URBAN SOLUTIONS AND SUSTAINABILITY

R&D CONGRESS 2023

BUILDING SUSTAINABLE, RESILIENT, AND LIVEABLE CITIES OF TOMORROW

4TH – 5TH OCTOBER 2023

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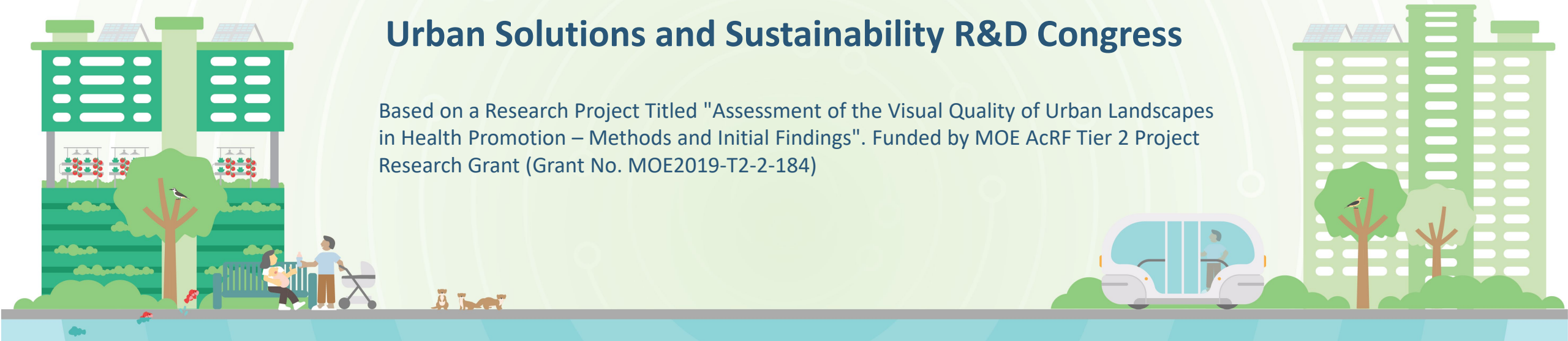
Measuring Urban Landscapes for Assessment of Restorative Potential

Urban Solutions and Sustainability R&D Congress

Based on a Research Project Titled "Assessment of the Visual Quality of Urban Landscapes in Health Promotion – Methods and Initial Findings". Funded by MOE AcRF Tier 2 Project Research Grant (Grant No. MOE2019-T2-2-184)



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Healing Effects of Urban Greening

Modifying hospitals' design by humanising spaces and especially through **reconnecting with nature** offers a therapeutic support that **can positively impact on the patients' psychological and physical well-being**; it can also improve their ability to recover, with varying results depending on the different levels of treatment (diagnosis, therapy, recovery) and on the disease in question.

Totaforti, S. Applying the benefits of biophilic theory to hospital design. City Territ Archit 5, 1 (2018). https://doi.org/10.1186/s40410-018-0077-5

Positive Effects of Urban Greening

The **positive effects** on the **health and performance** of human beings in response to **biophilic design of the built environment** have been verified by extensive scientific studies in **different settings**: healthcare facilities, workplaces, children's spaces, community spaces, etc.

Totaforti, S. Applying the benefits of biophilic theory to hospital design. City Territ Archit 5, 1 (2018). https://doi.org/10.1186/s40410-018-0077-5

Positive Effects of Urban Greening

Do All Types of Restorative Environments in the Urban Park Provide the Same Level of Benefits for Young Adults? A Field Experiment in Nanjing, China
Yuanbi Li, Jinguang Zhang, Bijun Jiang, Hongyi Li, Bing Zhao · Psychology · Forests · 2023
Previous research has consistently shown that exposure to natural environments provides a variety of health benefits. The purpose of this study is to investigate the restorative benefits of... Expand
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The Influence of Virtual Forest Walk on Physiological and Psychological Responses
Emad Alyan, Théo Combe, D. R. Awang Rambli, S. Sulaiman, F. Mérienne, N. Diyana · Psychology · International journal of environmental research... · 2021
TLDR Investigation of virtual forest therapy based on realistic versus dreamlike environments showed that virtual forest environments could have positive stress-relieving effects, however, realistic graphics were more efficient in reducing stress. Expand
10 · PDF · Save · Alert

Effects of Vegetation Structure on Psychological Restoration in an Urban Rooftop Space
Juyoung Lee, M. Kang, Sungku Lee, Seo-Hui Lee · Psychology · International journal of environmental research... · 2022
Connectedness to nature has been recognized as an important factor for well-being, with rooftop green spaces being used for stress reduction in modern cities. This study aimed to examine... Expand
PDF · View 6 excerpts, cites background and results · Save · Alert

The Stress Reduction Effect of Nature Through Virtual Reality (VR): a Systematic Review Protocol
Ambra Gentile, A. Bianco, P. Nordström, A. Nordström · Business · 2021
TLDR The current systematic review protocol aims at establishing the main steps that will be undertaken to investigate the stress-reduction effects of virtual nature studies, and provides the protocol that would be used in the systematic review concerning the stress reduction effect of virtual reality. Expand
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The restorative effects of short-term exposure to nature in immersive virtual environments (IVEs) as evidenced by participants' brain activities.
Gaochao Zhang, Guowei Wu, J. Yang · Psychology · Journal of environmental management · 2022
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The Effects of Urban Natural Environments on Preference and Self-Reported Psychological Restoration of the Elderly
Ling Qiu, Qujing Chen, Tian Gao · Psychology · International journal of environmental research... · 2021
TLDR Blue space and partly-closed green space were more preferred by the elderly, and also had more psychological restorative effects on the elderly and open green space with more Prospect, Serene and Social qualities could also increase psychological restoration of older adults. Expand
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Virtual Reality to Evaluate the Impact of Colorful Interventions and Nature Elements on Spontaneous Walking, Gaze, and Emotion
A. Batistatou, Florentin Vandeville, Y. Delevoye-Turrell · Psychology · Frontiers in Virtual Reality · 2022
Green environments are said to have a positive impact on spontaneous physical activity and well-being. However, high quality psychological measures in natural settings are difficult to collect. In... Expand
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Attention and Emotion Recovery Effects of Urban Parks during COVID-19—Psychological Symptoms as Moderators
Ziliang Jin, Jiangping Wang, X. Liu · Psychology · Forests · 2022
Previous research that compared the restorative effects of natural settings with poor-quality urban settings may have exaggerated the restorative benefits of greenspace. Few studies have been... Expand
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The Contribution to Stress Recovery and Attention Restoration Potential of Exposure to Urban Green Spaces in Low-Density Residential Areas
Shuping Huang, Jinda Qi, Wei Li, Jianwen Dong, C. V. D. van den Bosch · Psychology · International journal of environmental research... · 2021
TLDR Exposure to green space led to significant changes in PRS, electrodermal activity (EDA), facial electromyography (EMG), respiration sensor (RESP), and photoplethysmography (PPG), and psychological and physiological responses were highly consistent and correlated. Expand
13 · PDF · View 1 excerpt, cites background · Save · Alert

Impact of Exposure to Natural and Built Environments on Positive and Negative Affect: A Systematic Review and Meta-Analysis
W. Yao, Fei Chen, Sanxi Wang, Xiaofeng Zhang · Psychology · Frontiers in Public Health · 2021
There is increasing evidence that the natural environment provides substantial benefits to human emotional well-being. The current study synthesized this body of research using the meta-analysis and... Expand
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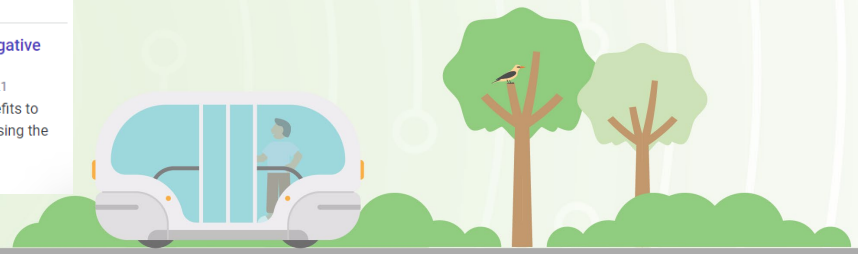
- Benefiting **physical and psychological health** (Huang et al., 2021; Takano et al., 2002)
- Improving **air quality and thermal comfort** (Javadi and Nasrollahi, 2021)
- Creating **social coherence** (Van den Berg et al., 2015)
- Providing **recreation, relaxation**, and landscape **aesthetics** (Javadi and Nasrollahi, 2021)



~~Why Green Our Cities?~~

How to Green Our Cities?

Urban Greening & Mental Health

Contact with nature has long been linked to **better mental health** – it's why sanatoriums and hospitals are often found in green surroundings. Living in greener surroundings is thought to **improve physical and mental health** by promoting physical activity, increasing psychological restoration and stress recovery, and strengthening social bonds in neighbourhoods.

Eco-Business, Greening the city to prevent mental illness (2022)
https://www.eco-business.com/opinion/greening-the-city-to-prevent-mental-illness/

Urban Greening & Mental Health – But How?

Types of **urban green space tend to affect residents' mental health through different paths**. Furthermore, this review discusses the details of each part under the influence paths. Finally, the policy implications for urban green space planning from three mediator levels are put forward based on an analysis of the situation in different countries.

Chen K. et al, How Does Urban Green Space Impact Residents' Mental Health: A Literature Review of Mediators (2021)

Given the increase in mental health problems and the current rapid urbanization worldwide, results of the present systematic review should be taken into account in future urban planning. However, further research is needed to provide more consistent evidence and more detailed information on the **mechanisms and the characteristics of the green and blue spaces that promote better mental health**.

Gascon M. et al, Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review (2015)

We also outline key questions for future work, including further inquiry into **which elements of the natural environment may have impacts on cognitive function and mental health**; what the most effective type, duration, and frequency of contact may be; and what the possible neural mechanisms are that could be responsible for the documented effects.

Bratman. et al, The impacts of nature experience on human cognitive function and mental health (2012)

What Is the Mechanism Behind It?

Characteristics of the Urban Landscape

Effect on People Exposed to these Landscapes

What Is the Mechanism Behind It?

