Monitoring the provision and condition of high- value restorative outdoor environments with remote sensing and Volunteered Geographic Information

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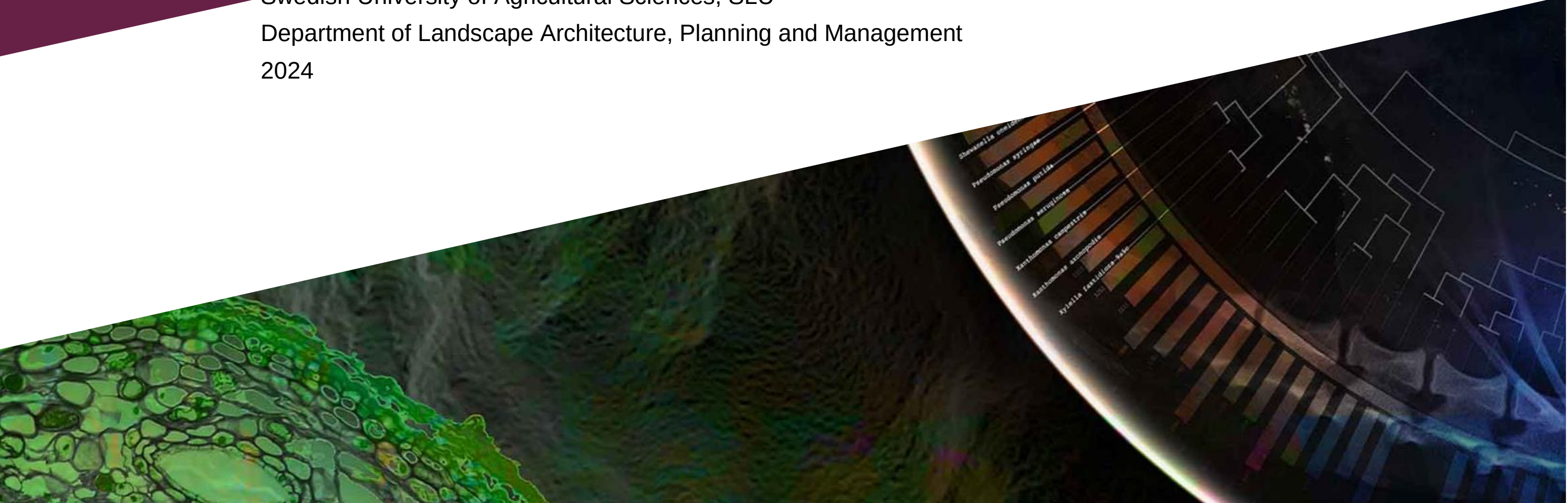

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Table of contents

1. Introduction

1.1 Restorative outdoor environments

Restorative outdoor environments play a pivotal role in promoting staff and student well-being, productivity, and overall satisfaction on the campus. Such environments are designed to rejuvenate, reduce stress, and foster a sense of belonging and motivation. Scientific research has highlighted the significance of these environments in various ways:

1. Enhanced Cognitive Function: restorative environments can enhance cognitive functioning, leading to improved task performance and decision-making abilities (S. Kaplan, 1995)
2. Reduced Mental Fatigue: Restorative settings have been shown to mitigate mental fatigue, which is crucial for maintaining consistent productivity levels throughout the workday.
3. Promotion of Well-being: According to a book by Collado et al. (2017), exposure to restorative environments, especially those with natural elements, can significantly boost psychological well-being.
4. Improved Job Satisfaction: Incorporating restorative elements in workplace design can lead to increased job satisfaction and reduced turnover intentions, as highlighted by Adevi & Mårtensson (2013).

Restorative workplace environments therefore offer tangible benefits that can enhance both individual and organizational outcomes.

There are a multitude of studies outlining the relationship between outdoor environment, greenness and human wellbeing. Hajrasouliha (2017) talks about morphological dimensions: land use organization, compactness, connectivity, configuration, campus living, greenness, context. In the same study, greenness is positively related to student satisfaction and antagonistic to urbanism, which is also positively associated to student satisfaction. Greenness index was comprised from: surface parking, pervious surfaces, tree canopy indices, measured in quarter mile buffer around campus. One unit increase is associated with retention rate of 0.2 percent.

