Leveraging Virtual Reality for Green Infrastructure Design: Implications for the Cultural Services Aesthetics & Sense of Place

Lauren Krauss, Megan Blumenauer, Megan A. Rippy,

VIRGINIA TECH™

From observations to models

The previous talk has shown us that green infrastructure can provide aesthetic and sense of place services and has placed that provisioning in context with other landscape forms

Now we're going to talk about how those services are actually provided using virtual reality and mental modeling to create some of the first-ever conceptual models for the provisioning of aesthetics and sense of place services by green stormwater infrastructure

My hope is that models like these might ultimately be leveraged to inform new designs *(putting cultural services on the same footing as the regulating services that green infrastructure is traditional designed for)*

Objectives

1) How might we go about unpacking cultural service provisioning?
   What process might we use to co-develop models for aesthetics and sense of place?
2) What do cultural services models tell us about how green infrastructure provides aesthetics and sense of place services to people?

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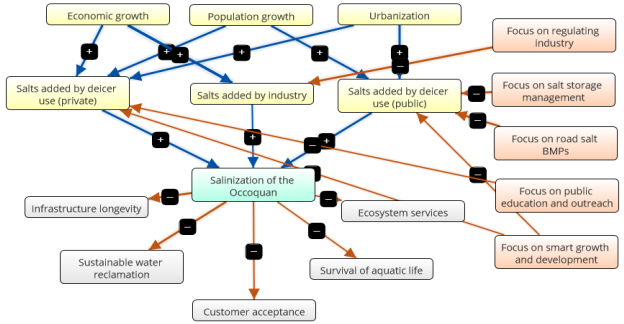
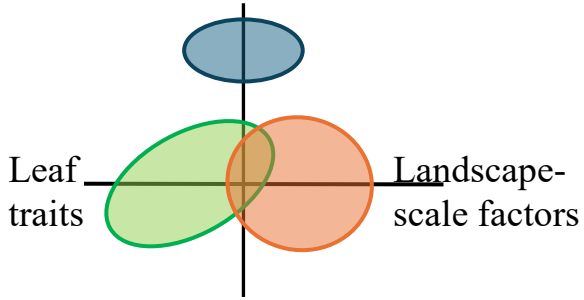
A process we might we use…

1. *People experience and rate virtual reality models of GSI that capture different plant/landscape traits*

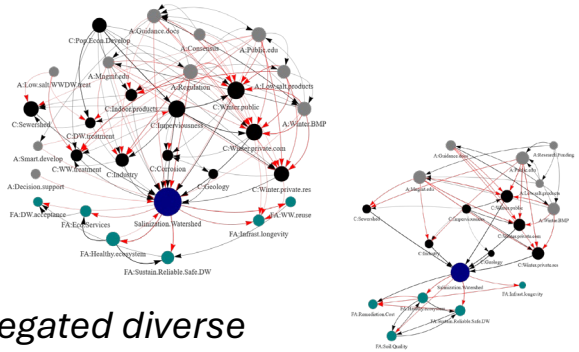
2. *People select concepts that capture plant/landscape traits that they feel influence cultural services*

3. *Build individual mental models*

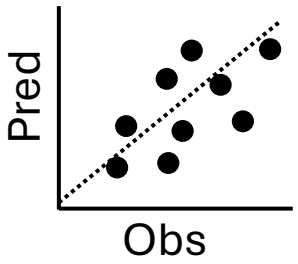




4. *Use principal component analysis and cluster analysis to identify groups of individuals with significantly different FCMs*



5. *Aggregated diverse perspectives to identify subgroup models and aggregated "collective" FCM*



6. *Use "collective" FCM to simulate the services provided by each virtual landscape and compare to people's actual aesthetics and sense of place ratings (model validation)*

In walking through the process I just described we'll learn how green infrastructure provides cultural services *(or at least how people perceive it does)*

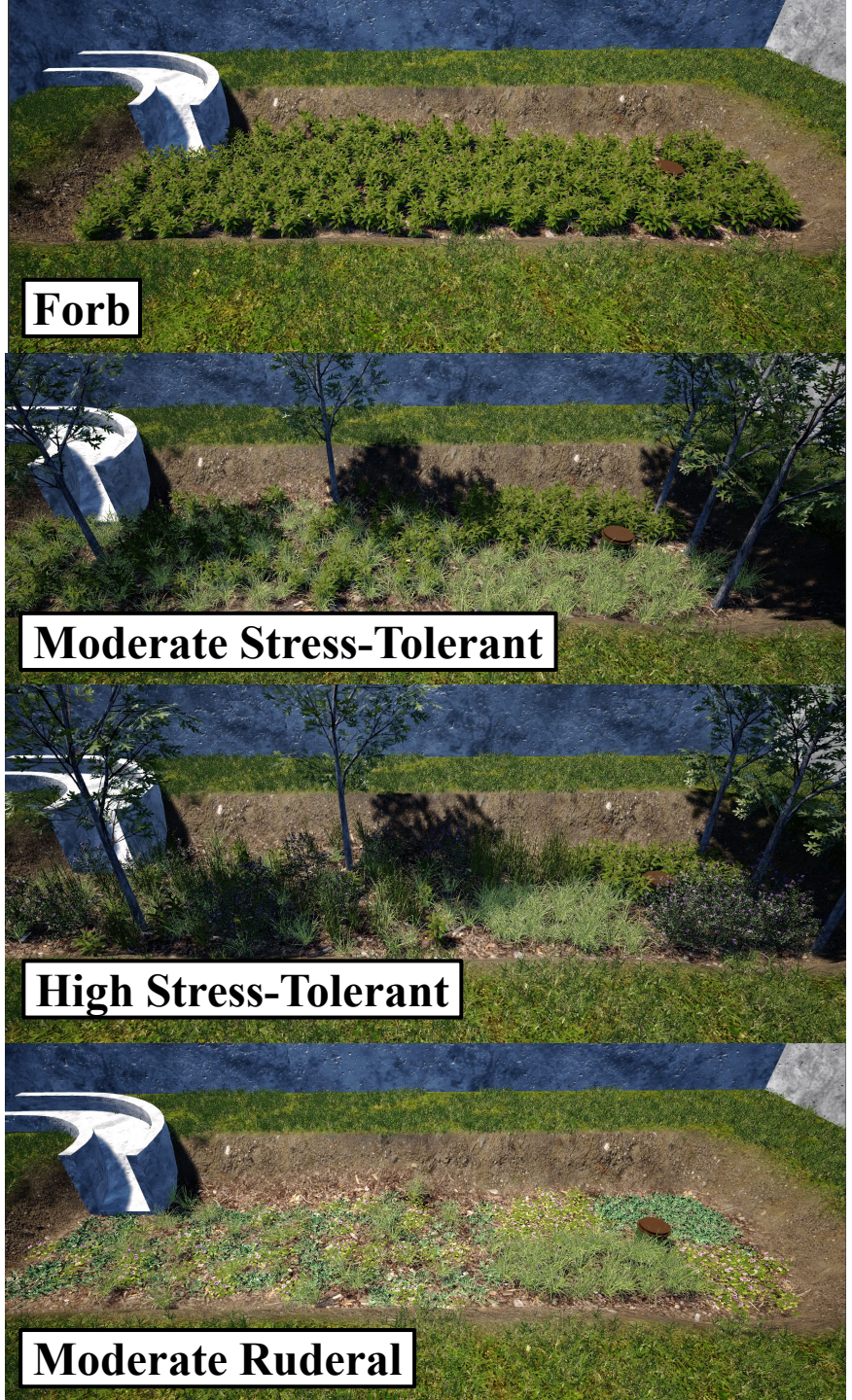
1) How might we go about unpacking cultural service provisioning?
   What process might we use to co-develop models for aesthetics and sense of place?
2) What do cultural services models tell us about how green infrastructure provides aesthetics and sense of place services to people?

