



Restorative Forest Environments in Scania:

Characteristics, Availability, and Accessibility for
Individuals with Stress-Related Exhaustion

Nicholas Moga

Degree project/Independent project • 15 credits

Swedish University of Agricultural Sciences, SLU

Faculty of Landscape Architecture, Horticulture and Crop Production Sciences

Department of Landscape Architecture, Planning and Management

Programme/Education: Forest and Landscape

Place of publication: Alnarp, 2026



Restorative Forest Environments in Scania: Characteristics, Availability, and Accessibility for Individuals with Stress-Related Exhaustion

Restaurativa Skogsmiljöer I Skåne: Egenskaper, Tillgång och Tillgänglighet för Personer med Stressrelaterad Utmattning

Nicholas Moga

Supervisor: Jonathan Stoltz, Department of People and Society, SLU
Examiner: Christopher Klich, Department of Landscape Architecture, Planning and Management, SLU

Credits: 15 credits
Level: First cycle, G2E
Course title: Independent project in Landscape architecture
Course code: EX1011
Programme/education: Forest and Landscape
Course coordinating dept: Department of Landscape Architecture, Planning and Management

Place of publication: Alnarp
Year of publication: 2026
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Keywords: restorative forest environment, stress-related exhaustion syndrome; forest restorative characteristics, accessibility, availability, Scania, Skåne, basal area, tree height, forest volume, species composition, traffic noise pollution, public transport

Swedish University of Agricultural Sciences

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Abstract

This study investigates the physical characteristics, availability, and accessibility of restorative forest environments in Scania, southern Sweden, for individuals with stress-related exhaustion syndrome. The study is based on the working hypothesis that more natural and wild forest environments, which may be especially beneficial for this target group, are often located relatively far from the region's largest urban centers. This may make them more difficult to access for people recovering from stress-related exhaustion. Therefore, the study aims to answer the following research question: How accessible are these restorative forest environments for people with stress-related exhaustion syndrome living in Malmö, Lund, and Helsingborg? A literature review was conducted to identify forest characteristics associated with restorative qualities. The main variables identified were tree age, tree sparsity, tree height, and species composition. These findings were translated into a GIS-based analysis using basal area forest volume, 3 height, species composition, rolled noise exclusion zones, and public transport proximity. Approximate travel times by public transport and private car were also assessed for selected candidate areas near Malmö, Lund, and Helsingborg. The results show that potential restorative forest environments are present in Scania, but their accessibility is limited and uneven. Larger, more continuous forested areas were generally located farther from the main urban centers, while areas close to Malmö and Lund were more fragmented and more affected by road infrastructure. Private car access was generally easier than public transport access, which often required longer travel times and transfers. The study concludes that restorative forest environments in Scania are not entirely inaccessible, but their accessibility is limited and uneven. The initial working hypothesis was partially supported as the most continuous forested areas were often located farther from the largest urban centers, while areas close to Malmö, Lund, and Helsingborg were generally more fragmented, more affected by traffic-related noise, or required a level of traffic effort that may be demanding for individuals with stress-related exhaustion. In this sense, accessibility should be understood not only as the physical presence of forest areas near urban centers, but also in terms of travel time, transport access, quietness, and the availability of compact forested areas.

Keywords: restorative forest environment, stress-related exhaustion syndrome; forest restorative characteristics, accessibility, availability, Scania, Skåne, basal area, tree height, forest volume, species composition, traffic noise pollution, public transport

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Abbreviations

Abbreviation	Description
SLU	Swedish University of Agricultural Sciences
FK	Försäkringskassan
SS	Socialstyrelsen
SRE	Stress-Related Exhaustion
PSD	Perceived Sensory Dynamics
HQRPF	High Quality Restorative Potential Forests

1. Introduction

Over the past decade and a half, in Sweden, stress-related illness has become an important public health issue, and overall psychiatric diagnoses have seen a substantial increase in long-term sickness absence. According to the Swedish Social Insurance Agency (Försäkringskassan- FK), the number of ongoing sickness absence cases related to psychiatric diagnoses increased from about 30,000 in 2010 to about 100,000 in 2024 (Figure 1).

