological with **Mediterranean** and **Tropical** groups

Top-down social filters for traits related with i. acquisitive strategies near roads, ii. sense of place in everyday locations, iii. aesthetic experiences in walkable areas

Species' functional grouping

Functional groups	Variable type	Independent variables	Trend	Adj. R ²
Temperate	Social	Roads***	+	0.21
		Public elements***	+	
Mediterranean	Social	Commercial/services-related amenities***	+	0.30
	Ecological	Land surface temperature (LST)***	∩	
		Urbanization index (UI)***	∩	
Tropical	Ecological	Normalized difference vegetation index (NDVI)***	-	0.21
		Land surface temperature (LST)***	∩	
	Social	Walking potential***	+	

*** p < 0.001



How is tree abundance and diversity associated with social and ecological factors?

Social factors associated with all groups, ecological with Mediterranean and Tropical groups

↪ Top-down social filters for traits related with i. acquisitive strategies near roads, ii. sense of place in everyday locations, iii. aesthetic experiences in walkable areas

Planning and management implications

- Models allow to quantify how much humans modify urban landscapes at structural & functional levels
- Changes in planting priorities
- Need for long-term monitoring to understand cause-effect relationships

Mediterranean	Ecological	Land surface temperature (LST)***	∩	0.30
		Urbanization index (UI)***	∩	
	Ecological	Normalized difference vegetation index (NDVI)***	-	
Tropical		Land surface temperature (LST)***	∩	0.21
	Social	Walking potential***	+	

*** p < 0.001



Rationale

Conceptual framework

- 1 How are species traits, social and ecological filters, and ecosystem services linked in urban systems?

Theoretical application of the framework rationale

- 2 How are trees' biodiversity facets distributed across a historical Mediterranean city?
- 3 How is tree abundance and diversity associated with social and ecological factors?

Nature-based solutions put into practice

- 4 What factors influence microclimate at a high spatial resolution?

biological facets



tree level



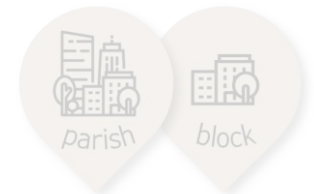
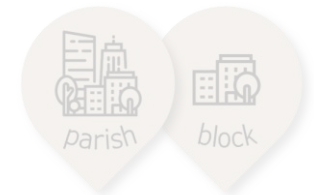
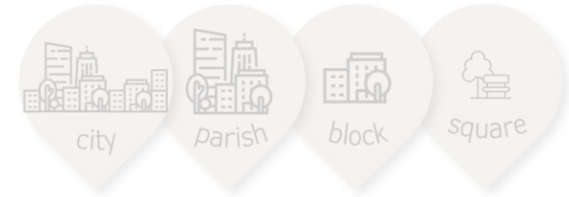
tree level