Step 1: VR model creation

- 10 VR models were prepared in Unreal Engine:
  - 4 monocultures
  - 3 polycultures with moderate biodiversity (competitive, ruderal, and stress-tolerant)
  - 3 polycultures with high biodiversity

- All models had the same basic layout, inlet, and outlet

- 10 participants (community members and students from Blacksburg Virginia) walked through each model using a Vive Oculus headset and were asked to provide aesthetics or sense of place scores (100 participants total)



Steps 2 & 3 – FCM creation

- Following their VR experience all participants were provided with 3 tables of plant concepts (plant traits, landscape characteristics, and intangibles)
- They were asked to select the most important concepts from each table or create their own (maximum of 5)
- They were asked to use those concepts to create a mental model for aesthetics or sense of place *(which concepts influence one-another and how strong are those relationships?)*

TABLE A: Plant characteristics

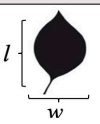
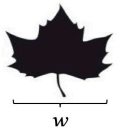
Abbreviation	*Definition*	*Examples*
Leaf area	Surface area of an average leaf (length x width)	*High*  *Low* 
Leaf width	Width of a leaf at its widest point (side to side, not along its stem)	*High*   *Low*
Silver leaves	Grey/green to silvery plant leaf color	
Green leaves	Bright or dark green plant leaf color	

TABLE B: Landscape level characteristics

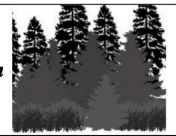
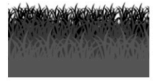
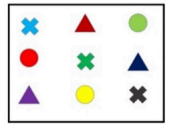
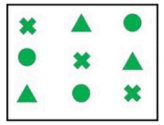
Abbreviation	*Definition*	*Examples*
Biodiversity	The number of different species within a landscape	*High*   *Low*
Structural diversity	The variety of different shapes, heights, and textures of plants within a landscape	*High*   *Low*
Diversity of color	The variety of different plant colors (leaves and flowers) within a landscape	*High*   *Low*

TABLE C: Perceptual Intangibles

Abbreviation	*Definition*
Number of native plants	Native plant species come from, and are locally adapted to, the region where they are planted
Number of exotic plants	Exotic plant species do not come from, and are not locally adapted to, the region where they are planted but are not expected to cause harm when introduced
Number of invasive plants	Invasive plant species do not come from, and are not locally adapted to, the region where they are planted. When introduced they cause or are likely to cause economic or environmental harm

What concepts did people select? - aesthetics

- Biodiversity was used in mental models for aesthetics far more often than any other characteristic
- Individual plant traits (leaf width, cool color flowers, lobed leaves) were used only rarely
- All traits except silver leaf color were used by at least one individual
- No one felt they needed concepts that were not included in the original concept lists

How about sense of place?

- Plant nativeness was more important than any other plant trait (biodiversity ranked second)
- Individual plant traits (silver leaves, rough leaves, leaf area) were used only rarely
- All concepts (including silver leaf color) were used