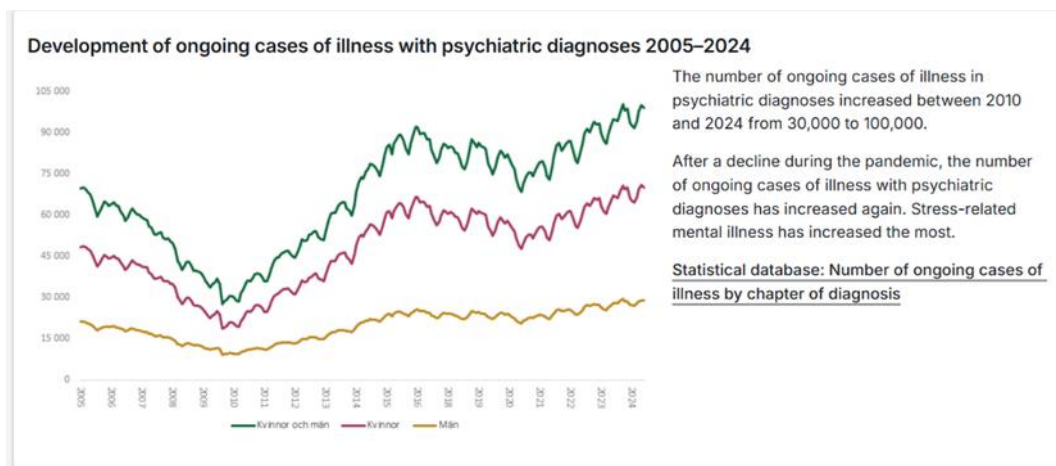


Figure 1. Development of ongoing cases of psychiatric diagnoses in Sweden 2005-2024. Source: Försäkringskassan Sweden (Försäkringskassan 2026)

The same source highlights stress-related mental illness, which has shown the strongest increase within the overall category of psychiatric diagnoses (Försäkringskassan 2026). Although the trend has not been identical every year, the long-term trend suggests that stress-related mental health remains a major and persistent challenge in Swedish working life and the social insurance system. This development is important not only because of the number of individuals affected, but also because of the depth and duration of the consequences and the number of resources needed during the recovery phase (Wallensten et al. 2019). Furthermore, FK reports that, nowadays, almost half of all ongoing sickness absence cases are related to psychiatric diagnoses, and these cases are, on average, longer than sickness absence related to many other diagnoses (Försäkringskassan 2026)

For the affected individual, stress-related exhaustion (SRE) is often not a brief interruption followed by a quick return to normal life. The National Board of Social Affairs and Health (Socialstyrelsen- SS) describes exhaustion syndrome as a condition marked by persistent physical and psychological exhaustion after

long-term stress exposure (*Utmattningssyndrom* 2017). The recovery process is often slow, so the acute phase may be followed by a recovery phase that can continue for many years, with residual symptoms (Glise et al. 2020). SS also states that individuals with persistent cognitive difficulties may be on full-time sick leave for one year or more, indicating that SRE should not be understood only as a period of tiredness or overload, but also as a condition that may affect concentration, memory, emotional stability, sensory tolerance, and the ability to handle everyday demands (Tavella et al. 2021). Overall, the energy resources available to such an individual are low. While conventional recovery is primarily in focus, via medication and psychological therapy, there is growing awareness of the benefits that natural environments can provide.

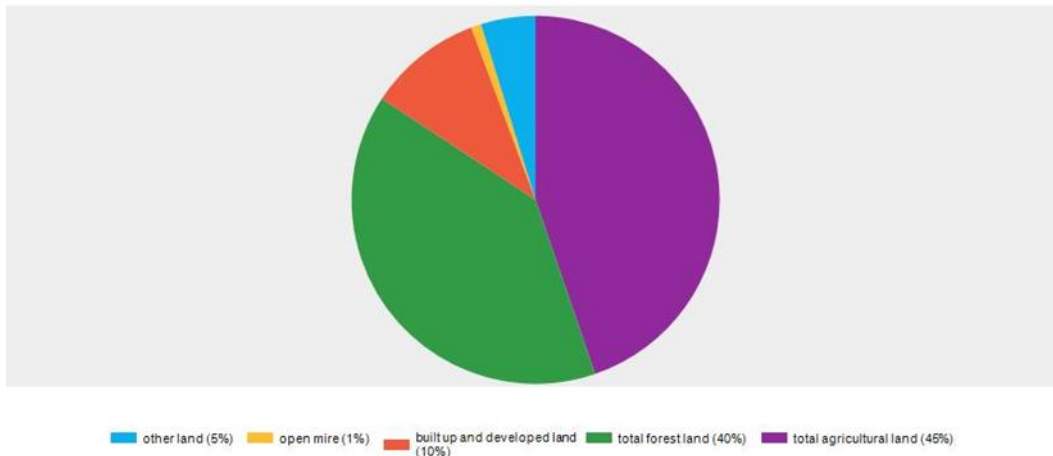
Previous research suggests that contact with natural environments can support recovery for people with stress-related illnesses. A review published in 2022 found that nature-based interventions may reduce stress, improve health and well-being, and overall can offer a low-demanding environment for meaningful activities and social interaction (Johansson et al. 2022). At the same time, research suggests that not all green environments are suitable for being categorized as restorative. A Swedish study on patients with exhaustion disorder found that visits to forest environments were perceived as significantly more restorative than visits to a green city environment, and that forest visits were associated with more positive psychological responses (Sonntag-Öström et al. 2014). Such environments are also described as places that support being away, extent, fascination, compatibility (Basu et al. 2019), and as settings with qualities such as serene, cohesive, shelter and natural (Stoltz & Grahn 2021). Deep recovery requires natural settings that provide space for individuals to be alone, feeling safe and undisturbed by the presence and activity of others. For individuals with SRE, this is especially important, as recovery often requires reduced demands and mild sensory stimulation. This is further supported by Staats and Hartig (2004), who state that escaping social demands and crowded urban areas is important for psychological restoration (Staats & Hartig 2004).