Kabisch et al. (2015) performed a review of literature on links between on human-environment interactions in urban green spaces. Greenness is associated with: lower overall mortality, reduced cardiovascular disease and respiratory disease mortality rate in. People have self-reported lower stress level, especially when participating in active exercise.

Roe et al. (2013) used salivary cortisol measurements as an indicator of wellbeing and green space. Green space was measured as the sum of parks, woodland, other natural environments within the postcode of the participant and found that it is a significant predictor of cortisol cycle as well as physical activity of study participants. Cortisol method seems much more reliable as self-reporting stress

Tyrväinen et al. (2014), proved that tranquilty and feeling of being in a forest is most coveted type of urban green space among participants, asserting that participants' perception of naturalness, wild woods as a self-reported measure, to have most ameliorative effects.

Our experiment specifically looked at the restorative effects of greenery or vegetation in vicinity of campuses in Alnarp and Lund and how the perception-rating of volunteered information within the same area is related to landscape characteristics that can be observed remotely using high-resolution imagery. Essentially, we combined two approaches in quantifying landscape perception to see if there is a connection between them that can be measured or quantified.

1.2 The eight basic qualities of urban space

Densification and urbanization are associated with degradation of the living environment whereas green space aesthetics have been highlighted as an important factor to support human health and well-being. Due to the need to be able to identify and grade aesthetic components of the urban environment conceptual frameworks were devised to provide a simple and quantifiable way to grade, compare and analyse different environments.

The framework mentioned here is the basis for our field assessment methodology, described further in the method section.

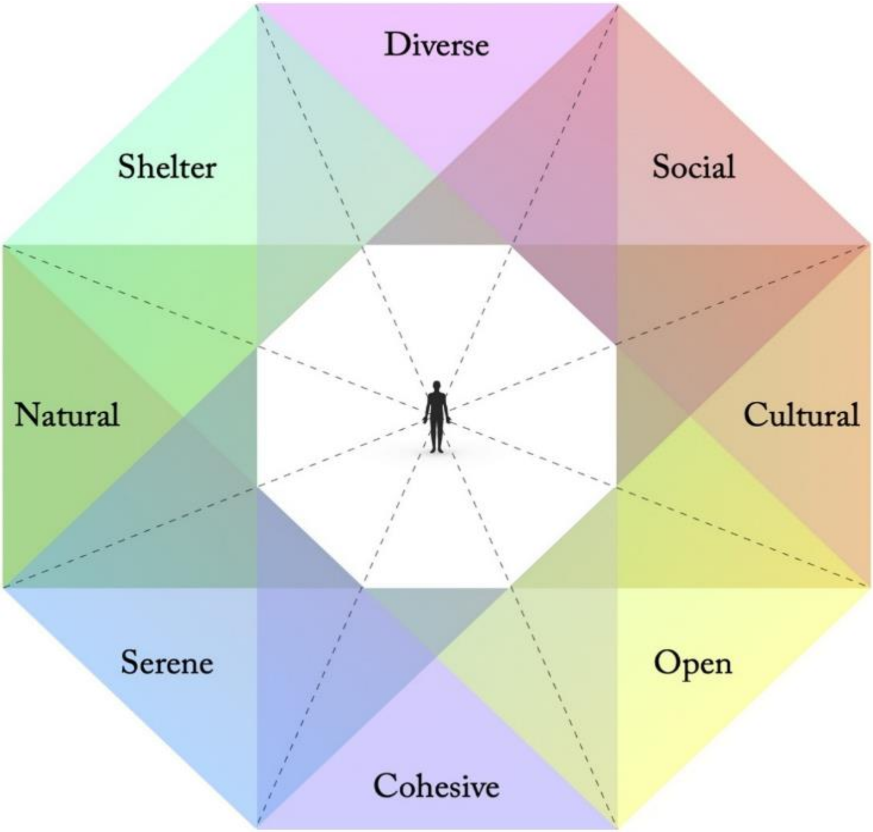

Figure 1: Perceived sensory dimensions and relations between them (Stoltz & Grahn, 2021)

1.3 Fractals and human well-being

Fractals are intricate patterns that repeat themselves at various scales and can be found throughout nature, from the branching of trees to jagged coastlines. In the realm of landscape design and architecture, the concept of fractals has garnered significant attention due to its potential influence on human well-being.