Aesthetics

Top five

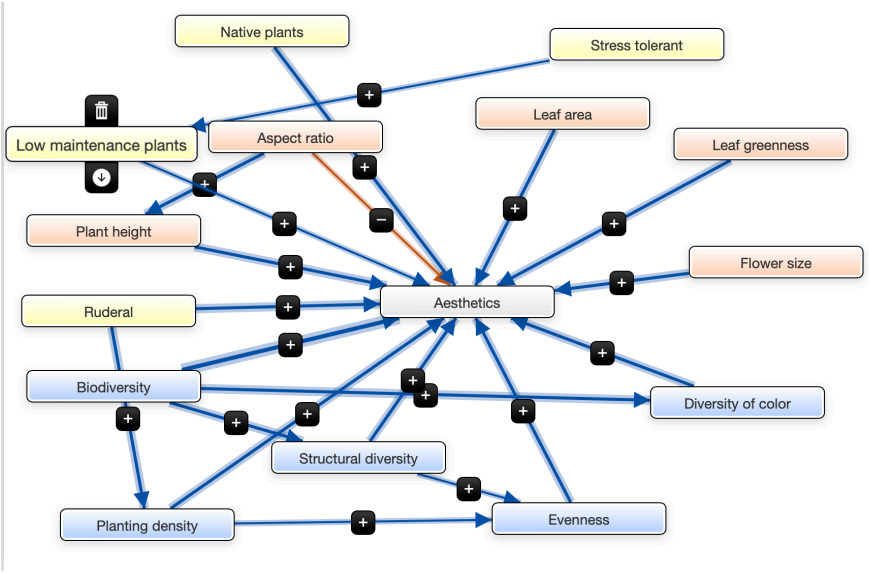
Bottom five

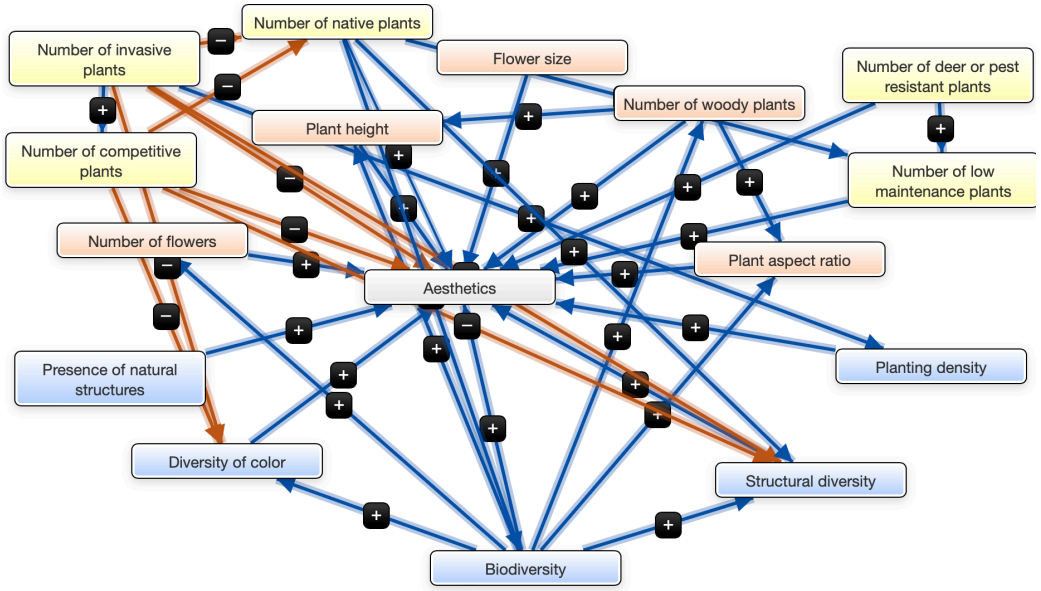
Sense of place

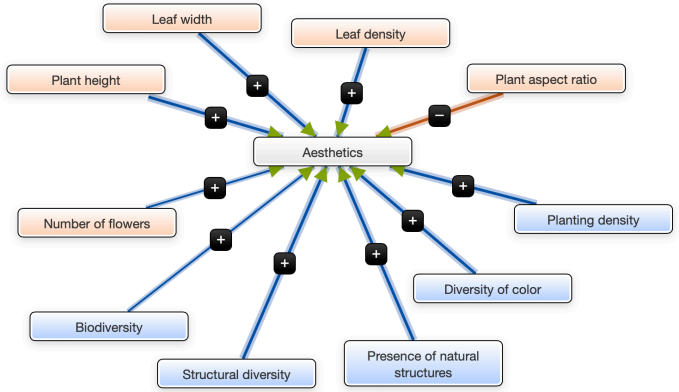
Top five

Bottom five

What do individual mental models look like?



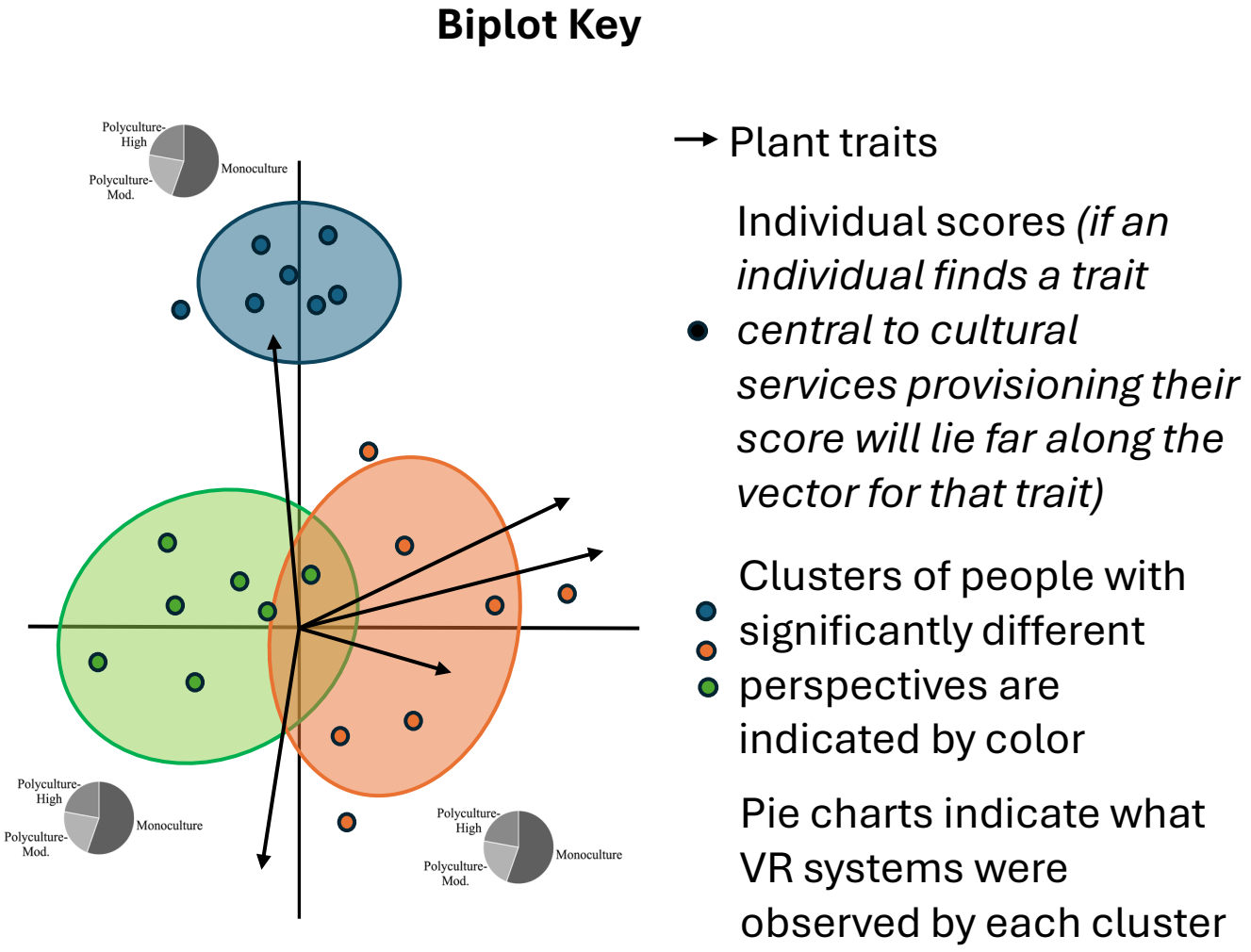




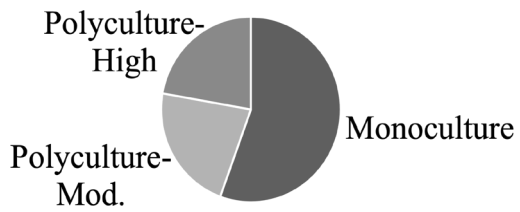
Quite structurally variable (no individual models are exactly the same)