1.2. Problem Definition

According to the Swedish University of Agricultural Sciences (SLU), Sweden is described as a forested country, with around 28 million hectares of forest cover from a total of 40.7 million hectares of land area, suggesting a heavily forested country with dominating species such as spruce and pine, since the country itself is located in the Boreal region (The latest statistics | slu.se n.d.). However, land use varies across regions, especially in southern Sweden, where Scania stands in

contrast to the many more forest-dominated parts of the country. Statistics Sweden shows that the region of Scania is characterized by a mixed landscape, mostly between forest and agricultural land, with 40% forest, 45% agricultural land, and 15% built-up, developed, other land, and open mire (Figure 2).

Land use in Sweden, hectares by land use category. Skåne county, 2020.

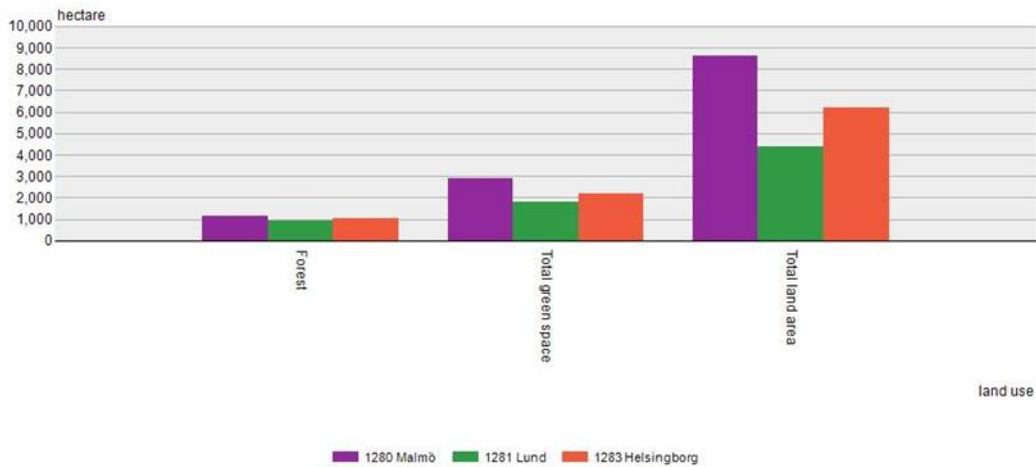


Source: Statistics Sweden

Figure 2 . Land use in the region of Scania, Sweden by category, 2020. Source: Statistics Sweden.(Land use in Sweden, hectares by land use category. Skåne county, 2020.. PxWeb 2026)

This suggests they might be unevenly distributed, more fragmented, or not in immediately adjacent urbanized parts of the region, and that the region is dominated by agricultural and urban features. Another important aspect is the distribution of the largest urban centers, which, in this case, are mostly located in the western part of the region. According to Statistics Sweden, the general availability of public green space in the biggest 3 urban centres (Malmö, Lund, and Helsingborg) is quite small (Figure 3) when we compare it to the total land area of the cities, and more importantly for this study, the specific amount of public forested area is very limited in all three municipalities.

Public green space in hectare by region and land use. 2020.



Source: Statistics Sweden

Figure 3. Public green space in the largest urban centers in Scania. Source: Statistics Sweden (Public green space in hectare by region and land use. 2020.. PxWeb 2026)

This indicates that these forested restorative environments for individuals with stress-related syndrome might be difficult to access in the first instance due to availability. Another important aspect, from an urban planning perspective, is the contribution of green urban spaces to health, well-being, and quality of life, which, in this case, might not be sufficient for individuals experiencing stress-related exhaustion. Previous research (Uebel et al. 2021; Li & Liu 2024; Tabassum 2025), sustain that urban green spaces located close to traffic roads, social activity zones, and other urban sensory inputs might contribute to a negative experience. In this case, urban parks with forests can exist, but they may not provide the same refuge, social quietness, and sensory protection that this group needs. Therefore, balancing future urban and forestry development with more tailored, accessible green spaces is crucial for current and future planning.