In the field of environmental psychology and landscape aesthetics, studies have suggested that humans have a preference for landscapes with certain fractal dimensions. Some researchers argue that our visual system evolved in a fractal environment, and therefore we are naturally tuned to process fractal patterns with particular dimensions.

Hagerhall et al. (2004) in the paper "Fractal dimension of landscape silhouette outlines as a predictor of landscape preference, found that landscapes with a medium fractal dimension were most preferred, indicating an optimal level of complexity.

Spehar et al. (2003) "Universal aesthetic of fractals", reported that both natural scenery and abstract art with a lower-to-mid-range fractal dimension are most appealing.

Akeson and Herbert (1997) in the study "The fractal dimension as a measure of the perceived complexity of natural scenes", found that the fractal dimension of a scene correlated with perceived wilderness.

These findings suggest that the fractal dimension could be a significant factor in the perception and preference of natural or wilderness-like environments. However, this is a complex area of study, and many factors can influence landscape perception and preference.

1.4 Remote sensing of vegetation

1.4.1 NDVI

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator used in remote sensing and satellite imagery analysis to assess the health, density, and vigor of vegetation in a particular area. NDVI is a valuable tool for monitoring changes in vegetation over time and is widely used in various fields, including agriculture, ecology, forestry, and environmental science. The reason for its widespread use is because NDVI is designed to be highly sensitive to the presence and condition of vegetation, it provides a numerical measure of vegetation status, ranging from -1 to 1, which allows for quantitative analysis, it minimizes the impact of atmospheric conditions, such as haze and cloud cover, on vegetation assessment and more.

NDVI is calculated from the reflectance values of two specific spectral bands typically found in remote sensing imagery:

- Near-Infrared (NIR): This spectral band is sensitive to the reflectance of vegetation and has relatively high reflectance values for healthy green plants. It is often represented as "NIR."

- Red: This spectral band corresponds to the red portion of the visible light spectrum and is sensitive to the reflectance of the ground surface and non-vegetated features. It is often represented as "Red."

The aerial ortophoto imagery supplied by Lantmäteriet includes these spectral bands, which allows for NDVI analysis at high resolution.

1.4.2 Surface model

LiDAR (Light Detection and Ranging) is a remote sensing technology that uses laser pulses to measure distances to objects, making it ideal for generating high-resolution terrain models and detecting vegetation canopy heights. This involves generating a digital elevation model (DEM) from ground points and subtracting it from digital terrain model (DTM) – a digital representation of the Earth's surface that describes the elevation of the terrain - which will then show height values of aboveground vegetation.

2. Methodological approach

2.1. Study sites

In total, three sites were selected for this case study: SLU campus Alnarp, Lund campus West, Lund campus East. We divided the Lund campus in two parts due to distinct urban character differences between them, where the western part is older and denser while the eastern is part of the ongoing expansion of the campus with younger developments.