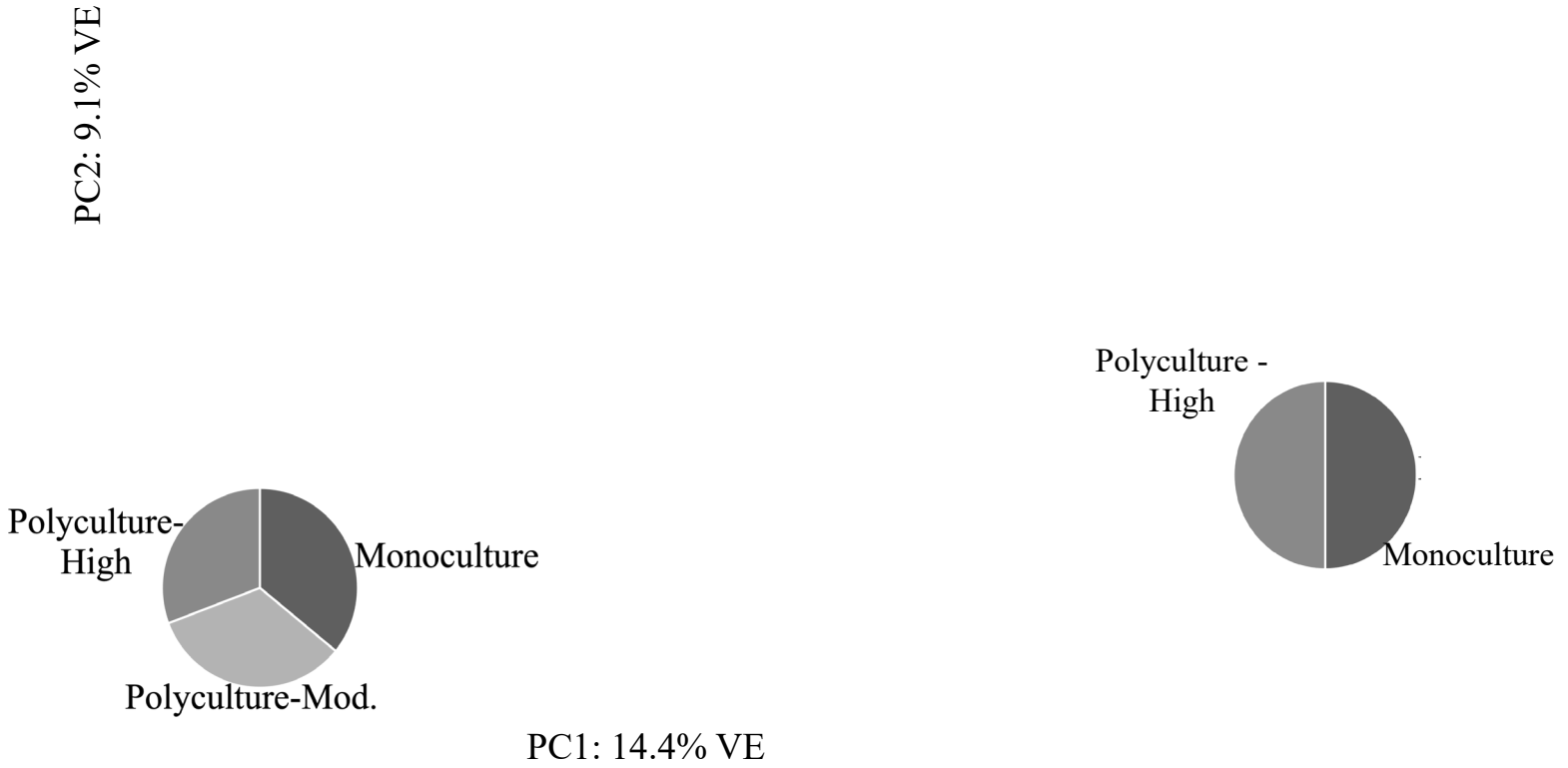
Step 4 – Identify groups of people with significantly different perspectives about cultural services provisioning

- Principal component analysis (PCA) was conducted on the weighted degree centrality scores for each concept included in each FCM
- Cluster analysis was conducted following PCA to identify groups with significantly different perspectives
- The type of VR models viewed by each cluster was examined to determine if they had any effect on differences in perspective



Aesthetics

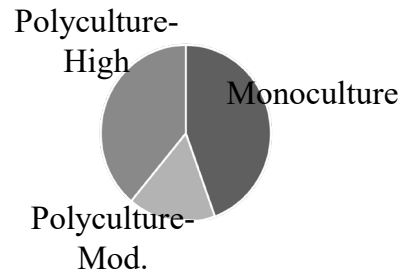


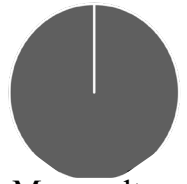


- Cluster analysis identified 3 major groups of people who perceive aesthetics differently
- Their FCMs are distinguished by how important they feel landscape scale factors are (PC1)
- **Cluster 1:** felt landscape-scale factors were less important for aesthetics (particularly invasive plants and structural diversity)
- **Cluster 2:** opposite of cluster 1
- **Cluster 3:** felt a mix of landscape scale factors and plant traits were important for aesthetics (e.g., brown leaves and native plants)
- Type of VR model viewed (pie charts) had minimal effects on

Sense of place

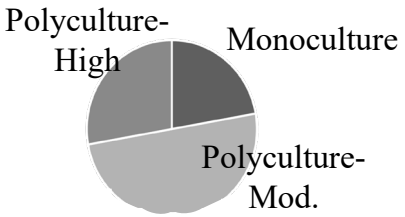
- Cluster analysis identified 3 groups of people who perceive sense of place differently
- **Cluster 1:** felt green leaves and whether plants match the surrounding landscape influences sense of place
- **Cluster 2:** felt color, planting density, and flowers influence sense of place
- **Cluster 3:** felt invasives, natives, and biodiversity influence sense of place
- Type of VR model viewed (pie charts) may matter *(biodiversity mattered most to people who viewed monocultures)*