green space level tree level

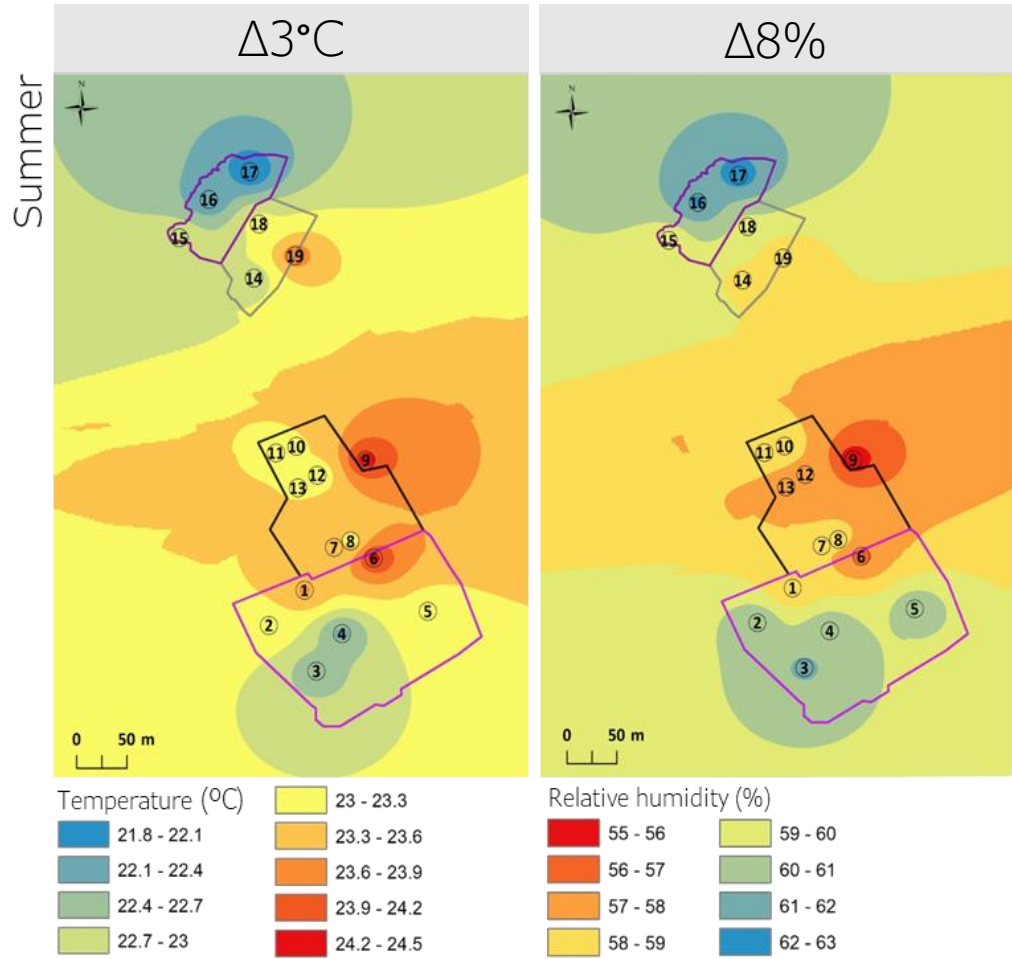
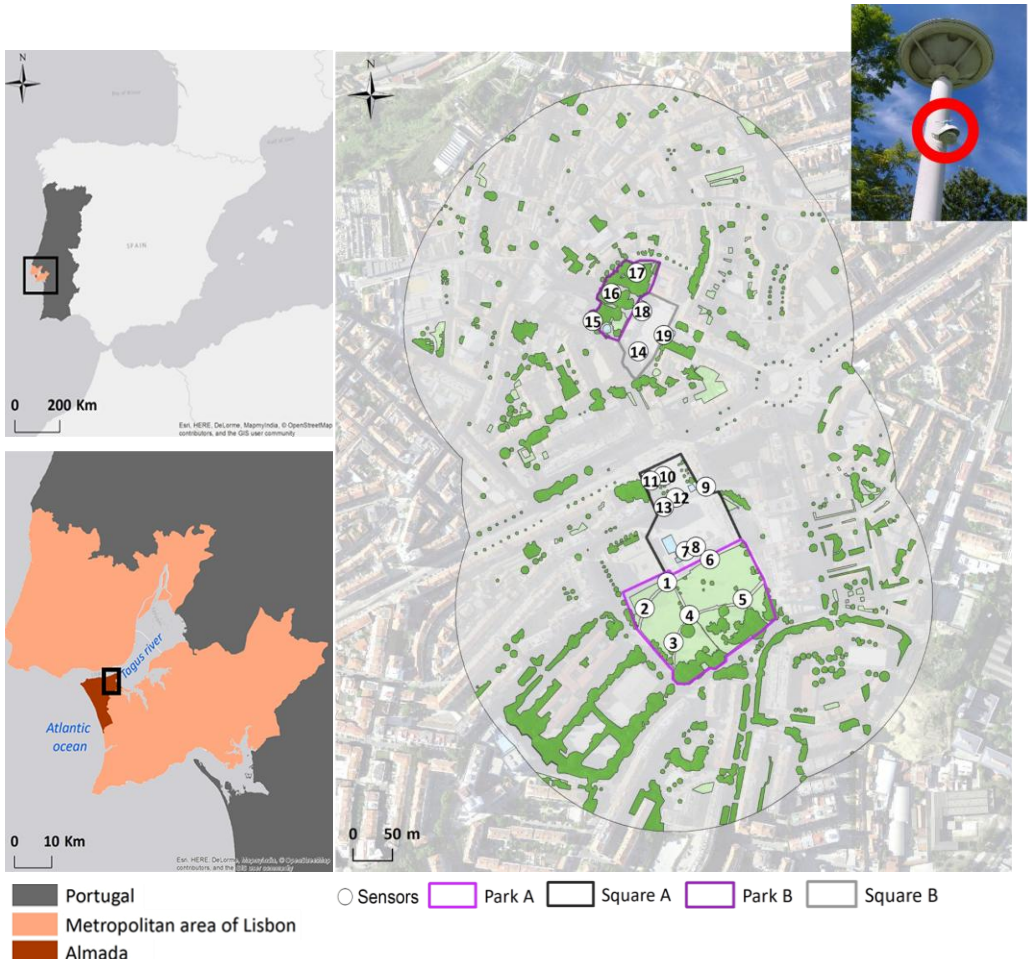