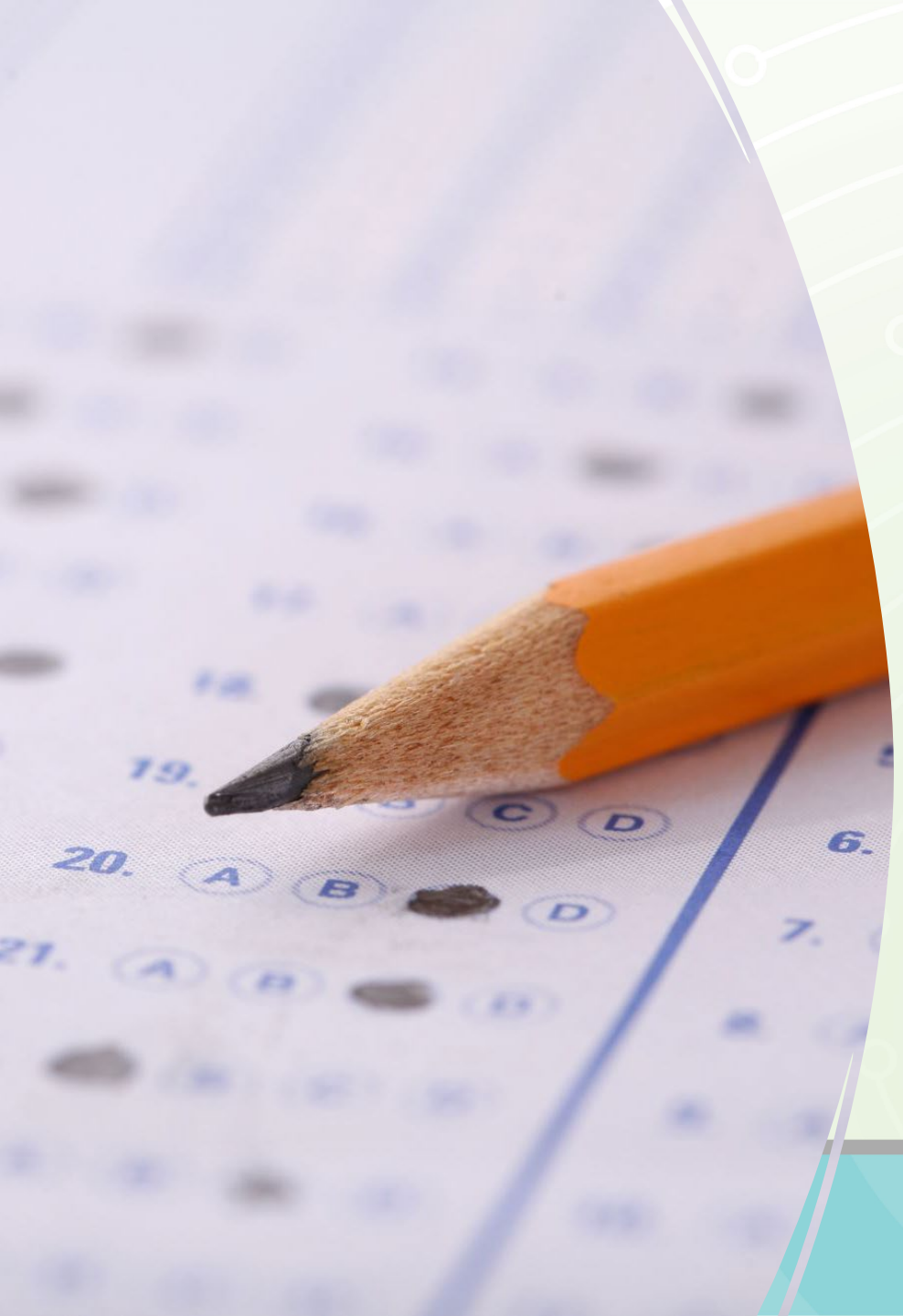
Characteristics of the Urban Landscape

Effect on People Exposed to these Landscapes

Attention Restoration Theory

Directed attention plays an important role in human information processing; its **fatigue**, in turn, has far-reaching consequences. Attention Restoration Theory provides an analysis of the kinds of experiences that lead to **recovery** from such fatigue. **Natural environments** turn out to be particularly rich in the characteristics necessary for **restorative experiences**.

Kaplan S., The restorative benefits of nature: Toward an integrative framework (1995). https://doi.org/10.1016/0272-4944(95)90001-2



Measuring Restorativeness

The **PRS-11** is a four-factor model that mirrored four elements of Attention Restoration Theory (ART) and has been demonstrated to be able to measure perceived restorativeness.

Fascination (3 questions)
Being Away (3 questions)
Coherence (3 questions)
Scope (2 questions)

Pasini et al., How to Measure The Restorative Quality of Environments: The PRS-11 (2014). https://doi: 10.1016/j.sbspro.2014.12.375

Physiological Response

Furthermore, DTR, DAR, TBR, and ABR, based on EEG recordings, were **used to explain the positive effect of indoor nature on attention and mental workload**. These findings may contribute to the knowledge base for understanding the underlying **mechanisms between indoor nature and perceived benefits**, and guide designers to create restorative and cognitive enhancing spaces in design practice.

Rhee J.H. et al., Effects of nature on restorative and cognitive benefits in indoor environment (2023). https://doi.org/10.1038/s41598-023-40408-x

What Is the Mechanism Behind It?

Characteristics of the Urban Landscape

Effect on People Exposed to these Landscapes

What Landscape Characteristics?

The experimental results show that all four natural spaces in the park have some degree of recovery. However, there were **discernible differences in the restorative effects of four selected natural sites**. Lakeside and Forest demonstrated the most robust restorative properties in terms of both negative emotion reduction and positive emotion enhancement.

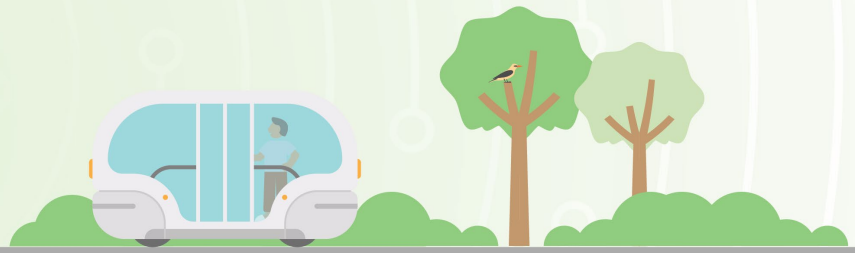
Li Y. et al, Do All Types of Restorative Environments in the Urban Park Provide the Same Level of Benefits for Young Adults? A Field Experiment in Nanjing, China (2023)

We therefore designed and conducted a randomised controlled experiment to identify the **restorative potential of different types of trees and grass** in an urban virtual reality (VR) environment. Repeated-measures analysis of variance with a general linear model indicated that the **grassy environment had the greatest effect on positive affect**.

Huang et al, Trees, grass, or concrete? The effects of different types of environments on stress reduction (2021)

However, a fully enclosed vegetation with trees was not associated with higher parasympathetic activities than a half-open vegetation model. Based on these findings, **an open and structured vegetation design that includes both grass and shrubs** may have more potential for stress reduction than a monotonous vegetation model.

Lee J. et al, Effects of Vegetation Structure on Psychological Restoration in an Urban Rooftop Space (2022)



Landscape Visual Quality

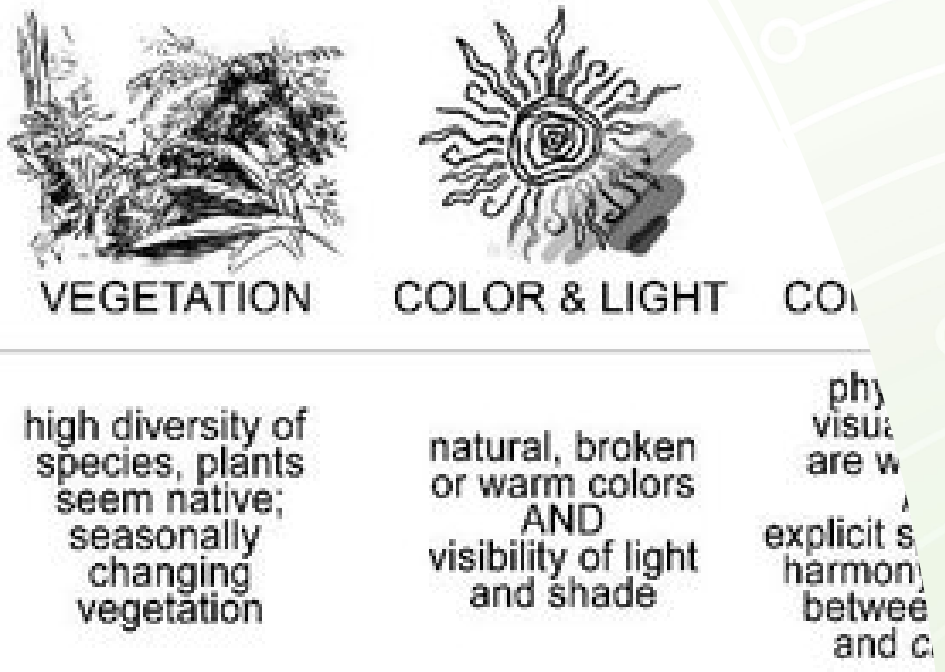
Based on this framework we assume that the assessment of visual landscape quality results from **how people perceive and evaluate the physical features in a landscape**, with some culturally shared preferences for some landscape features over others. Visual landscape quality is thus the result of **how individuals evaluate the physical and biological components of landscapes** based on their social, cultural and individual background and experiences.

Wartmann F. M. et al, Factors influencing visual landscape quality perceived by the public. Results from a national survey (2021) https://doi.org/10.1016/j.landurbplan.2020.104024

Quality over Quantity

Residents of neighbourhoods with **high quality POS had higher odds of low psychosocial distress** than residents of neighbourhoods with low quality POS. This appeared to be irrespective of whether or not they used POS. However, the quantity of neighbourhood POS was not associated with low psychological distress. From a mental health perspective, POS **quality within a neighbourhood appears to be more important than POS quantity**. This finding has policy implications and warrants further investigation.