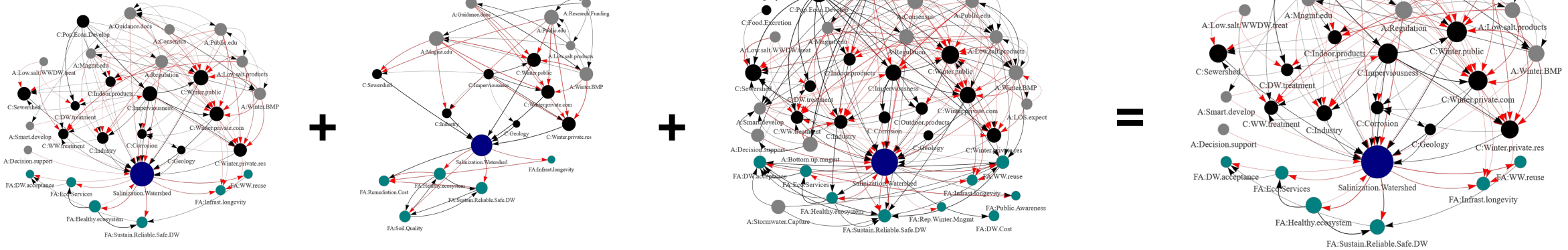
PC2: 9.9% VE

Cluster



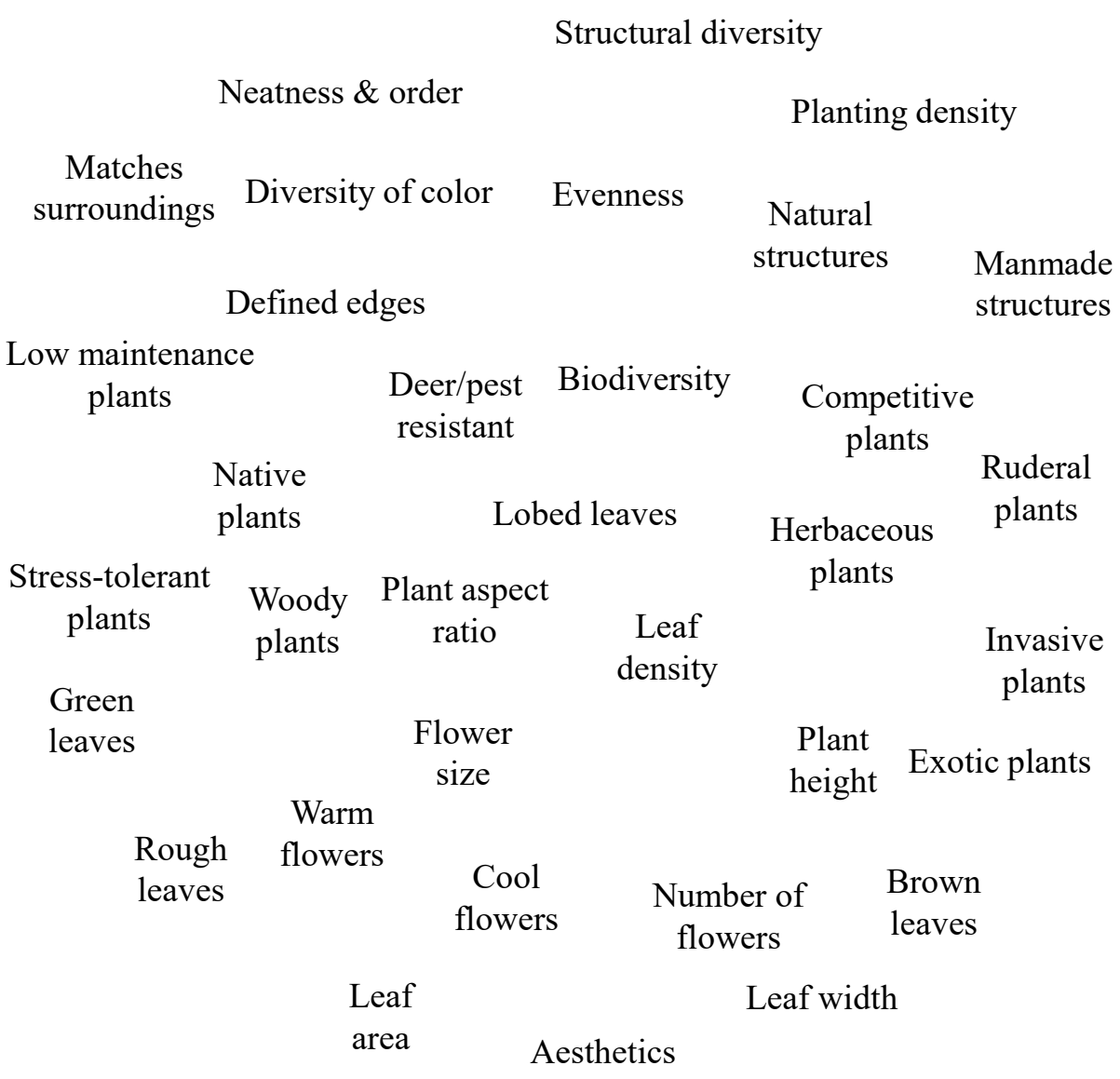
PC1: 13.5% VE

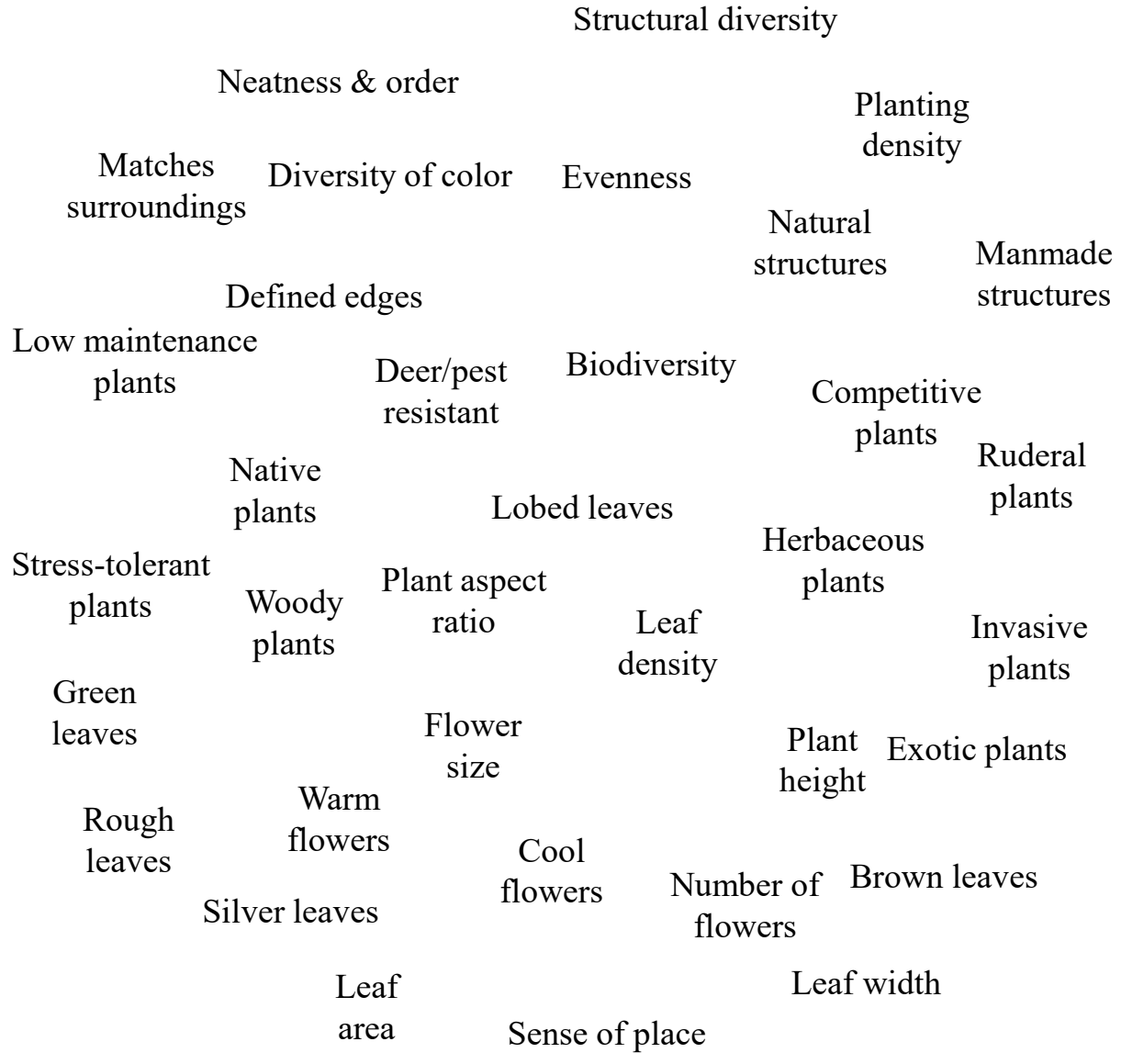
5. Aggregate diverse perspectives to characterize unique groups (mean of their respective adjacency matrices). Then aggregate the groups (median) to create a single "collective" FCM for each service that harnesses the "wisdom of the crowd"