spatial scale

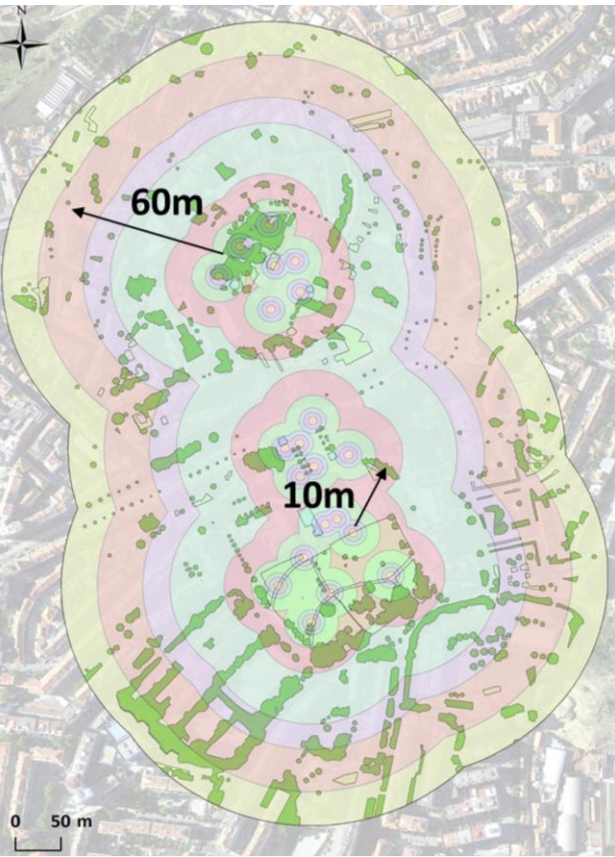


What factors influence microclimate at a high spatial resolution?

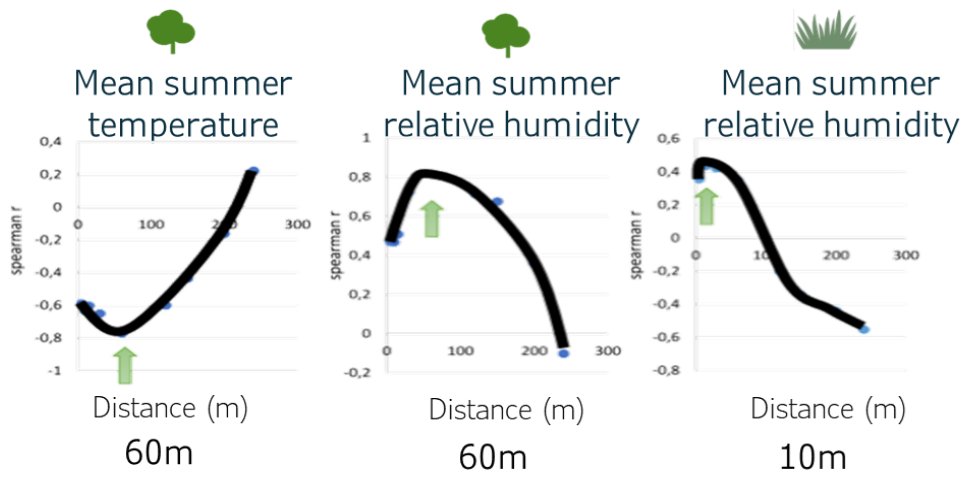
Microclimate varies locally in squares and adjacent green spaces



What factors influence microclimate at a high spatial resolution?