Francis J. et al, Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia (2012) https://doi.org/10.1016/j.socscimed.2012.01.032

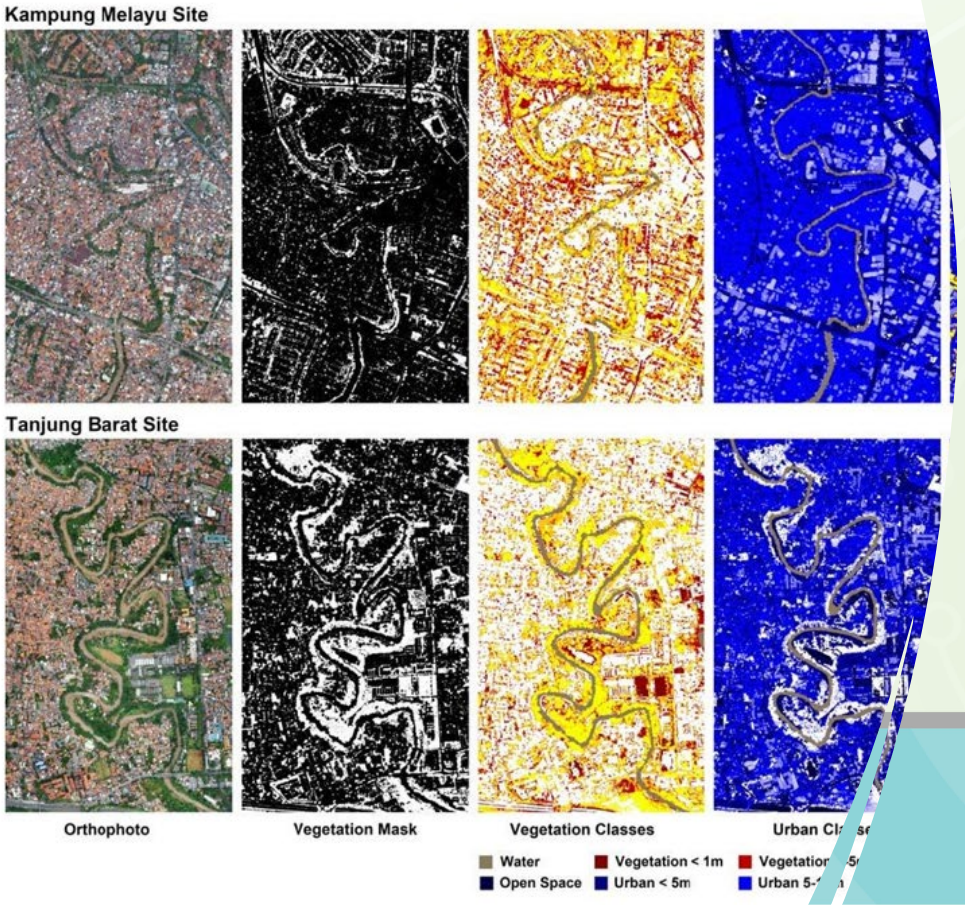


Measuring Visual Quality (Qualitative)

Regardless of behavioral tendencies indexed by the frontal asymmetry, the passive exposure to the Therapeutic Garden improved mood in both groups. Moreover, the findings further confirmed that **different designs** of green spaces (**measurable with visual quality assessment tools** such as Contemplative Landscape Model) can **induce different psychophysiological responses**.

Olszewska-Guizzo, A. et al, Therapeutic Garden with Contemplative Features Induces Desirable Changes in Mood and Brain Activity in Depressed Adults (2022) https://doi.org/10.3389/fpsyt.2022.757056

Metric	Description
Patch Richness (PR) *Unit: N.A.*	Provides the total number of different classes in a given landsc Can be used as an initial measure of landscape diversity which is a However since classes are usually operator determined, this does no information especially so for the examples explored here whereby th
Class Area Proportion (CAP) & Percentage of Landscape (PLAND) *Unit: Ha (CAP)* *Unit: % (PLAND)*	Calculates the area (CAP) and proportion (PLAND) of landscape cove The CAP or PLAND is possibly the single most important landscape des existence and identity of the matrix in a landscape (the predominant class landscape) as well as helps identify at risk or rare classes.
Number of Patches (NP) & Patch Density (PD) *Unit: N.A.(NP)* *Unit: Patches/100Ha (PD)*	NP counts the total number of patches. PD calculates the number of patches NP and PD are used as a measure of landscape configuration dealing with the class or landscape, i.e. a higher NP or PD might indicate fragmentation

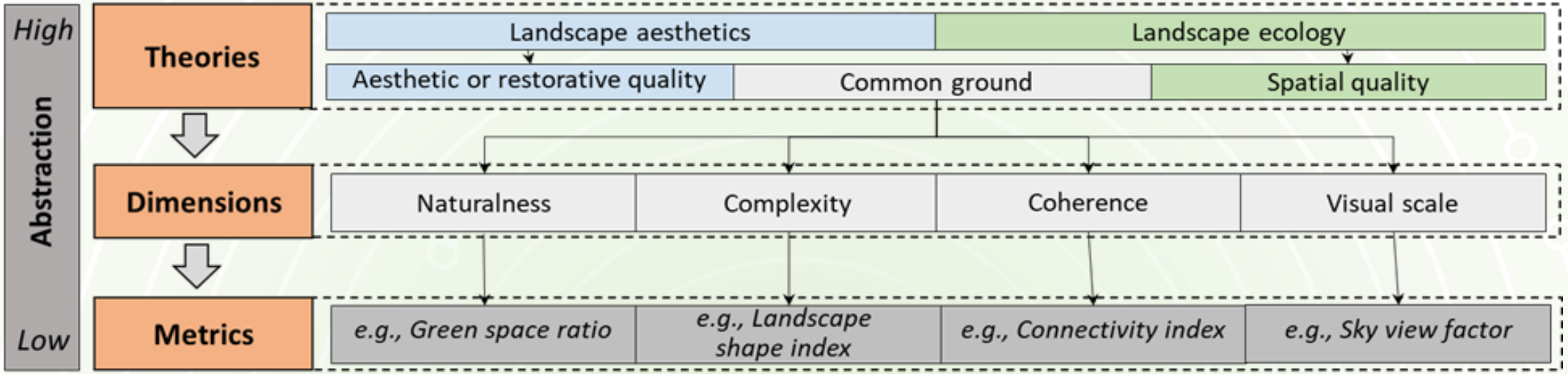


Measuring Spatial Quality (Quantitative)

Landscape ecology is largely based on the idea that **environmental patterns influence ecological processes**. These patterns are often quantified using **landscape metrics as indicators** for: land use changes, habitat functions (biodiversity, habitats), landscape regulating functions (fire control, microclimate control, etc.), and information functions (landscape aesthetics).

Uuemaa et al., Trends in the use of landscape spatial metrics as landscape indicators: A review (2013) https://doi.org/10.1016/j.ecolind.2012.07.018

Linking Visual and Spatial Quality



A conceptual framework for landscape visual quality representation adapted from Tveit et al. (2006)

Measuring at the Right Scale

…a set of urban landscape metrics, such as sky view factor (SVF), standard deviations for building and vegetation height, building volume and aboveground biomass, building compactness ratio, daily shadow patterns, and surface roughness. These metrics commonly assess LVQ from a top-down plan view, while **LVQ needs to be quantified at the appropriate scale** in 3D based on what a user might see or experience in a given landscape, i.e. **at the human scale and eye level**.

Qi J. et al., Development and application of 3D spatial metrics using point clouds for landscape visual quality assessment (2022) https://doi.org/10.1016/j.landurbplan.2022.104585

Research Objectives

- Develop Methods to Measure Landscape Metrics at the Human Scale
- Establish Relationship between Metrics and Restorative Potential
- Predict Restorative Potential through Landscape Metrics

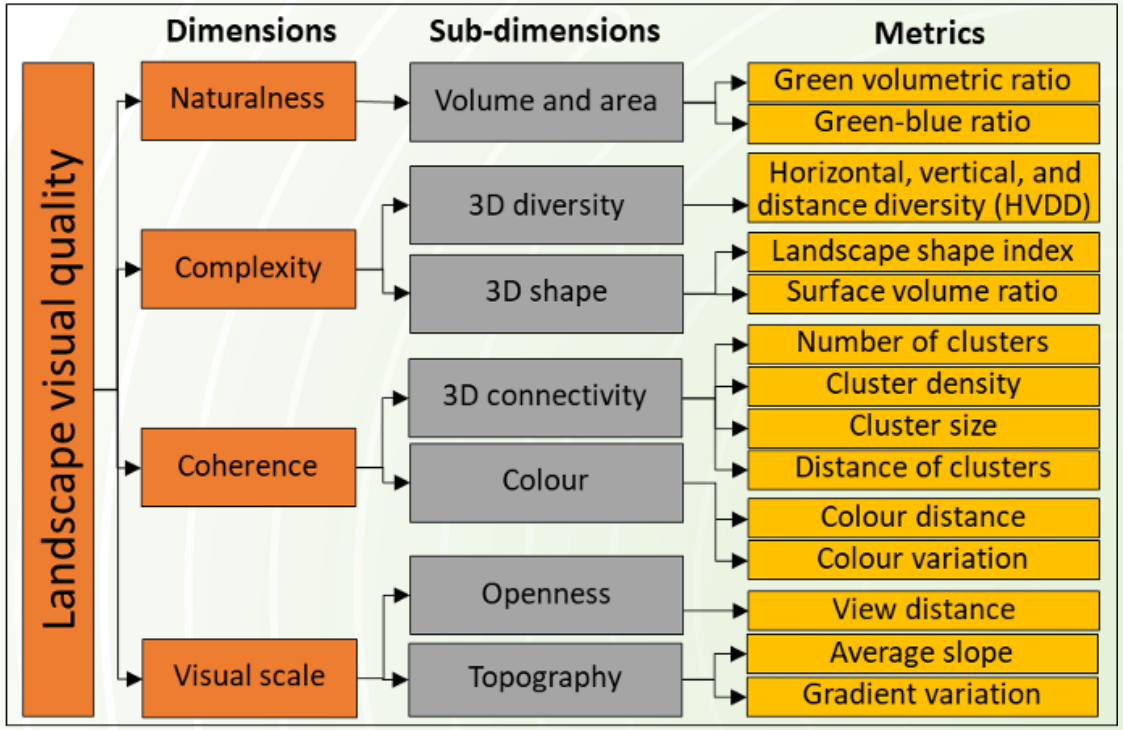
Two Novel Methods of Measuring Urban Landscapes