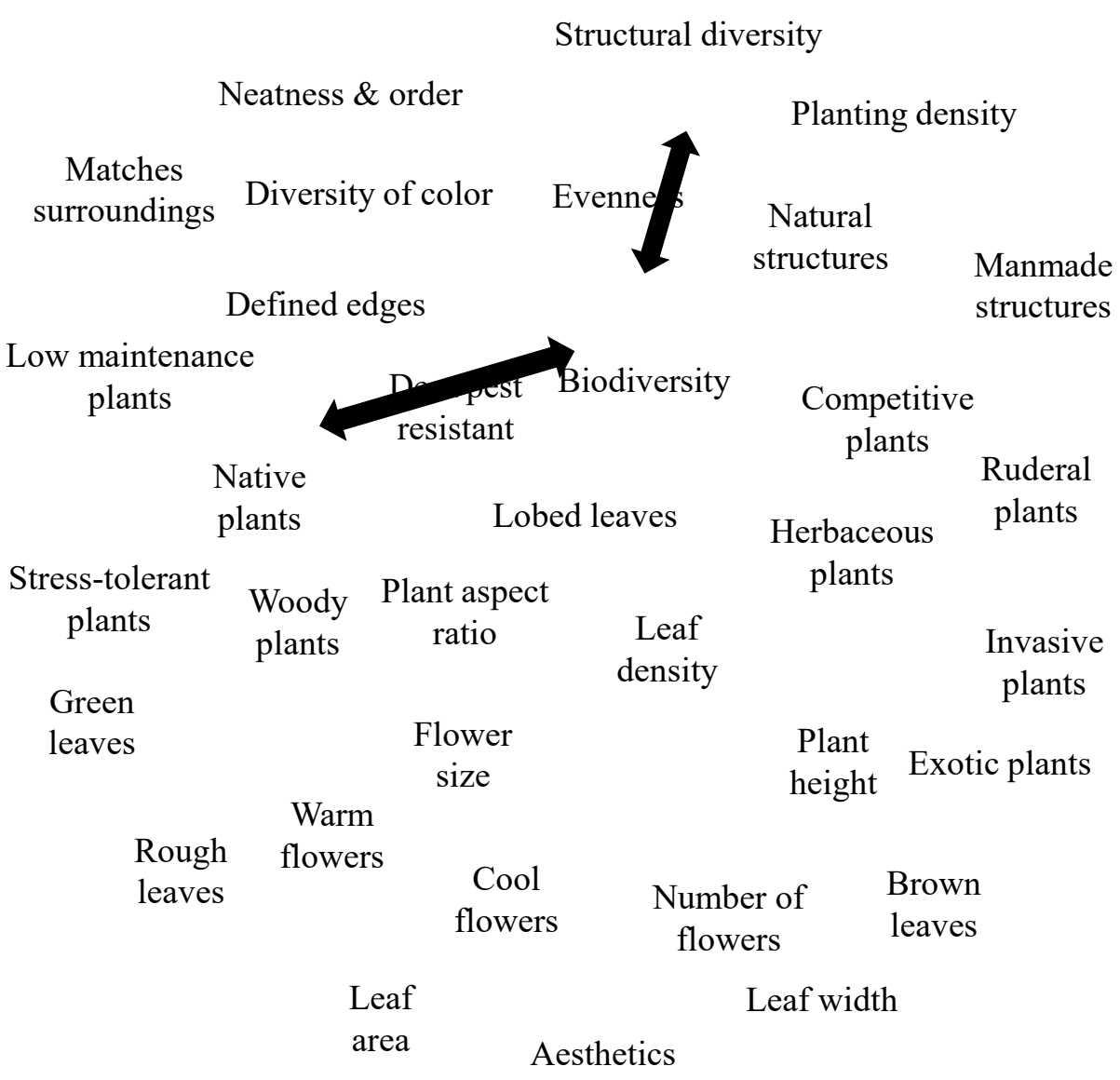
Cluster 1 + Cluster 2 + Cluster 3 = Aggregate

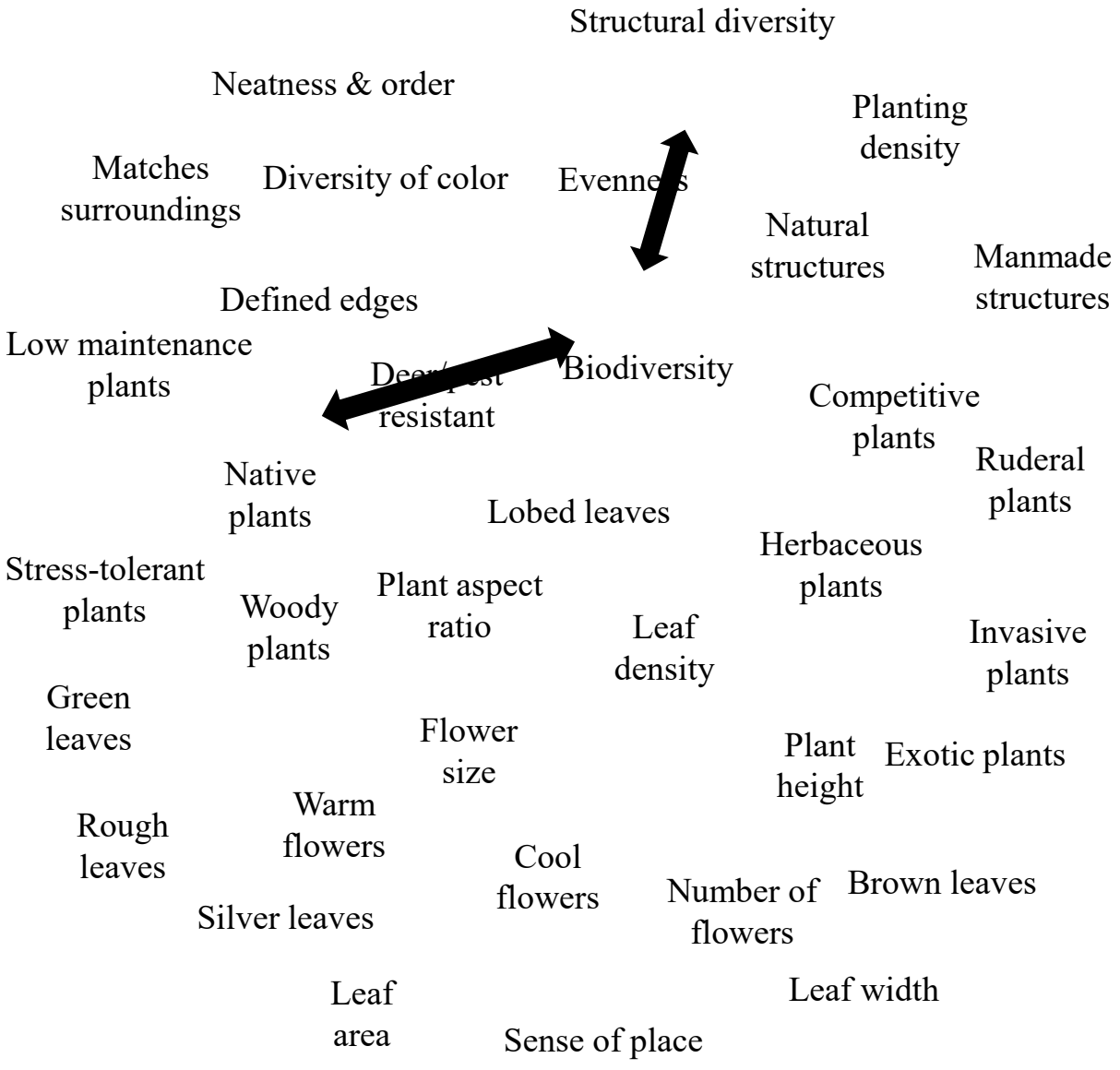
Mental Models of Aesthetics and Sense of Place *(structurally similar, different concepts emphasized, different levels of connectivity)*