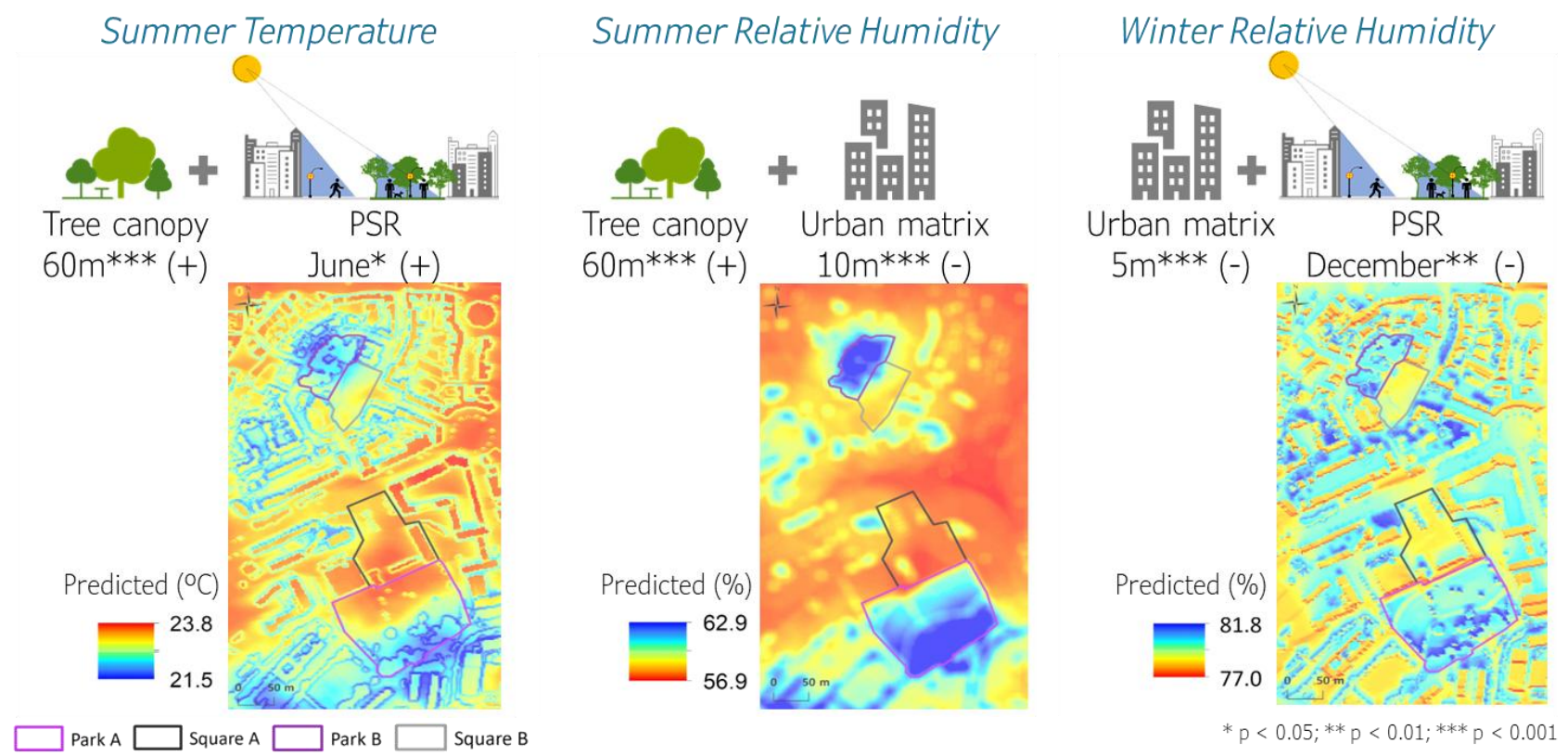


Trees have a stronger effect on microclimate amelioration than herbaceous vegetation