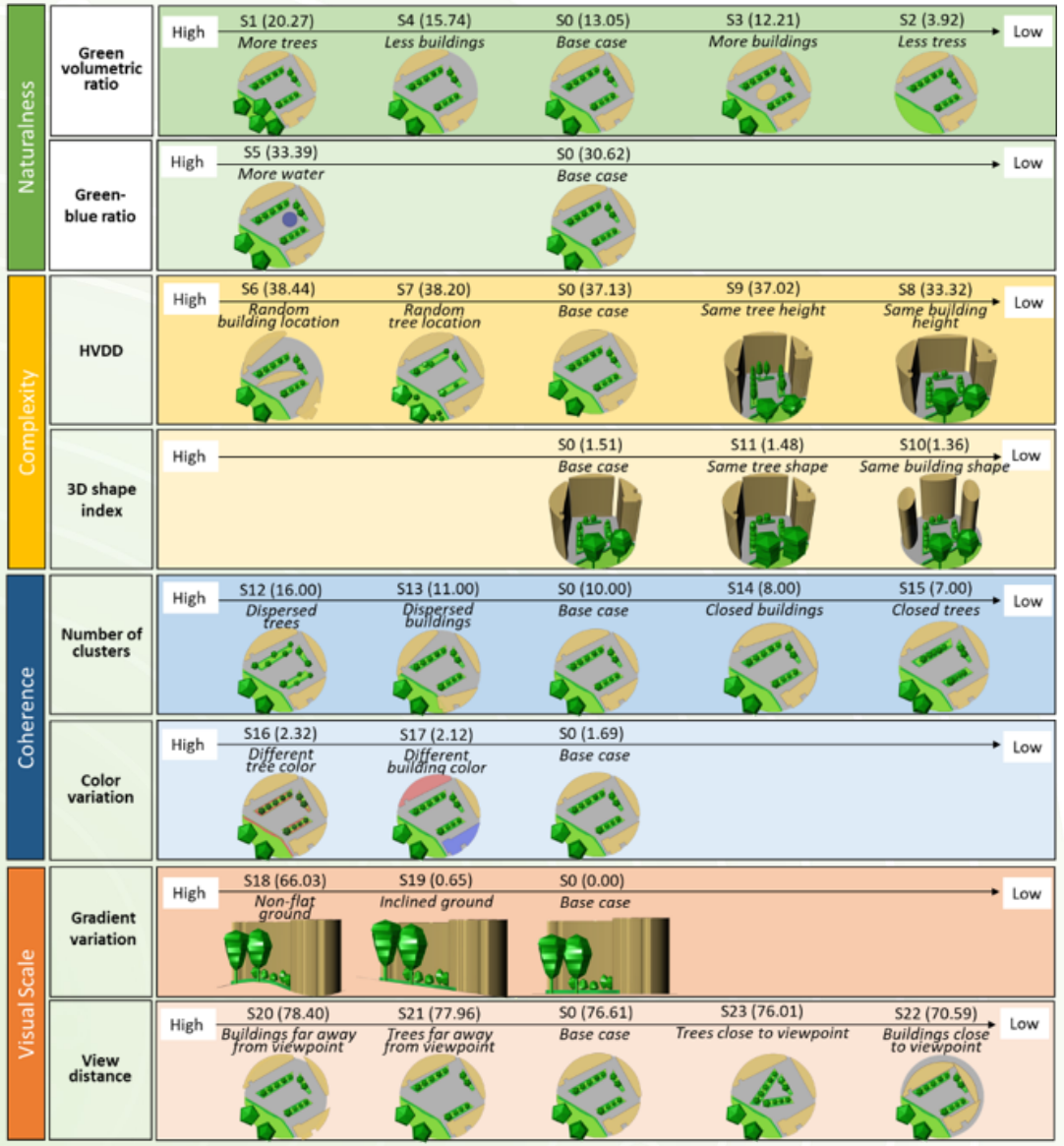
LiDAR-based 3D Metrics

Panoramic-based Image Metrics

Development of 3D Metrics

- References Dimensions of Landscape Visual Quality
- Provides a means to measure spatial organization of landscapes at the human scale

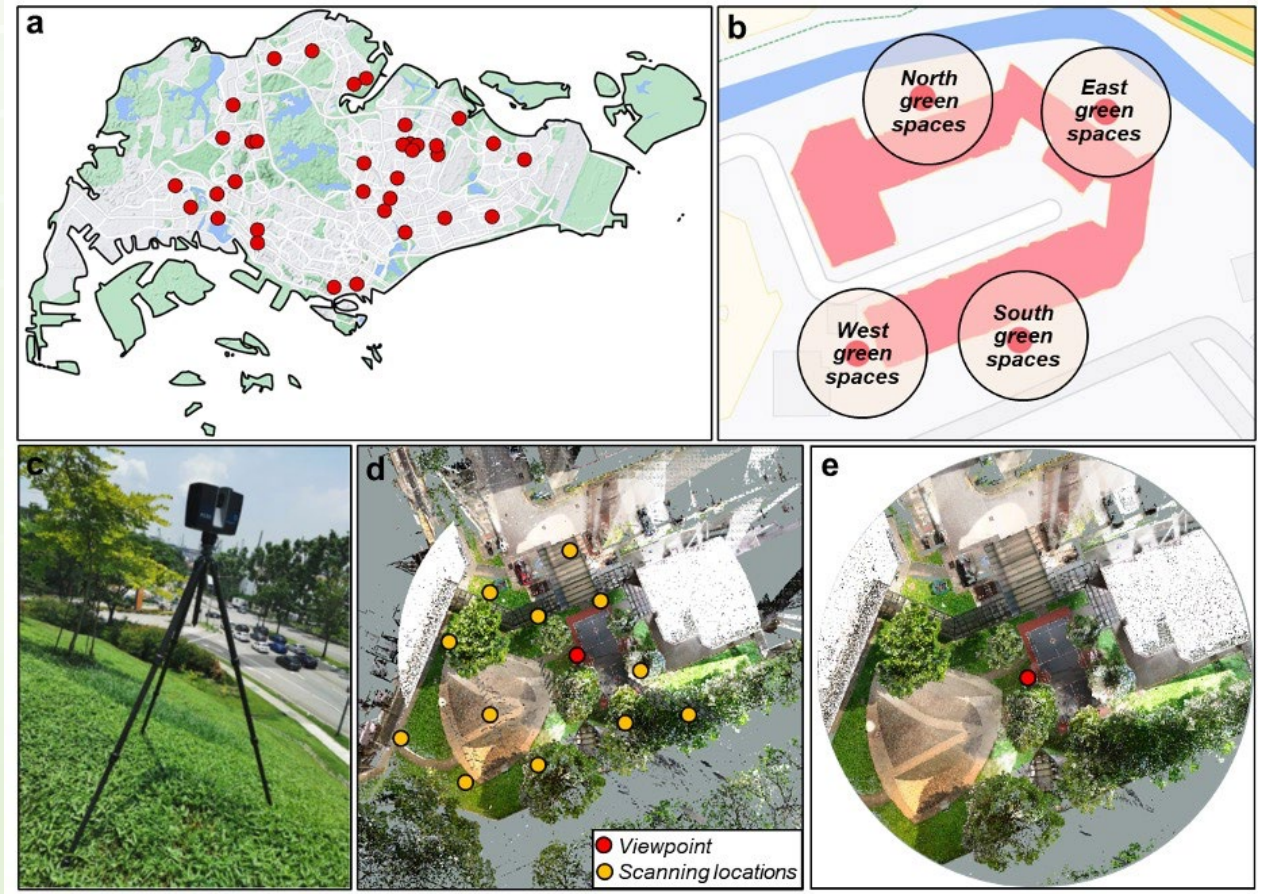




Qi et al., Development and application of 3D spatial metrics using point clouds for landscape visual quality assessment (2022), https://doi.org/10.1016/j.landurbplan.2022.104585

Scanning Methodology

- 177 sites in Singapore Scanned
  - HDB urban landscapes + Parks & Gardens



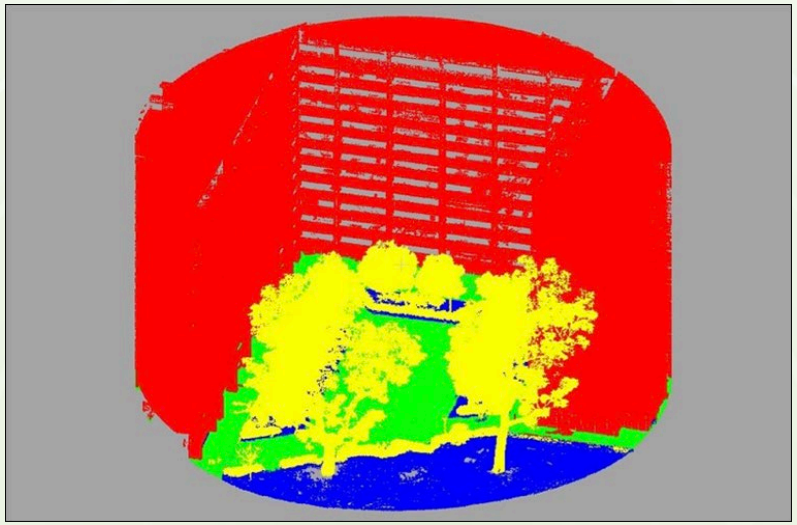
Qi et al., Development and application of 3D spatial metrics using point clouds for landscape visual quality assessment (2022), https://doi.org/10.1016/j.landurbplan.2022.104585