1.3. Research Objective

Within this context, the present study focuses on restorative forested environments in the region of Scania and their availability and accessibility for individuals with SRE syndrome. Availability refers to the presence and spatial distribution of potential restorative forest environments in Scania. It focuses on whether such forest environments exist in the region, where they are located, and whether compact candidate areas occur near Malmö, Lund, and Helsingborg. Accessibility refers to the practical possibility of reaching these environments from the selected urban centers, considering proximity to regional public transport stops and the approximate travel times by public transport and private car. The

study is based on the idea that access to nature is not only a matter of presence or absence but also of quality, suitability, and accessibility. A forested area might appear on the map, but it might not be suitable for this targeted user group. Urban forested green areas will be excluded from this research due to the existence of urban noise pollution, such as traffic, social activities, and sensory overload, qualities that do not meet the basic criteria for a restorative forested environment. The present study aims to identify, examine, and map natural forest settings outside the edges of urban areas that may be considered restorative for individuals with stress-related syndromes. By mapping and analyzing the availability and accessibility of these environments in the region of Scania, this study also aims to contribute to a better understanding of the current distribution of restorative forest environments and to raise awareness of their relevance for future urban and forest planning. This study uses the following working hypothesis: the more natural and wild forest environments, which may be most beneficial for this target group, are often located relatively far from the biggest urban centers in the region of Scania, making them more difficult for individuals recovering from stress-related exhaustion to access. Therefore, this study also aims to answer the following research question: *How accessible are these restorative forest environments for people with stress-related exhaustion syndrome in Malmö, Lund, and Helsingborg?*

2. Methods

2.1 Overall Study Design

This study was conducted by a two-step research approach, combining a literature review with spatial analysis. Initially, a literature review was undertaken to identify forest features that could aid in the restoration of individuals with SRE syndrome. Subsequently, these features were transformed into spatial criteria and used in ArcGIS to locate, map, and evaluate, in terms of accessibility, restorative forest environments within the Scania region, but urban forested green areas were excluded from the analysis due to the presence of urban noise pollution, traffic, social activity, and other sensory loads that may reduce their restorative qualities for this user group. However, the focus remained on analysis of the three major urban centers in Scania, namely Malmö, Lund, and Helsingborg.

2.2 Literature-based Criteria Development

This study takes the Perceived Sensory Dimensions (PSD) framework as its theoretical starting point, which identifies eight environmental dimensions, some of which are considered particularly relevant to individuals affected by stress-related exhaustion. The PSD framework describes the eight environmental dimensions as Serene, Natural, Cohesive, Sheltered, Open, Cultural, Social, and Diverse, defining them as qualities of how people perceive and experience these environments. As Stoltz and Grahn point out, although the PSDs are primarily defined as perceived qualities and not as specific features, there is still a strong relationship between the physical structure of a landscape and perceivedness. The relationship between these two levels of analysis may be particularly important when questions of physical scale are considered. In other words, the way an environment is perceived is closely linked to how it is physically formed, such as its size, degree of enclosure, spatial coherence, and level of disturbance.

The model also describes opposing dynamics between qualities considered particularly important for restorative processes and qualities that are often perceived as stimulating and highly valuable but less restorative. In the visual model (Figure 4), Sheltered, Natural, Serene, and Cohesive are placed on the restorative side, while Diverse, Social, Cultural, and Open are placed on the more stimulating side.

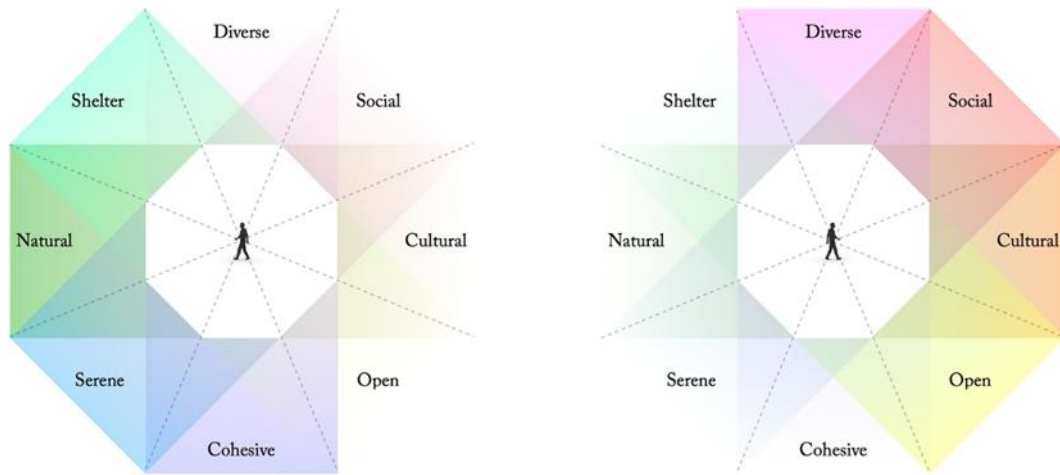


Figure 4. PSD model for perceived qualities as important for restorative processes (left) and perceived qualities for stimulating processes (right). Reproduced from (Stoltz & Grahn 2021) under a Creative Commons license.