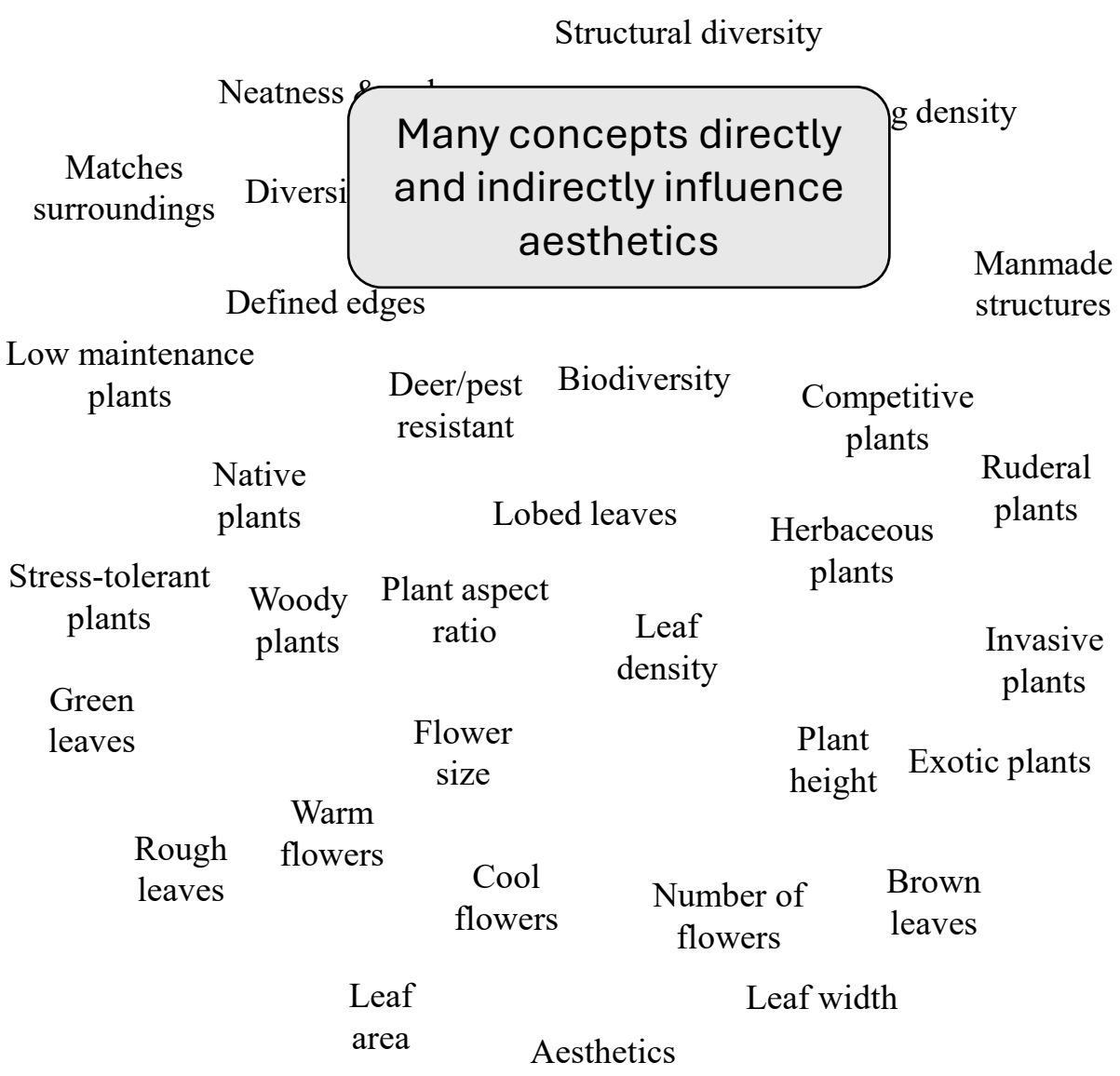


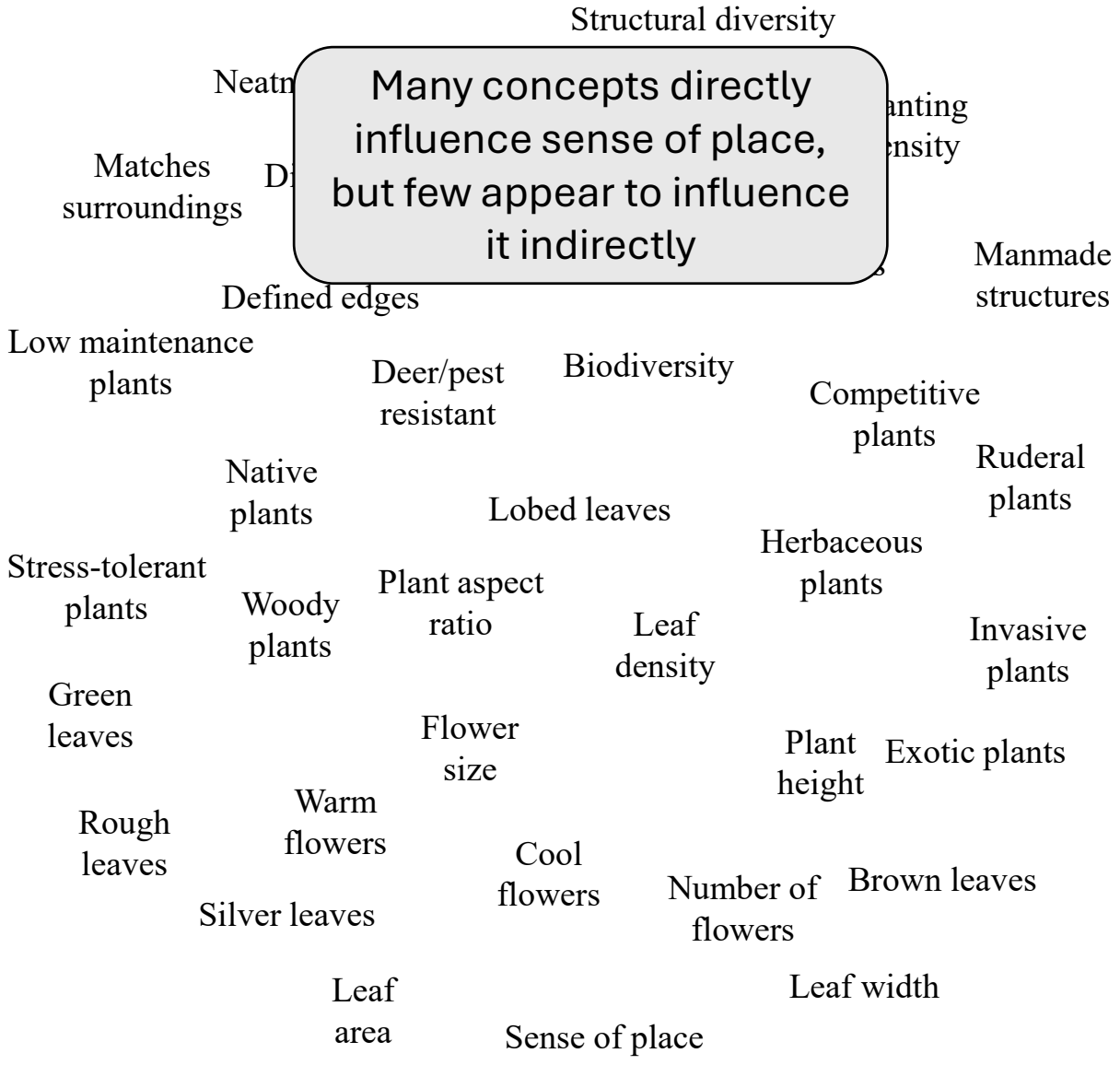
Mental Models of Aesthetics and Sense of Place *(structurally similar, **different concepts emphasized**, different levels of connectivity)*