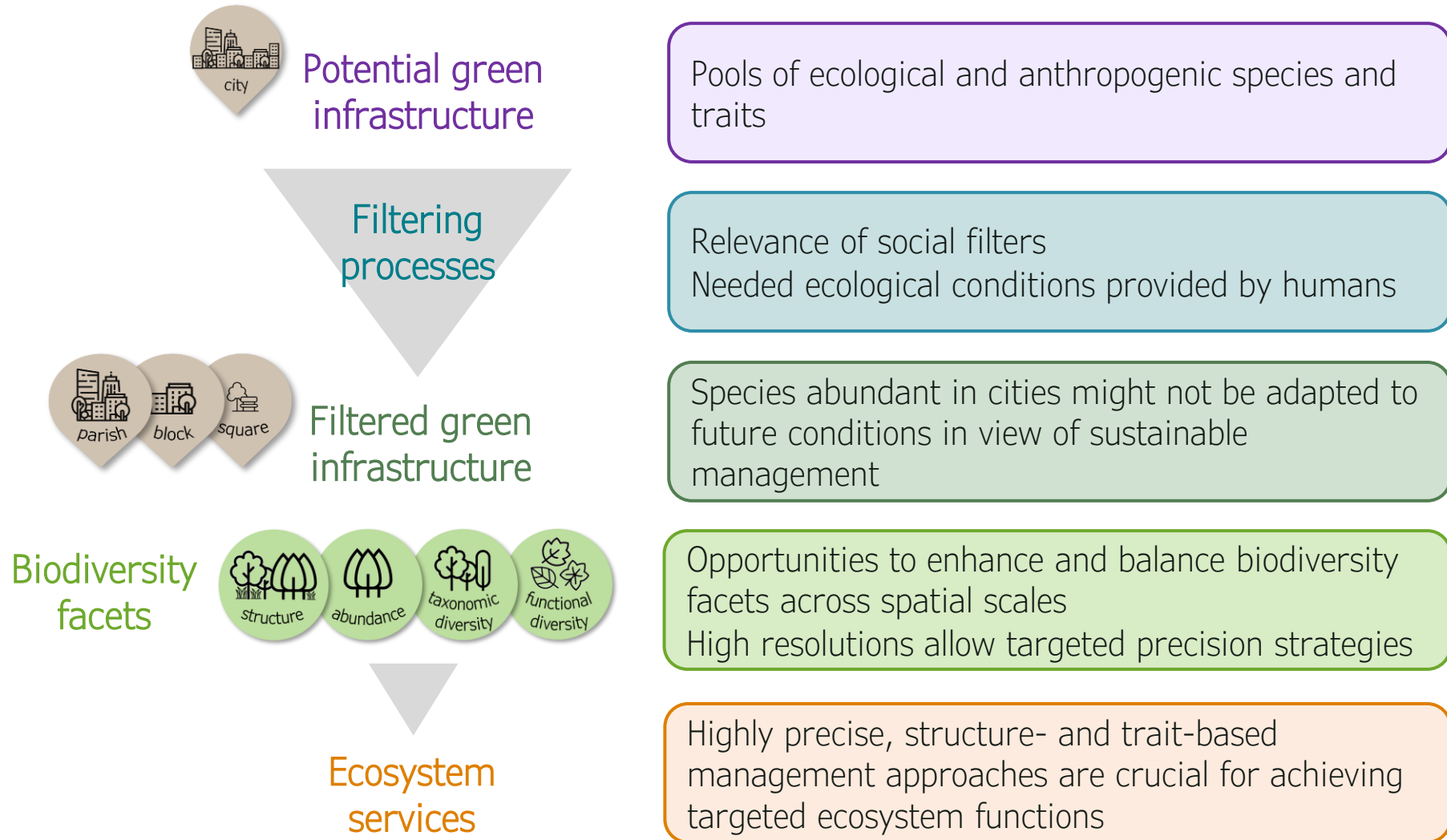
What factors influence microclimate at a high spatial resolution?

Green space structure, tree abundance, urban matrix and urban geometry highly influence microclimate



General conclusions

Lessons learnt for scaling up the rationale of the Social-Ecological Traits Framework



The background of the slide features a light gray gradient with a white, torn-paper-like border at the top and bottom edges. The text is centered in the white area.

Feedback loops are central to socio-ecological systems.

Do you recall one positive or negative feedback loop involving urban trees and human behavior?