However, Stoltz and Grahn also note that, when the scale is considered, Sheltered, Social, Diverse, and Cultural may be supported further by denser planning and design strategies, while Natural, Serene, Cohesive, and Open are more associated with natural, wild forest environments and, overall, larger green areas. This distinction is important for the present study, since the focus is on restorative forest environments for individuals with SRE syndrome, the framework suggests that environments with stronger restorative potential are more likely to be found in larger and less densely planned green areas, where qualities such as serenity, naturalness, and coherence can be maintained. Therefore, this supports the decision to focus the spatial analysis on forest environments outside urban areas, where these qualities are more likely to occur and where sensory and social disturbances may be lower. However, the PSD framework is not used in this study as a direct measurement tool but as a conceptual starting point that guides the literature review to further identify the physical forest characteristics, which will later be translated and applied in the GIS analysis.

2.3 Literature Review and Development of Spatial Criteria

Building on the theoretical use of the Perceived Sensory Dimensions (PSD) framework, a targeted literature review was carried out to translate relevant perceived qualities into physical forest features that can be spatially examined. Although the PSD model explains how environments are perceived, this study required an additional step to link these perceived qualities to observable,

mappable forest characteristics. Therefore, the literature review focused on identifying which physical characteristics of forest environments may support restoration for individuals with SRE syndrome.

A particular focus was on the PSD qualities Natural, Serene, Cohesive, and Sheltered, as these are more closely related to restorative processes and to environments with lower levels of sensory and social demand. Stoltz and Grahn (Stoltz & Grahn 2021), describe the “*Natural*” dimension as an environment perceived as self-developed, non-artificial, and relatively untouched by intensive human activity. “*Serene*” refers to calm, peaceful settings characterized by low levels of noise, traffic, and other disturbing stimuli. “*Cohesive*” describes environments that are perceived as spatially unified, continuous, and easy to understand as a whole, while “*Sheltered*” refers to environments that provide a sense of refuge, safety, and enclosure. Together, these qualities are relevant for individuals with SRE, whose recovery may benefit from environments that offer reduced social pressure, sensory overload, and cognitive demands (Berman et al. 2008; Pálsdóttir et al. 2018). Because the PSD framework describes perceived rather than measurable qualities, these dimensions could not be mapped directly in ArcGIS; they needed to be translated into a limited set of physical landscape indicators that could serve as proxies for restorative forest qualities. In this sense, the literature review focused on forest characteristics that have previously been identified as the most important stand-level indicators of restorative qualities, namely tree age, tree sparsity, and tree height (Stoltz et al. 2016). A targeted review of the academic literature was then conducted to further support these variables and define measurable forest characteristics in terms of stand maturity, degree of openness or density, and vertical development. To provide a sustained framework, at least two academic sources were sought for each variable to serve as a basis for their later processing in ArcGIS.

Literature searches were carried out using academic search platforms such as: ScienceDirect, Asta AI, Google Scholar, with a combination of words such as “*restorative forest characteristics*”, “*forest age restorative forest*”, “*mental health and forest bathing*”, “*exhaustion syndrome forest therapy*”, “*species composition restorative forest*”, “*recovery from burnout, nature based solutions*”, “*forest therapy*”, “*conifer vs broadleaves vs mixed species in restorative forest*”, “*restorative forest environment physical characteristics*”. A particular focus was also placed on the importance of the search results, and in this case, the selection of results was based on “*perfectly relevant*” and “*relevant*” literature as a boundary. The results were then, as a first step, analyzed by reading the Abstract section, followed by the Results section. Furthermore, if relevant data were found on these first two sections, more details were searched in the “*Results*”,

“*Discussion*,” and “*Conclusion*” sections. The search strategy was optimized, meaning that search terms were further refined during the search process as new relevant information and recurring characteristics were identified in the literature. The purpose of this step was not to conduct a systematic review of all existing studies, but rather to develop a theoretically grounded set of criteria for spatial analysis.

2.4 ArcGIS, Definition of Variables and Identification of Restorative Forest Environments in Scania

To perform the GIS analysis, several raster and vector datasets were downloaded from the Swedish Forest Agency (SFA) geodata service, the SLU GET geodata service, the OpenStreetMap service, and the ArcGIS Online open maps service. The spatial analysis was then organized into a step-by-step GIS workflow, shown in Figure 5. The workflow summarises the main input datasets, processing steps, and outputs used to identify potential restorative forest environments and assess their accessibility. Table 1 provides an overview of the spatial datasets used, their sources, data formats, and analytical purposes.