Figure 2: Alnarp site

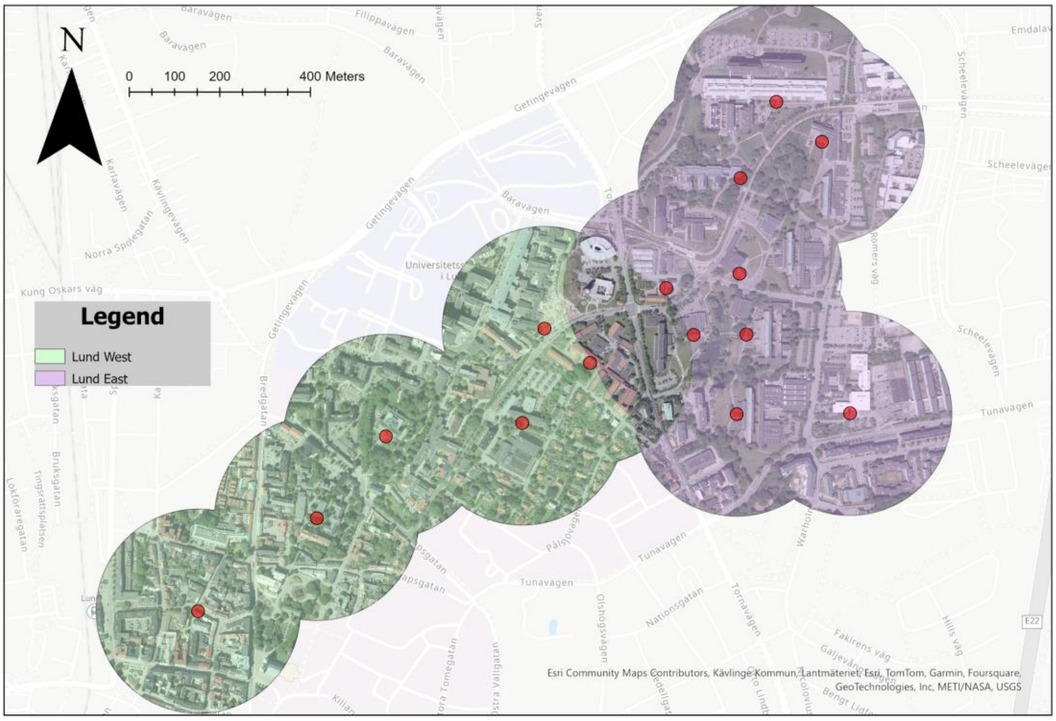

Figure 3: Lund sites: East and West campus

2.2. Field collection of data

The field collection of data was following the methodology designed after the framework of eight basic qualities of urban space (Stoltz & Grahn, 2021). A team of two observers walked the study area and marked their observations in tandem.

Each quality aspect had several sub-categories for ranking on the point scale from 0-3. The sum of these points then represented the total score in a specific aspect.

2.3. Remote sensing of data

We compiled the spatial information required from available databases with the goedata extraction tool (GET) hosted by SLU. This included orthophoto imagery in high resolution (25cm) that included the infrared spectrum, as well as LiDAR data to create a vegetation surface model to separate vegetation into height classes.

Figure 4: Vegetation map of Alnarp study site

2.4. Spatial pattern analysis

We used the program Fragstats for spatial pattern analysis for quantifying landscape metrics such as Fractal Index and Edge Density. We added edge density, because in the context of landscape fragmentation it refers to the amount of edge, or boundary, between different habitat types or land cover classes relative to the total landscape area. It's a measure used to quantify the degree of fragmentation in a landscape. Specifically, edge density can be defined as the proportion of the total landscape area occupied by the borders or edges between different habitat patches or land cover types (McGarigal, 2023).

3. Results

Table 1: Qualitative grading of the environment in three aspects of human perception

Sum of grades for near- and neighboring environment (0-400 m)			
	Naturalness	Spaciousness	Diversity
Alnarp	18	26	20
Lund East	12	23	13
Lund West	10	19	11

The results below are shown as a series of charts where a qualitative aspect was plotted against the two selected landscape parameters; either fractal index or edge density.