Metrics from Scans

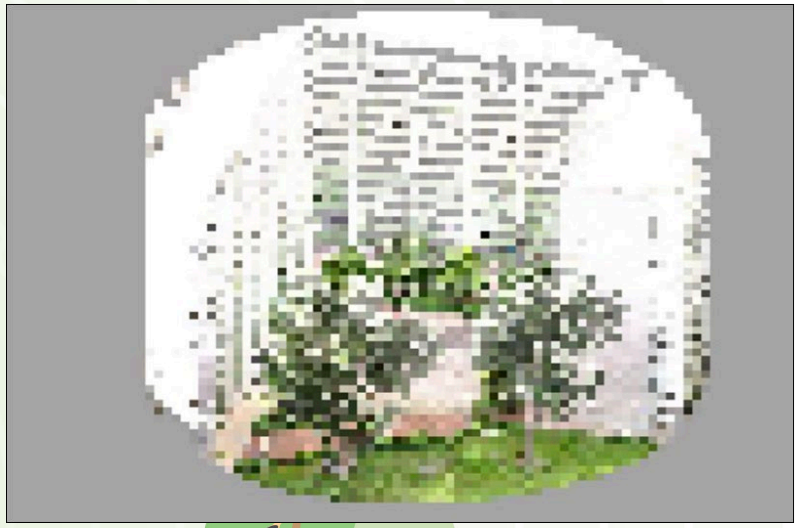
- Collection -> Classification -> Voxelisation -> Measurement

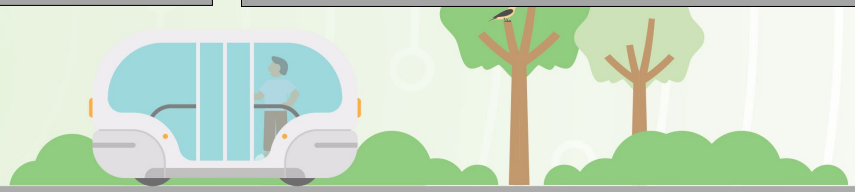
Step 1:Generation or collection

Step 2:Classification

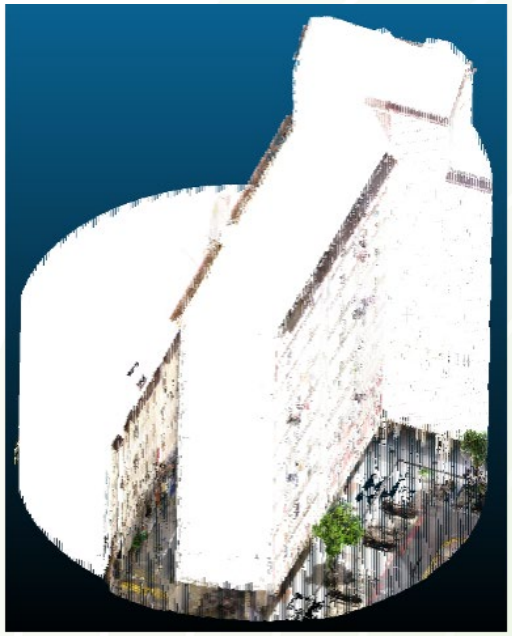


Step 3:Voxelization



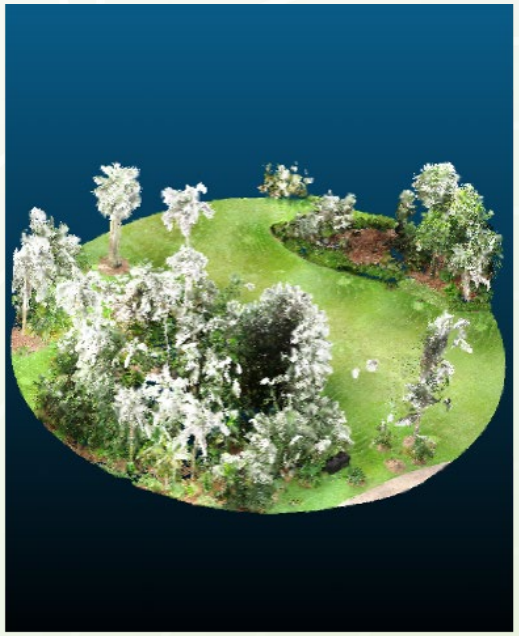


Qi et al., Development and application of 3D spatial metrics using point clouds for landscape visual quality assessment (2022), https://doi.org/10.1016/j.landurbplan.2022.104585



Postcode: 381114_South

Low green volumetric ratio:
0.09% (low naturalness)

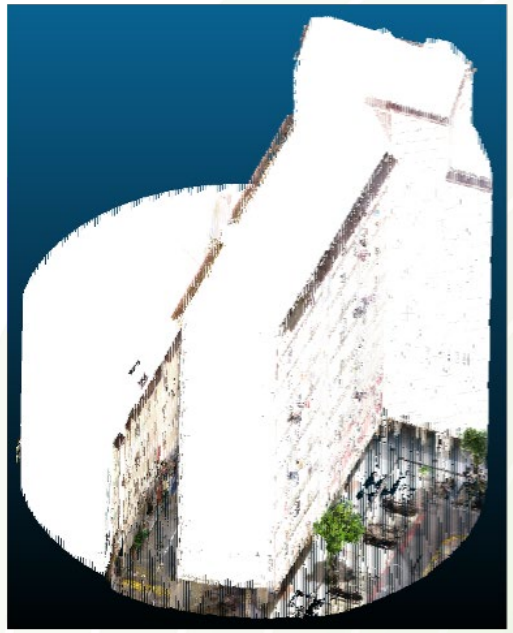


Postcode: SBG_Palm

High green volumetric ratio
100% (high naturalness)

Naturalness Dimension

- Purpose – To quantify the level of greening in a landscape
- E.g. Green Volumetric Ratio



Postcode: 381114_South

Landscape shape index:
2.416 (high regularity)

Postcode: SBG_SwanLakeB

Landscape shape index:
25.345 (low regularity)

Complexity Dimension

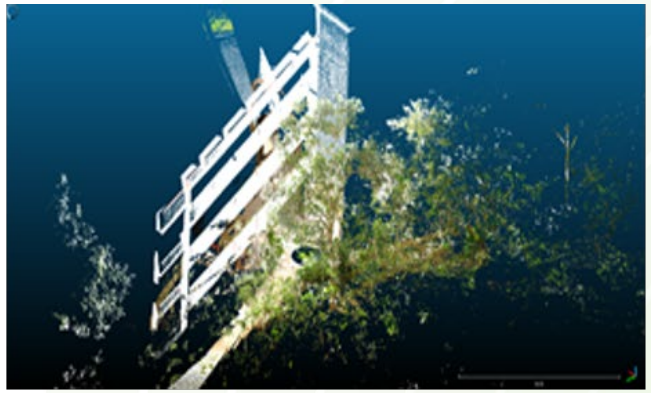
- Purpose – To quantify the regularity of the landscape
- E.g. Landscape Shape Index

Postcode: 730103_North
Number of clusters: 1
(high connectivity)

Postcode: 550327_North
Number of clusters: 16
(low connectivity)

Coherence Dimension

- Purpose – Quantify the connectivity of the landscape
- E.g. Number of Clusters



Postcode: 730103_West

View distance: 15.510 m (Low openness)

Postcode: 530662_East

View distance: 137.280 m (High openness)

Visual Scale Dimension

- Purpose – Quantify the openness of a landscape
- E.g. View Distance

Metrics	
Naturalness	Green volumetric ratio
	Green volume
	Grey volume
	Green area ratio
	Grey area ratio
	Blue area ratio
Complexity	Whole horizontal, vertical, and distance diversity
	Green horizontal, vertical, and distance diversity
	Grey horizontal, vertical, and distance diversity
	Whole horizontal diversity
	Green horizontal diversity
	Grey horizontal diversity
	Whole vertical diversity
	Green vertical diversity
	Grey vertical diversity
	Whole distance diversity
	Green distance diversity
	Grey distance diversity
	Whole landscape shape index
	Green landscape shape index
	Grey landscape shape index
Coherence	Whole cluster number
	Green cluster number
	Grey cluster number
	Whole cluster density
	Green cluster density
	Grey cluster density
	Whole cluster size
	Green cluster size
	Grey cluster size
	Whole distance of clusters
	Green distance of clusters
	Grey distance of clusters
	Colorfulness
	Color variations
Visual scale	Whole view distance
	Distance to green
	Distance to grey
	Front-background ratio
	Slope
	Gradient variation

East

West

North

South

Location	Green Gray Volumetric Ratios							
	Volume of whole area	Volume of Ground_Green	Volume of Ground_Grey	Volume of Nonground_Green	Volume of Nonground_Grey	Volume of Blue	Volume of Other	Green/Grey ratio
East	2220.54	92.60	61.13	109.13	1952.10	5.58	0.00	0.10
West	1460.00	99.77	164.29	348.28	847.67	0.00	0.00	0.44
North	3290.88	90.05	60.74	504.98	2593.48	41.63	0.00	0.22
South	1963.84	40.69	102.16	180.34	1640.66	0.00	0.00	0.13

Development of Image-based Metrics

- Founded on Perceived Sensory Dimensions (PSD)
- Characterises landscapes based on human perception and psychological benefits

The related PSD statements used in the online survey to investigate the correlation with metrics.