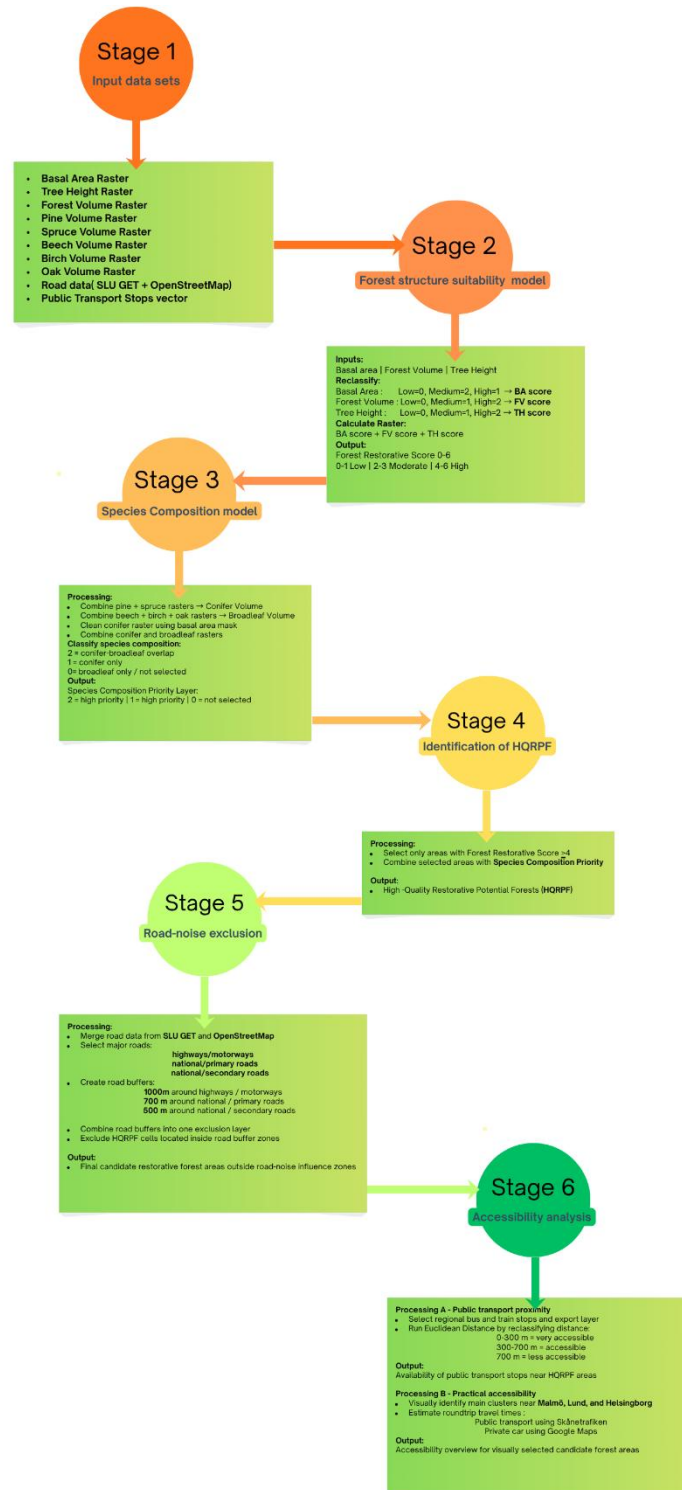


Figure 5. GIS workflow showing the main input datasets, processing steps, and outputs used to identify High-Quality Restorative Potential Forests and assess their accessibility in Scania

Table 1. Overview of spatial datasets

Dataset	Format	Cell Size	Source	Used in Analysis
SLU Skogskarta Tall Volym	Raster	12,5 x 12,5 m	SFA	Conifer species composition
SLU Skogskarta Gran Volym	Raster	12,5 x 12,5 m	SFA	Conifer species composition
SLU Skogskarta Ek Volym	Raster	12,5 x 12,5 m	SFA	Broadleaf species composition
SLU Skogskarta Bok Volym	Raster	12,5 x 12,5 m	SFA	Broadleaf species composition
SLU Skogskarta Björk Volym	Raster	12,5 x 12,5 m	SFA	Broadleaf species composition
SLU Skogskarta Grundyta	Raster	10 x 10 m	SFA	Basal area/forest structure suitability
Skogliga grunddata-Trädhöjd (omdrev 2,2018-2025)	Raster	1 x 1 m	SFA	Forest structure suitability
Skogliga grunddata-Volym (omdrev 2,2018-2025)	Raster	10 x 10 m	SFA	Forest structure suitability
Road map	Vector	Not - applicable	SLU GET geodata service	Road-noise buffer
Road map	Vector	Not applicable	OpenStreetMap	Supplementary road data for missing segments
Kollektiv trafik karta	Vector	Not - applicable	ArcGIS Online maps	Public transport accessibility