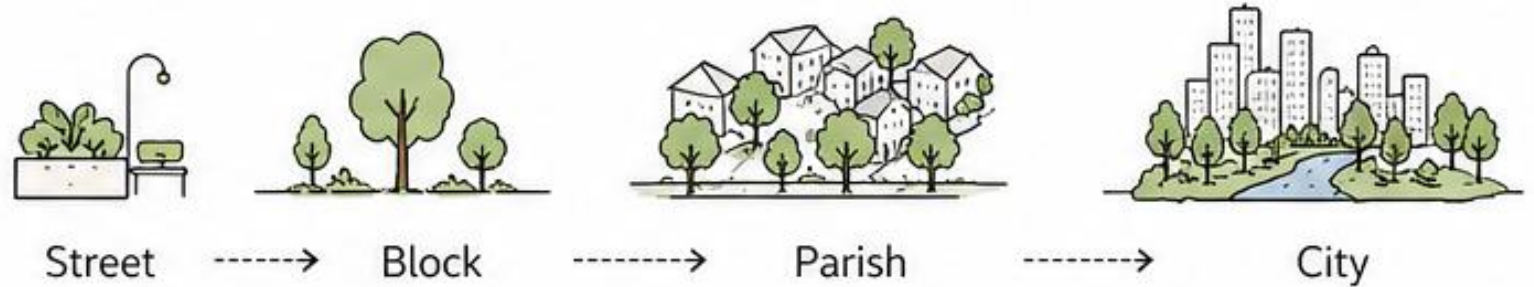
General recommendations for the **planning** and **management** of **urban green infrastructure**

1 Consider different **biodiversity facets** and plan at different spatial scales

City-level strategies miss local heterogeneity.

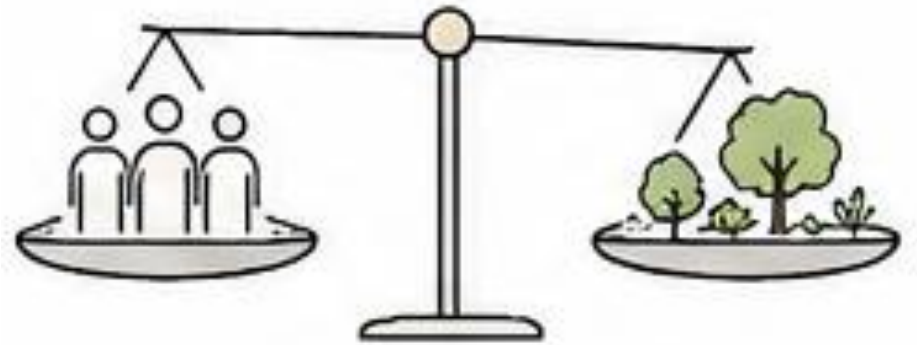
Street-level models are needed.

Different factors matter at parish vs. local scales.



General recommendations for the **planning** and **management** of **urban green infrastructure**

2 Prioritize **social preferences** and **needs** while accounting for possible **trade-offs**



General recommendations for the **planning** and **management** of **urban green infrastructure**

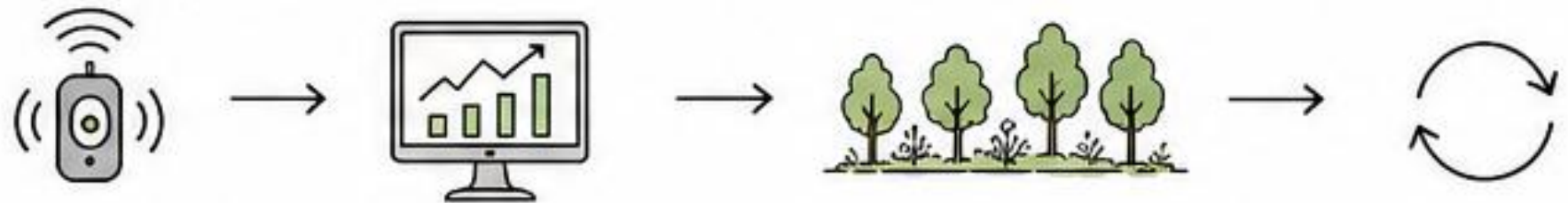
- 3 Use **trait-based approaches** to promote **multifunctionality and functional diversity**, prioritizing traits that provide **resilience to future conditions**



General recommendations for the **planning** and **management** of **urban green infrastructure**

4 Monitor the effective delivery of **ecosystem services**

Governance needs to monitor outcomes and adapt, not plant and forget.



General recommendations for the **planning** and **management** of **urban green infrastructure**

5 Prioritize equity in green space distribution



General recommendations for the **planning** and **management** of **urban green infrastructure**

6 When possible, use **high-resolution spatial data**



Cities are what we make them

Thank you!

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