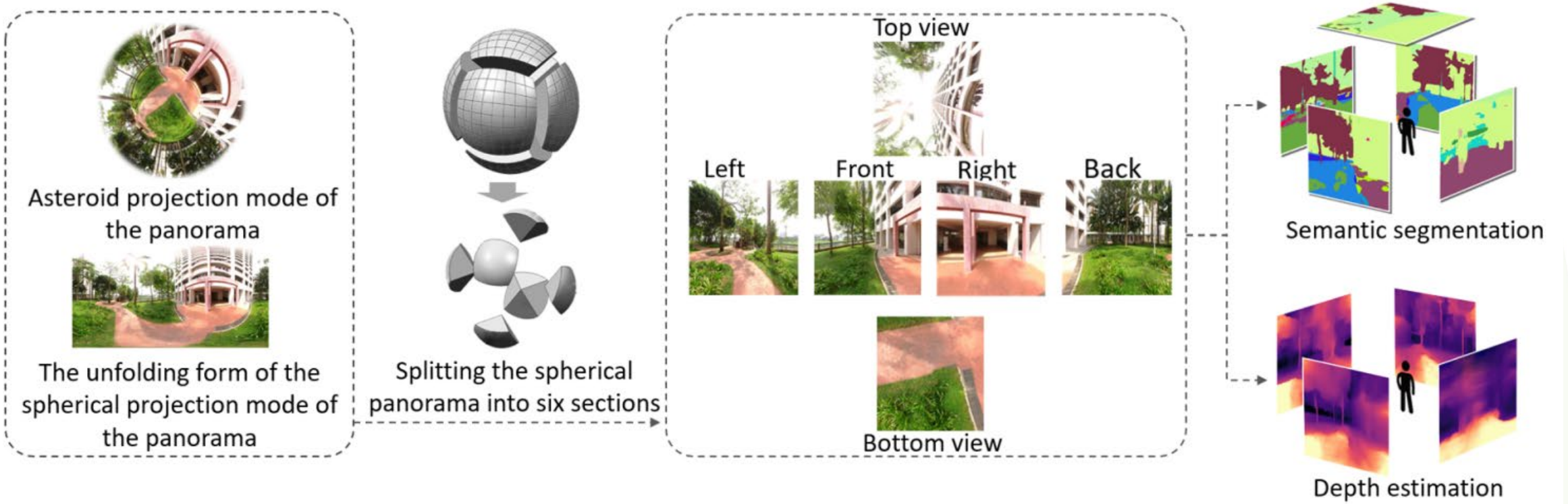
Dimension	Statement
Natural	The place provides a sense of intimacy with nature.
Open	The place has a wide view to see the surroundings in the distance.
Cohesive	The place is spacious for free movement and uneasy to be disturbed by others.
Sheltered	The place is sheltered and safe.
Serene	The place is peaceful and quiet.
Cultivated	There are many artificial elements with a sense of man-made, managed, and cultivated features.
Diverse	The place has a sense of diversity and variation, providing a rich sensory experience.

Dimension	Metrics
Natural	Naturalness
	Wildness
	Green view index (GVI)
	Tree
	Flora
	Grass
	Water
Open	Depth
	Sky
Cohesive	Spatial division
	Free space
Sheltered	Overhead shelter
	Depth variation
	GVI variation
Serene	Disturbance
Cultivated	Building
	Service facility
Diverse	Diversity of plant groups
	Diversity of sensory dimensions

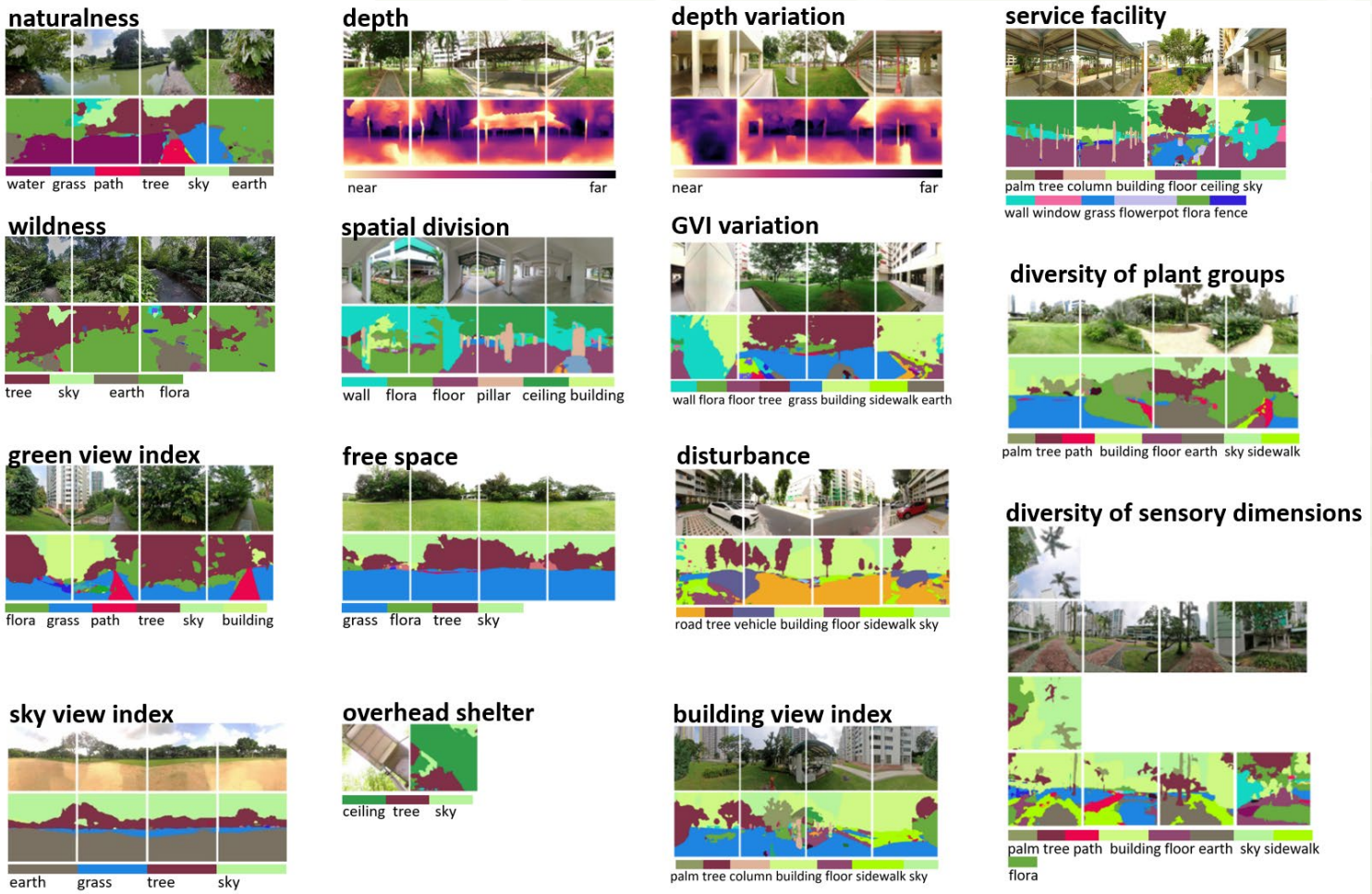
Zhang et al., Assessment of visual landscape quality of urban green spaces using image-based metrics derived from perceived sensory dimensions (2023)

Processing Panoramic Images

- Uses panoramic images as an input
- Processed using image segmentation and depth estimation machine learning algorithms



Zhang et al., Assessment of visual landscape quality of urban green spaces using image-based metrics derived from perceived sensory dimensions (2023)



Measurement of Metrics

- Various metrics are calculated based on the processed images

Zhang et al., Assessment of visual landscape quality of urban green spaces using image-based metrics derived from perceived sensory dimensions (2023)

Metrics	High value (top 25%)	Medium value (top 25%)	Low value (top 25%)
Naturalness	 naturalness = 1.569	 naturalness = 1.183	 naturalness = 0.234
Wildness	 wildness = 1.549	 wildness = 0.772	 wildness = 0
Green view index (GVI)	 GVI = 0.909	 GVI = 0.544	 GVI = 0
Depth	 depth = 0.479	 depth = 0.233	 depth = 0.154
Sky view index (SVI)	 SVI = 0.377	 SVI = 0.046	 SVI = 0.000
Spatial division	 spatial division= 0.481	 spatial division= 0.056	 spatial division= 0.000
Free space	 free space = 0.554	 free space = 0.167	 free space = 0.000

Examples of Scenes & Metrics

- 2442 panoramas were collected in Singapore by onsite collection and Google Street View imagery.
- Scenes were randomly sampled based on the metric results categorized by high (top 25%), medium (middle 50%), and low values (bottom 25%).

Metrics	High value (top 25%)	Medium value (top 25%)	Low value (top 25%)
Overhead shelter	 overhead shelter = 1	 overhead shelter = 0.355	 overhead shelter = 0
Depth variation	 depth variation= 0.333	 depth variation= 0.020	 depth variation= 0.001
GVI variance	 GVI variance = 0.364	 GVI variance = 0.105	 GVI variance = 0.009
Disturbance	 disturbance= 0.345	 disturbance = 0.042	 disturbance = 0.000
Building view index (BVI)	 BVI = 0.521	 BVI = 0.110	 BVI = 0
Service facility	 service facility = 0.675	 service facility = 0.043	 service facility = 0
Diversity of plant groups	 diversity of plant groups= 1.078	 diversity of plant groups= 0.676	 diversity of plant groups= 0.101
Diversity of sensory dimensions	 diversity of sensory dimensions= 1.625	 diversity of sensory dimensions = 1.066	 diversity of sensory dimensions = 0.170

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Image-based Metrics & PSD

- Correlation study between image-based metrics developed and perceived sensory dimensions

The related PSD statements used in the online survey to investigate the correlation with metrics.

Dimension	Statement
Natural	The place provides a sense of intimacy with nature.
Open	The place has a wide view to see the surroundings in the distance.
Cohesive	The place is spacious for free movement and uneasy to be disturbed by others.
Sheltered	The place is sheltered and safe.
Serene	The place is peaceful and quiet.
Cultivated	There are many artificial elements with a sense of man-made, managed, and cultivated features.
Diverse	The place has a sense of diversity and variation, providing a rich sensory experience.