Mental Models of Aesthetics and Sense of Place *(structurally similar, different concepts emphasized, **different levels of connectivity**)*





6. *Use "collective" FCMs to simulate the services provided by each virtual landscape*

FCMs can be used to perform semi-quantitative dynamic simulations that predict aesthetics and sense of place scores for a specific combination of plant traits, landscape-scale factors and perceptual intangibles

How this works

- A concept (or set of concepts) in an FCM is activated (set to 1) and this activates other concepts to different degrees depending on the strength of their connection
- The signal reverberates around the network, dampening slightly at each step
- The integration of the signal from activation to dampening gives you the magnitude of effect on a concept of interest (aesthetics or sense of place)

Simulation results can be compared to people's actual aesthetics and sense of place ratings for each virtual landscape to validate the models

We find that the aesthetics model reproduces people's stated perceptions well, but that the sense of place model tends to overpredict services provisioning

- Each row represents a different system *(monocultures on top, medium biodiversity polycultures in the middle, high biodiversity polycultures at the bottom)*
- Observed aesthetic and sense of place scores (black and grey circles, respectively) were generally lower for monocultures than medium or high biodiversity polycultures
  - ➢ Differences not always statistically significant (note overlapping 95% confidence intervals)
- Simulated aesthetic scores match observed aesthetics scores well (generally within 95% CI bounds)
- Sense of place scores tend to be biased high, but the pattern is generally correct (lower for monocultures, higher for polycultures)

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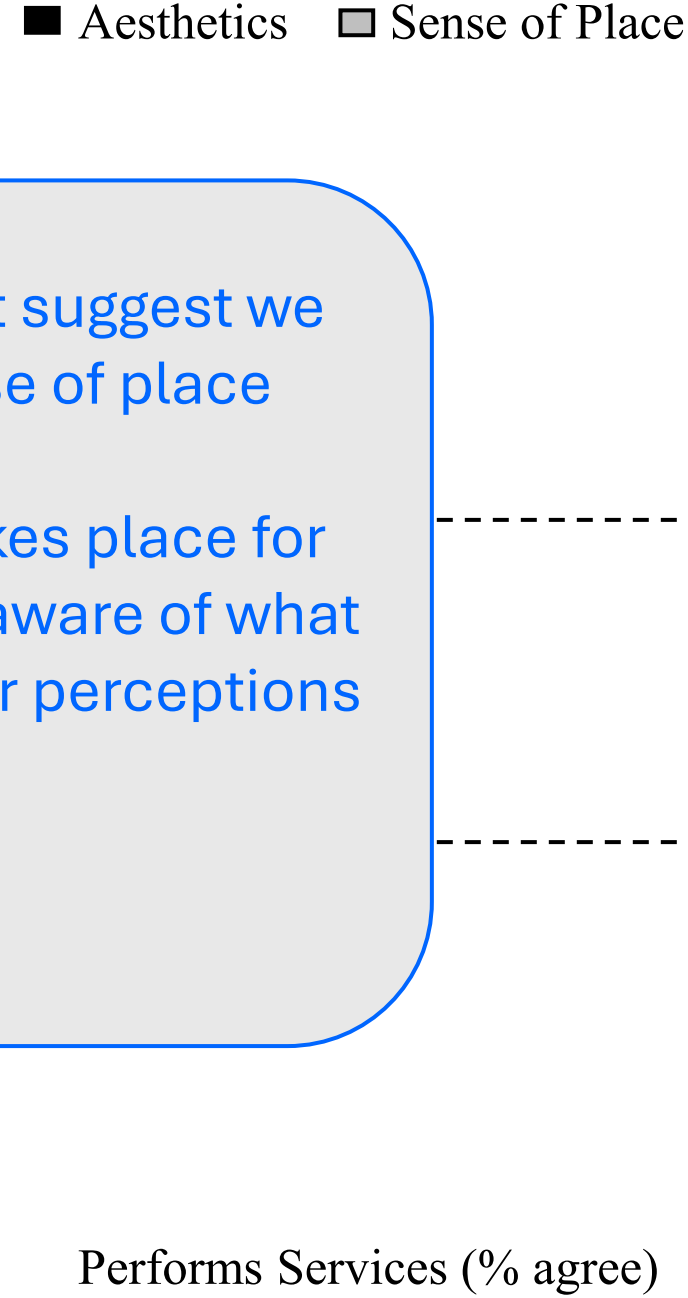
Our results are really promising for aesthetics, but suggest we have a ways to go with respect to modeling sense of place

It may be harder for people to articulate what evokes place for them than what they feel is aesthetic – if we aren't aware of what influences us, the models we produce based on our perceptions will be biased

That could be what we are seeing here



Summarize and Conclude

Using virtual reality to expose people to green infrastructure, translating those experiences into mental models of cultural services, and validating the models with ratings of the original infrastructure can be a valuable way to help us understand how services are provided (moving a bit towards mechanism)

Many of the concepts that influence aesthetics also influence sense of place but how these concepts are related differ, with models of aesthetics appearing richer and more complex than models of sense of place

Mental models for aesthetics also appear to be more reliable and match people's experiences better than mental models for sense of place

Further work is needed to better understand sense of place (what might we be missing and what are the best approaches for filling in the gaps, so that we can improve our capacity to design green infrastructure that helps connect people to place)