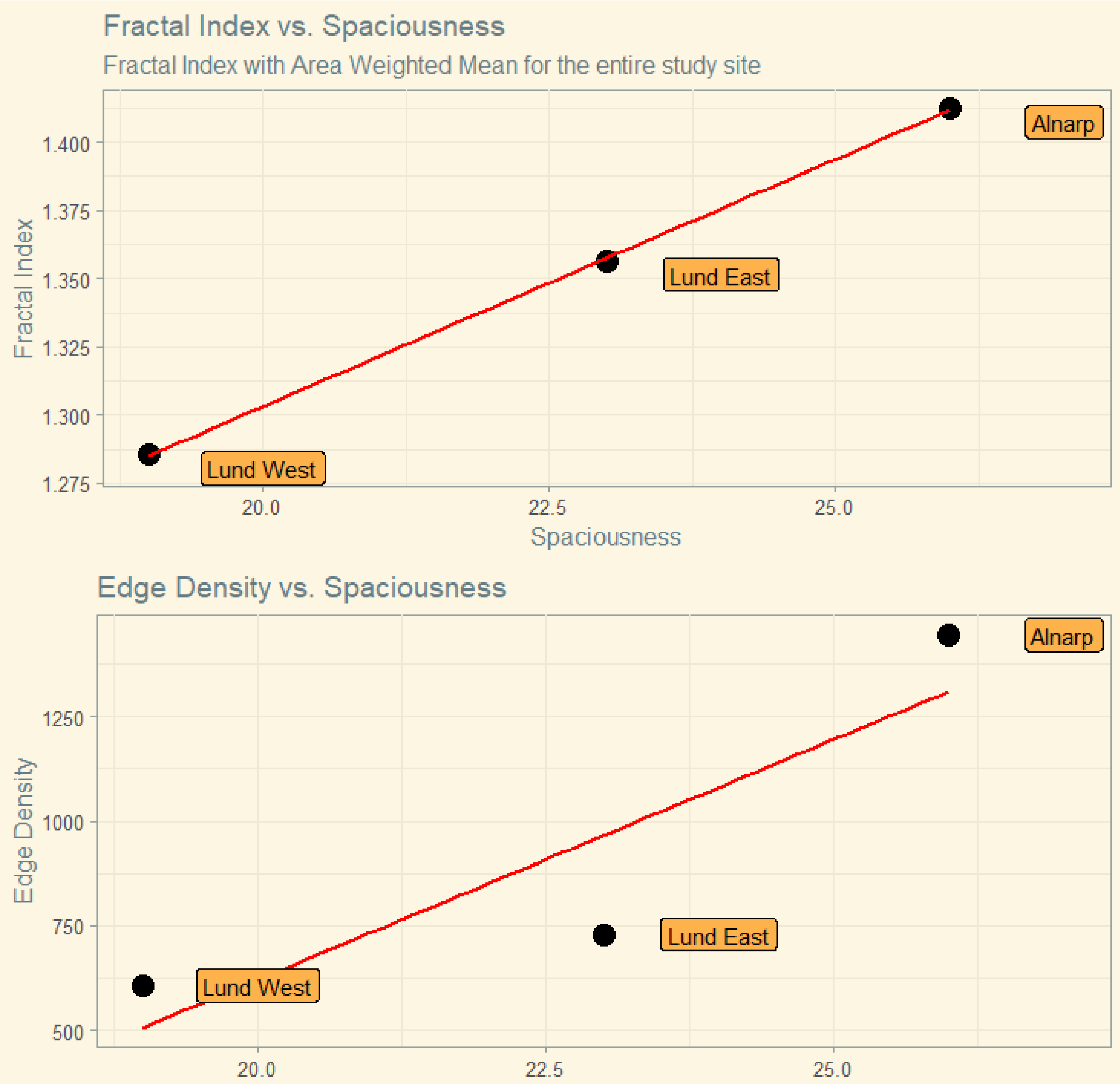

Figure 5: Spaciousness compared to landscape fragmentation

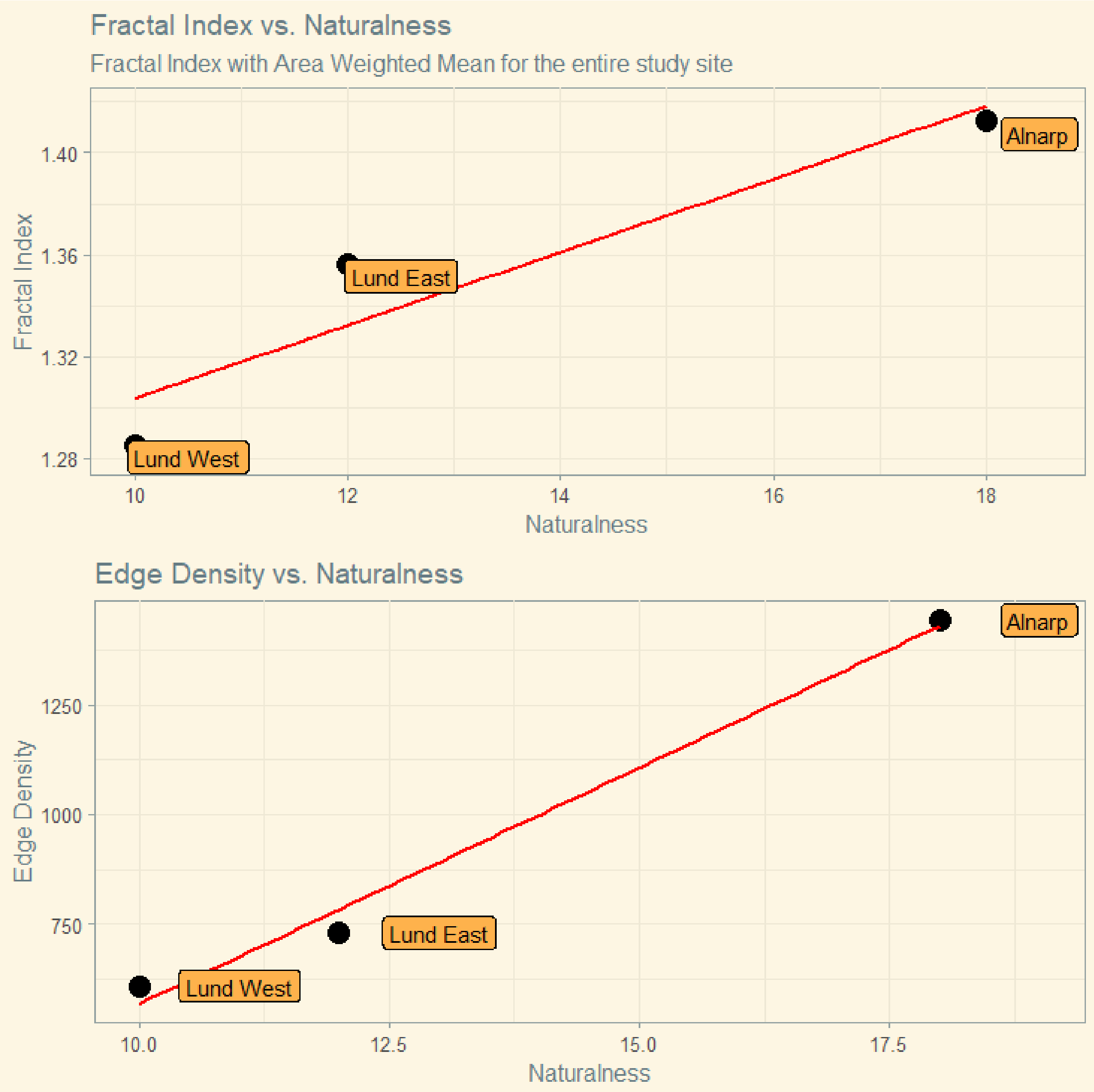

Figure 6: Naturalness compared to landscape fragmentation

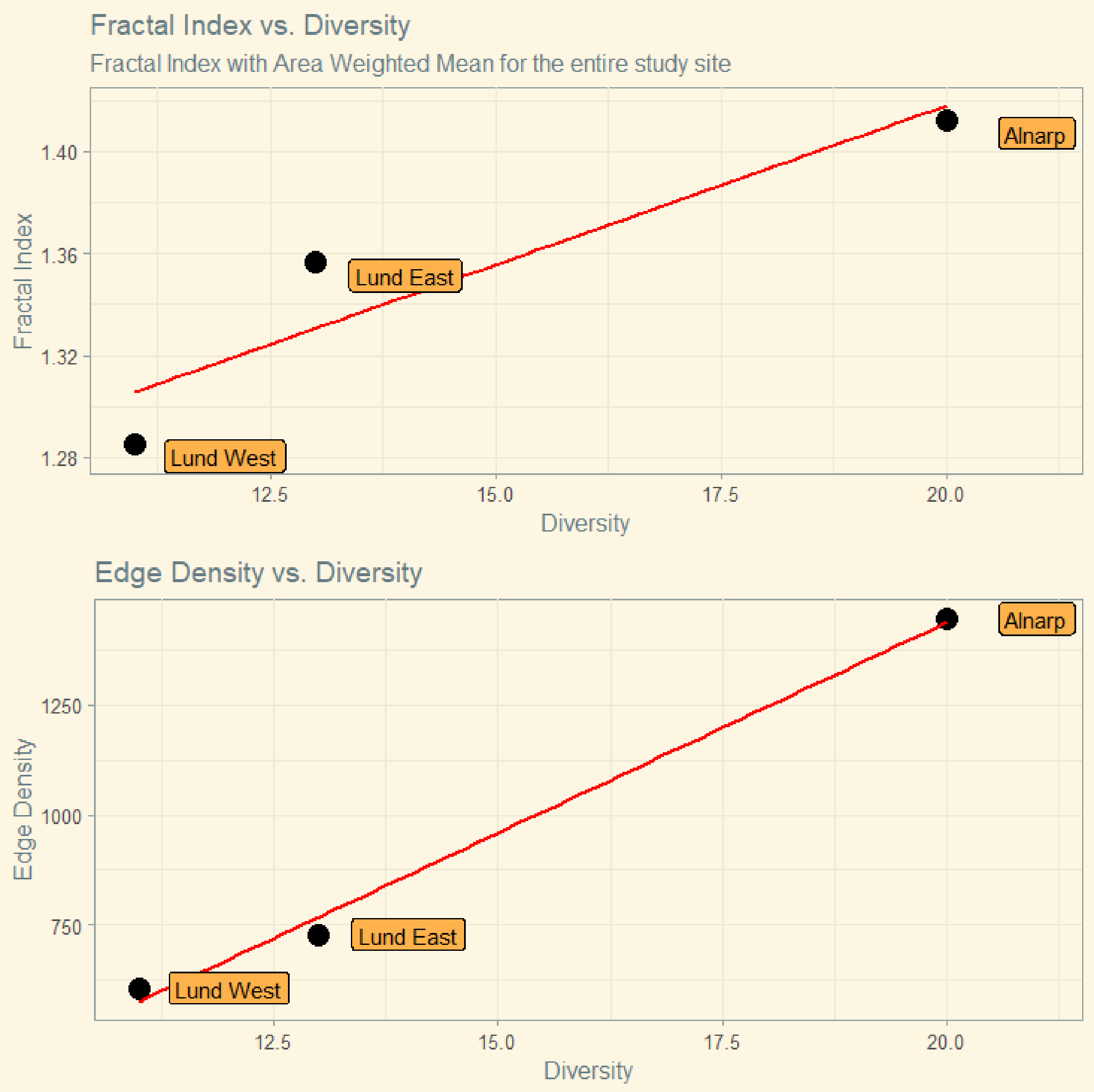

Figure 7: Diversity compared to landscape fragmentation

4. Discussion

We found a striking consistency across all three qualitative aspects when compared to remote sensing values. Granted, as only three sites were included in the study, we need to approach our conclusions with caution. However, our findings point to a trend that merits further exploration. While the fit between our qualitative assessments and remote sensing data is good, there is insufficient evidence to assert that subsequent observations would necessarily follow the same trend. However, the pattern aligns with the Attention Restoration Theory (ART) proposed by R. Kaplan & Kaplan, (1989), which suggests that natural environments possess restorative qualities that can improve cognitive function and reduce mental fatigue. Similarly, Ulrich, (1984) implies in his stress recovery theory (SRT) that certain environmental features can elicit positive emotional responses that aid in stress recovery.

Our results support previous studies that have demonstrated the potential of planar geometry, as derived from remote sensing imagery, to predict how a landscape is perceived, including in urban settings. This is supported by the work of Herzog & Bosley, (1992), who found that certain spatial properties of landscapes, such as complexity and coherence, significantly influence their restorative potential. Moreover, our findings suggest the possibility of distinguishing subtle qualitative nuances about landscape character, echoing the conclusions of Tveit et al., (2006), who identified specific visual aspects of landscapes that contribute to their perceived restorative qualities.