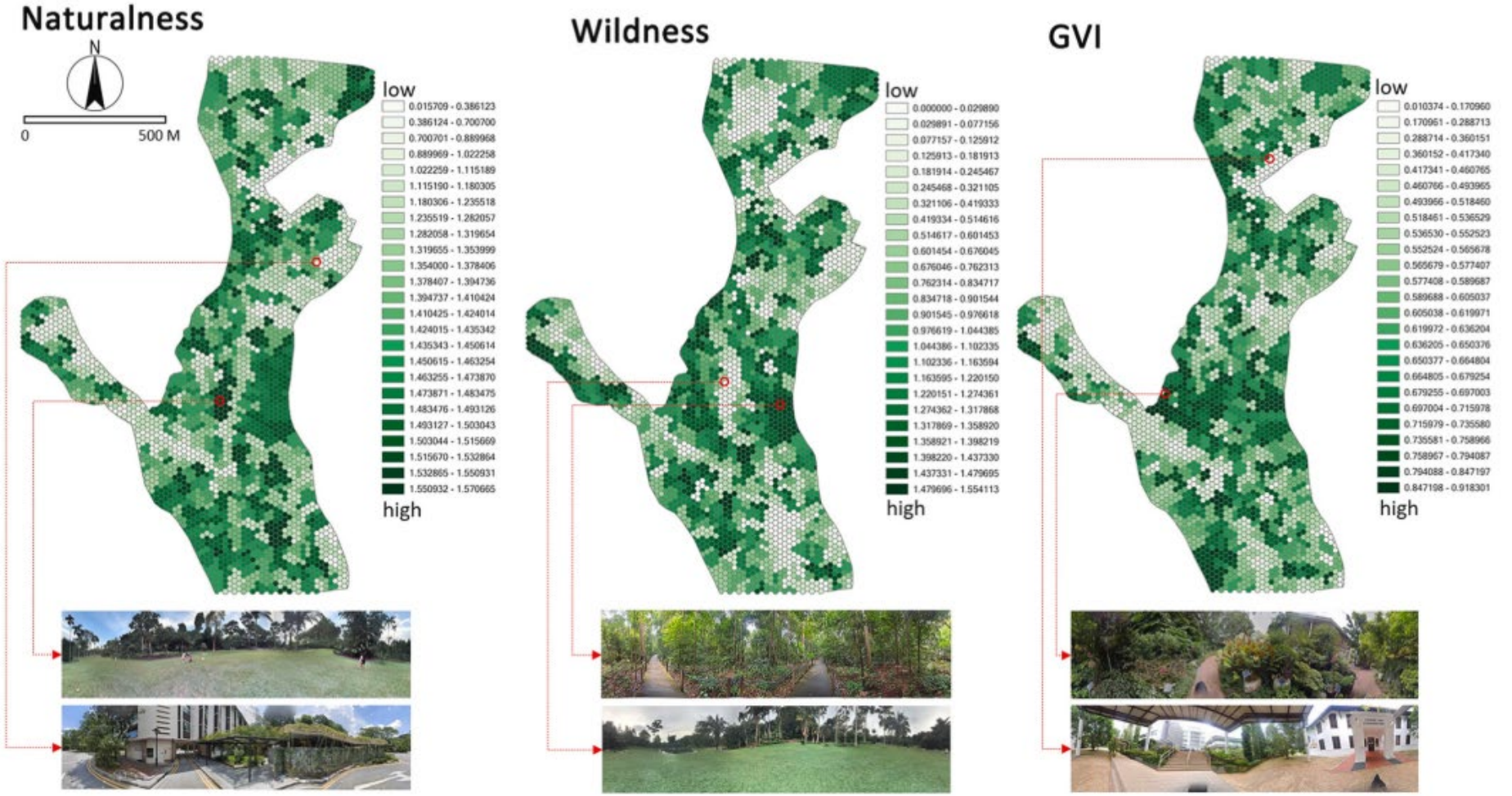
Bivariate correlation between metrics and corresponding PSD responses.

PSD	Metrics	Correlation with dimension
Natural	Naturalness	0.864***
	Wildness	0.524***
	GVI	0.733***
	Tree	0.666***
	Flora	0.409***
	Grass	0.233**
	Water	0.327***
Open	SVI	0.656***
	Depth	0.418***
Cohesive	Spatial division	−0.528***
	Free space	0.305***
Sheltered	Overhead shelter	0.033
	Depth variation	0.147
	GVI variation	0.339***
Serene	Disturbance	−0.301***
Cultivated	BVI	0.437***
	Service facility	0.422***
Diverse	Diversity of plant groups	0.526***
	Diversity of sensory dimensions	−0.437***

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$.

Zhang et al., Assessment of visual landscape quality of urban green spaces using image-based metrics derived from perceived sensory dimensions (2023)

Mapping of Metrics using Google Street View



Zhang et al., Assessment of visual landscape quality of urban green spaces using image-based metrics derived from perceived sensory dimensions (2023)

Linking Metrics to Restorative Potential

Online Survey

- 1500 respondents
- 100 scenes
- 60 responses per scene
- Determine Perceived Restorativeness (**PRS-11**) of scanned landscapes
- Determine Perceived Sensory Dimensions (**PSD**) of scanned landscapes

Everything seems to have its proper position
To stop thinking about the things I must get done, I'd like to go to such a place
The place is large enough to allow exploration in many directions
My attention is drawn to many interesting things
It is hard to be bored
There is a clear order in the physical arrangement of the place
The place is a refuge from nuisances
To get away from things that usually demand my attention, I like to go to such a place
It is easy to see how things are organised
The place is fascinating
There are few boundaries to limit my possibility for moving about

60%

Please proceed to look around the entire scene

Imagine you are now in the presented place. To what extent would you agree with the following statements?

(Please read all the statements carefully and answer them to the best of your ability. Random answers will be detected by the system, which might lead to your response being invalidated)

	Disagree	Mostly disagree	Slightly disagree	Neutral	Slightly agree	Mostly agree	Agree
First Set of Statements							
There is a clear order in the physical arrangement of the place	○	○	○	●	○	○	○
It is easy to see how things are organised	○	○	○	○	●	○	○
To stop thinking about the things I must get done, I'd like to go to such a place	○	○	○	●	○	○	○

Linking 3D Metrics to Restorative Potential

LiDAR scan

3D point cloud data

Panorama

3D metrics for measurement of spatial characteristics of green and grey components

Regression model

Key 3D metrics

Panoramic image for online survey

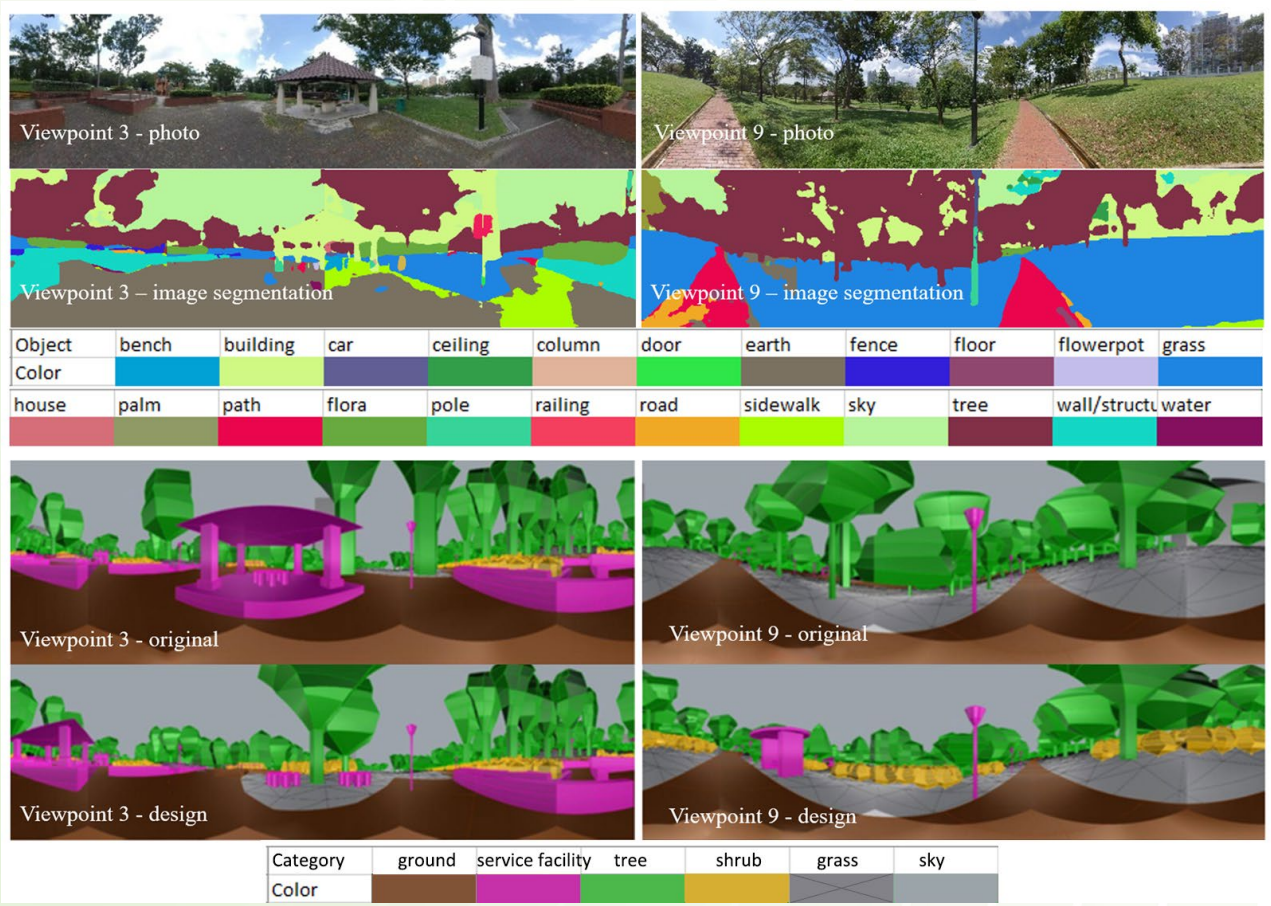
Restorative potential

Metrics		Examples of high PR		Examples of Low PR	
		Park: 4.09	HBD: 3.61	Park: 3.47	HDB: 2.78
					