2.4.1 Forest Physical Characteristics and Suitability

To apply the criteria developed through the literature review, spatial data layers were selected for operationalization as supporting indicators of restorative forest character. In this sense, three main forest structure variables were selected: basal area, forest height, and forest volume. An important limitation was the unavailability of vector layers for the entire region of Scania; therefore, raster and vectors were used.

These selected forest characteristics were not represented by a single variable in a one-to-one way. Instead, they were operationalized through combinations of the available raster variables. Mature or more developed forest character and the degree of openness or density were represented through the combined use of tree height, forest volume, and basal area. Vertical development was mainly represented by tree height. In this way, the three raster variables were used together to approximate the forest characteristics described in the literature, rather than being treated as independent indicators of restorative quality. Therefore, the GIS model should be understood as a combined structural suitability model. No single raster variable was interpreted as sufficient to define a restorative forest environment on its own. Instead, restorative potential was identified where several structural conditions occurred together. Each raster was reclassified into three suitability classes and assigned a numerical score from 0 to 2, as in Table 2.

Table 2. Classification of forest variables into suitability/potential

Raster Variable	Original Class/Values	Suitability Score	Interpretation
Basal Area	Low	0	Low suitability
	Medium	2	Most Suitable; represents moderate density and openness (Chiang et al. 2017)
	High	1	Suitable, but potentially denser and less open
Forest Volume	Low	0	Low suitability
	Medium	1	Moderate suitability
	High	2	Most suitable; indicates a more developed forest structure

	Low	0	Low suitability
Tree Height	Medium	1	Moderate suitability
	High	2	Most suitable; indicates stronger vertical forest development

This scoring in Table 2, was based on the idea that restorative forest environments require a balance between developed forest structure and visual openness. For basal area, the medium class was given the highest score because it was interpreted as representing a more balanced forest density, where some enclosure is present but visibility and openness are still maintained. A very high basal area may indicate denser forest conditions, which can reduce visual openness and may be experienced as less accessible, less safe, or more demanding for some users. In contrast, high forest volume and high tree height were given the highest scores because they were interpreted as indicators of more mature and vertically developed forest structure.

Basal area, forest volume, and tree height were weighted equally in the final structural suitability score. This was done because the available literature did not provide a clear basis for assigning a stronger weight to one variable over the others at the regional scale. Equal weighting also made the model more transparent and reproducible. The resulting score should be understood as a screening model for identifying areas where several favorable structural conditions occur together, rather than as an exact measurement.

The three reclassified raster layers were then combined using Raster Calculator by summing the individual scores for basal area, forest volume, and tree height. This produced a forest restorative score ranging from 0 to 6, with higher values indicating a stronger match to the selected forest-structure criteria, as shown in Table 3.

Table 3. Forest restorative score for potential high restorative quality

Forest Restorative Score	Final Category	Interpretation
0-1	Low restorative potential	Not suitable or weak match with the selected forest criteria
2-3	Moderate restorative potential	Suitable, but not the strongest match

2.4.2 Selecting roads for noise pollution exclusion

During the first step of visual analysis, the map was found to contain incomplete road segments in some areas. Therefore, an additional road dataset was downloaded from OpenStreetMap. The two road buffer layers were then combined in ArcGIS, using the SLU GET road layer as the primary source and the OpenStreetMap road layer to fill in missing areas, resulting in a more complete road layer for the study area.

The road layer was examined in its attribute table, using the road classification field to identify different road types. Only larger roads were selected because they were expected to have higher traffic intensity and therefore a greater potential contribution to traffic-related noise pollution. The selected road features were exported as a new, separate layer. Buffer zones were created around each road type and used as exclusion zones for potential traffic-related noise disturbance. Measured road-noise studies show that high noise levels occur close to major roads (Johnson & Saunders 1968; Uebel et al. 2021), while previous studies have shown that effects from roads and traffic noise can extend several hundred meters from roads and, in some cases, up to approximately 1 km or more (Forman et al. 2002; Benítez-López et al. 2010). These selected road classes and buffer distances are shown in Table 4. These buffers should be interpreted as screening zones for potential disturbance, not as exact acoustic measurements.