However, it would be presumptuous to claim that all eight sensory dimensions can be consistently estimated by the remote sensing methodology alone. More conclusive evidence of landscapes' restorative potential through remote sensing would require a much larger dataset and greater statistical power. This is a reminder of the limitations inherent in using remote sensing data for qualitative landscape assessment, as discussed in the book by Conzen & Whitehand, (1981), who argue that while remote sensing offers valuable quantitative data, it may not fully capture the experiential qualities that contribute to a landscape's restorative effects.

In conclusion, our study contributes to the growing body of literature that explores the intersection of remote sensing technology and landscape perception. By building upon the foundational theories of ART and SRT, and drawing parallels with prior empirical research, we underscore the potential of remote sensing as a tool for assessing the restorative qualities of environments. However, we also highlight the need for further research that combines quantitative remote sensing data with qualitative assessments to more accurately capture the complexity of human-environment interactions.

5. References

Adevi, A. A., & Mårtensson, F. (2013). Stress rehabilitation through garden therapy: The garden as a place in the recovery from stress. *Urban Forestry & Urban Greening*, *12*(2), 230–237. https://doi.org/10.1016/j.ufug.2013.01.007

Collado, S., Staats, H., Corraliza, J. A., & Hartig, T. (2017). Restorative environments and health. In *Handbook of environmental psychology and quality of life research* (pp. 127–148). Springer International Publishing/Springer Nature. https://doi.org/10.1007/978-3-319-31416-7_7

Conzen, M. R. G., & Whitehand, J. W. R. (Eds.). (1981). *The Urban landscape: Historical development and management*. Academic Press.

Hagerhall, C. M., Purcell, T., & Taylor, R. (2004). Fractal dimension of landscape silhouette outlines as a predictor of landscape preference. *Journal of Environmental Psychology*, *24*(2), 247–255. https://doi.org/10.1016/j.jenvp.2003.12.004

Hajrasouliha, A. (2017). Campus score: Measuring university campus qualities. *Landscape and Urban Planning*, *158*, 166–176. https://doi.org/10.1016/j.landurbplan.2016.10.007

Herzog, T. R., & Bosley, P. J. (1992). Tranquility and preference as affective qualities of natural environments. *Journal of Environmental Psychology*, *12*(2), 115–127. https://doi.org/10.1016/S0272-4944(05)80064-7

Kabisch, N., Qureshi, S., & Haase, D. (2015). Human–environment interactions in urban green spaces—A systematic review of contemporary issues and prospects for future research. *Environmental Impact Assessment Review*, *50*, 25–34. https://doi.org/10.1016/j.eiar.2014.08.007

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge Univ. Press.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

McGarigal K., SA Cushman, and E Ene. 2023. FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors; available at the following web site: https://www.fragstats.org

Roe, J., Thompson, C., Aspinall, P., Brewer, M., Duff, E., Miller, D., Mitchell, R., & Clow, A. (2013). Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities. *International Journal of Environmental Research and Public Health*, *10*(9), 4086–4103. https://doi.org/10.3390/ijerph10094086

Spehar, B., Clifford, C. W. G., Newell, B. R., & Taylor, R. P. (2003). Universal aesthetic of fractals. *Computers & Graphics*, *27*(5), 813–820. https://doi.org/10.1016/S0097-8493(03)00154-7

Stoltz, J., & Grahn, P. (2021). Perceived sensory dimensions: An evidence-based approach to greenspace aesthetics. *Urban Forestry & Urban Greening*, *59*, 126989. https://doi.org/10.1016/j.ufug.2021.126989

Tveit, M., Ode, Å., & Fry, G. (2006). Key concepts in a framework for analysing visual landscape character. *Landscape Research*, *31*(3), 229–255. https://doi.org/10.1080/01426390600783269

Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. *Journal of Environmental Psychology*, *38*, 1–9. https://doi.org/10.1016/j.jenvp.2013.12.005

Ulrich, R. S. (1984). View Through a Window May Influence Recovery from Surgery. *Science*, *224*(4647), 420–421. https://doi.org/10.1126/science.6143402

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