Naturalness	Green volumetric ratio	93.24	17.40	99.92	0.10
	Green volume	238.57	1129.21	1729.76	35.76
	Grey volume	17.31	5349.08	0.00	36899.90
	Green area ratio	80.45	62.24	87.69	1.74
	Grey area ratio	5.32	37.76	12.31	98.26
	Blue area ratio	14.23	0.00	0.00	0.00
Complexity	Whole horizontal diversity	17.02	59.44	1.45	14.03
	Green horizontal diversity	25.42	18.17	1.57	132.46
	Grey horizontal diversity	82.72	97.72	19.13	14.07
	Whole vertical diversity	39.47	22.86	28.05	13.28
	Grey vertical diversity	137.42	18.36	41.39	13.26
	Whole landscape shape index	7.72	5.65	11.19	2.13
Coherence	Whole cluster number	6.00	3.00	3.00	3.00
	Green cluster number	5.00	4.00	3.00	2.00
	Grey cluster number	1.00	3.00	0.00	2.00
	Whole cluster size	42.36	2154.00	570.64	12311.00
	Green cluster size	47.37	278.13	570.64	17.75
	Grey cluster size	13.34	1780.56	0.00	18449.04
	Whole distance of clusters	19.05	16.89	13.72	18.12
	Green distance of clusters	20.44	13.97	13.72	13.32
	Grey distance of clusters	0.00	13.20	0.00	14.60
	Colorfulness	46.92	34.86	39.59	29.43
Visual scale	Whole view distance	58.69	39.70	20.18	41.07
	Distance to grey	24.80	2.04	150.00	8.94
	Front-background ratio	42.92	24.45	6.49	13.23
	Slope	12.63	12.25	5.36	3.34
	Gradient variation	161.22	149.19	34.99	21.45

Predicting Restorative Potential

Comparing Metrics – Panorama vs 3D model

Metrics	Descriptive statistics for 3D-model-based metrics			Descriptive statistics for Image-based metrics			**Welch's ANOVA (p-value)**	**Bivariate Correlation**
	mean	min	max	mean	min	max		
Tree	0.320	0.184	0.439	0.281	0.102	0.421	0.406	0.891***
Shrub	0.017	0.000	0.120	0.008	0.000	0.034	0.499	0.782**
Grass	0.316	0.021	0.487	0.303	0.057	0.494	0.850	0.697***
GVI	0.653	0.304	0.856	0.592	0.313	0.866	0.449	0.733**
Sky	0.121	0.049	0.216	0.137	0.018	0.354	0.712	0.903***
Depth	0.175	0.127	0.234	0.335	0.289	0.380	0.000	0.903***
Overhead shelter	0.293	0	0.996	0.197	0.000	0.517	0.399	0.535*
Building	0.023	0.003	0.135	0.051	0.006	0.134	0.138	0.600*
Service facility	0.076	0.002	0.356	0.022	0.001	0.071	0.270	0.527*
Path	0.127	0.002	0.407	0.053	0.000	0.150	0.107	0.608**
Diversity of plant groups index	0.719	0.531	0.933	0.683	0.559	0.763	0.358	0.624**

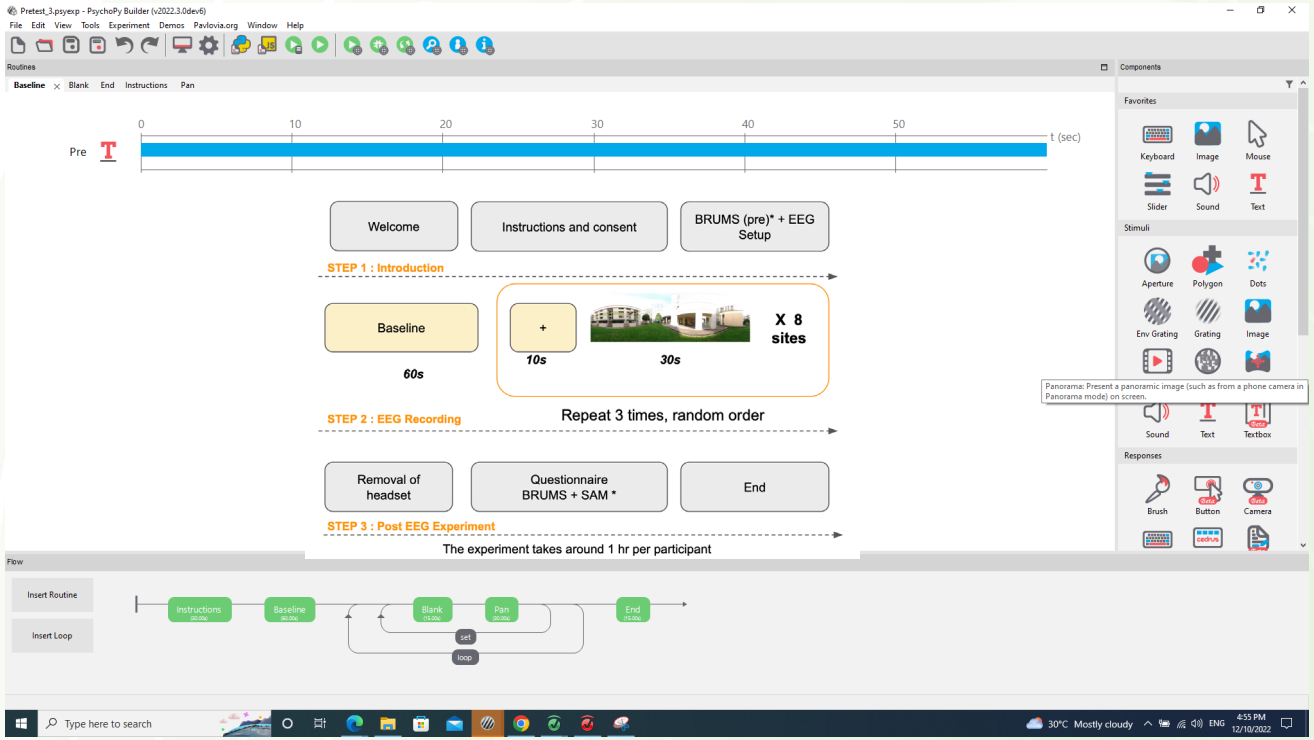


Zhang et al., Linking Image-based Metrics to 3D-model-based Metrics for Assessment of Visual Landscape Quality (2023)

Further Work

Physiological Responses via EEG

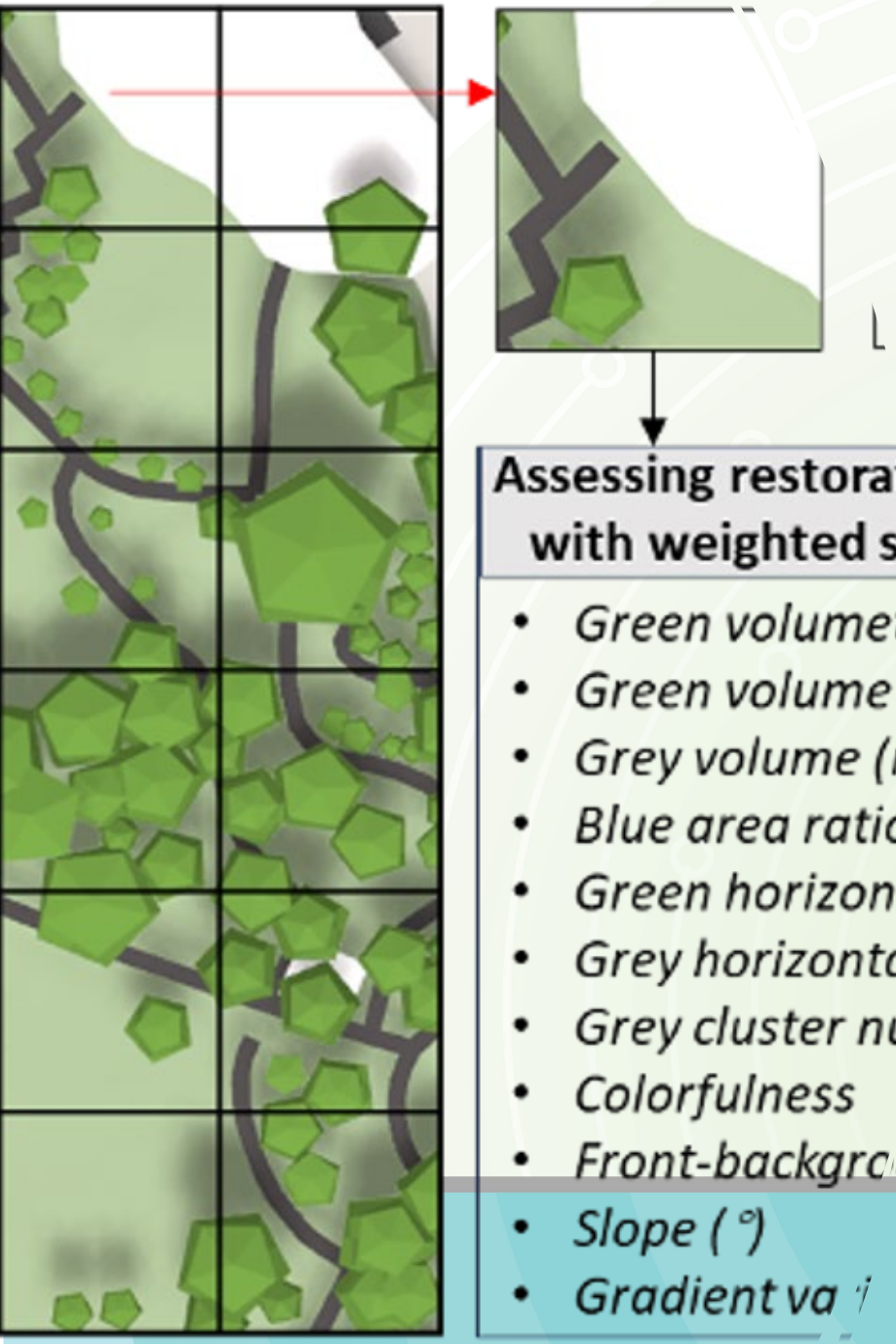
- Lab experiment completed (n=149)
- EEG data being analysed



EEG Protocol for the experiment is set up with **PsychoPy-2022**

Conclusions

- Developed **two novel methods of measuring landscapes** at the human scale
    - Attempts to **quantify the spatial quality** of landscapes
    - Metrics can potentially be used to correlate with **other phenomena** (e.g. thermal comfort, preference, biodiversity, etc)



Conclusions

- Developing ways to **measure designed landscapes** and **different scenarios**
  - Potentially helps designers and planners **target specific desired outcomes** through predictions
  - Requires more work

Thank You

Based on a Research Project Titled "Assessment of the Visual Quality of Urban Landscapes in Health Promotion – Methods and Initial Findings". Funded by MOE AcRF Tier 2 Project Research Grant (Grant No. MOE2019-T2-2-184)