Table 4. Selection of road types and Buffer distance applied

Road type	Approximate speed limit	Buffer distance
Highway/motorway	110 km/h	1000 m
National/primary road	90 km/h	700 m
National/secondary road	70-80 km/h	500 m

2.4.3 Additional restorative indicator variable: Species composition

Species composition was included as an additional criterion in the GIS analysis. This variable was added because several studies discussed tree species composition as part of the physical character of restorative forest

environments (Chiang et al. 2017; Sacchelli et al. 2020). It was not used as part of the initial forest structure score, but as a second step to further refine the areas already identified as having high restorative potential. The analysis was developed using species-specific volume rasters, and, due to the limited availability of both raster and vector data, the following species were analyzed: pine (*Pinus* spp.), spruce (*Picea* spp.), oak (*Quercus* spp.), beech (*Fagus* spp.), birch (*Betula* spp.). Pine and spruce were grouped as conifer species, while beech, birch, and oak were grouped as broadleaf species. As a limitation, because the analysis was based on raster data rather than stand-level polygons, the output was not interpreted as a formal mixed-forest stand classification; it was used to identify areas where volumes of coniferous and broadleaved species co-occurred in the available raster data.

The coniferous species rasters were combined into one volume layer, and the broadleaved species rasters were combined into a broadleaf volume layer. Because the spruce raster contained some error values in water areas, the conifer raster was cleaned using the basal area raster as a mask before it was used in the final analysis. These two layers were then used to identify areas with conifer-only composition and areas where coniferous and broadleaved species overlapped. Where volumes of both coniferous and broadleaf species were present, they were assigned the highest species priority value 2, and areas with conifer volume only were assigned a medium priority value 1 and broadleaf volume only were assigned the lowest priority value of 0.

2.4.4 Identification of High-Quality Restorative Potential Forests (HQRPF)

The species composition priority layer was then combined with the forest restorative score layer developed in Section 2.4.1 to identify Restorative Potential Forests. Only areas with a forest restorative score of 4 or higher were selected. These areas were then classified into three final value categories ranging from 0 to 2, where value 2 represents high-quality restorative-potential areas with conifer-broadleaf overlap, value 1 represents high-quality restorative-potential areas with a conifer-only composition, and value 0 represents areas that were not selected. The layer was then combined with the final road buffer raster to exclude areas that may be affected by traffic-related noise. The cells located inside the road buffer were assigned a value of 0, while cells located outside the road buffer were assigned their original value. The resulting layer represented the ideal candidate areas for a high-quality, restorative-potential forest environment (HQRPF), located outside selected road-noise influence zones.

2.4.5 Public Transport Accessibility

Public transport accessibility was analyzed using regional public transport stops. From the public transport layer, only regional bus and train services were selected, as in Table 5. This selection was made because it focuses on forest environments outside urban areas.

Table 5. Public Transport categories included in analysis

Public Transport Category	Transport Type
Regionbuss	Regional Bus
SkåneExpressen	Express Regional Bus
Öresundståg	Train
Pågatåg	Train
PågatågExpress	Express Train
Krösatåg	Train

A Euclidean Distance analysis was then performed in ArcGIS to calculate the straight-line distance from each raster cell to the nearest selected public transport stop. The resulting distance raster was reclassified into three accessibility classes: 0-300 m as very accessible, 300-700 m as accessible, and distances greater than 700 m as less accessible. This accessibility layer was then combined with the H-QRPF layer to identify the areas that were also reachable by regional public transport. As a limitation, this step of the analysis measured spatial proximity to public transport stops and did not account for timetable frequency, travel time, or walking path conditions.

2.5 Accessibility analysis

In order to approximate a practical accessibility by both public transport and private car, the candidate areas identified in Section 2.4.5 were examined more closely. The final GIS output was first inspected at the regional scale to understand the overall spatial distribution of H-QRPF in Scania. The map was then examined at a more detailed local scale around the three urban areas of interest: Malmö, Lund, and Helsingborg. The visual inspection was used to identify larger and more compact clusters of candidate forest areas. These clusters were considered relevant for the accessibility assessment because they may represent more continuous forest environments, rather than very small or scattered patches. After the main clusters had been visually identified, the final candidate layer was turned off in ArcGIS to examine the underlying basemap and identify the real geographical names of the surrounding forest areas, nature reserves, and nearby settlements.

Public transport accessibility was assessed in three steps. First, the spatial proximity of a bus or train station is described in Section 2.4.6. The purpose of this step was to analyze whether regional bus or train stops were located near the edges of the candidate forest areas. This was important because accessibility was understood as the ability to reach the forest entrance. In a second step, the visually identified forested areas were compared with the nearest relevant public transport stop. In a third step, approximate public transport travel times were checked using the skånetrafiken app. Malmö C, Lund C, and Helsingborg C were used as starting points. For each selected candidate area, the nearest relevant stop or access point was identified, and travel time was calculated for a weekday midday departure. The one-way time was rounded to an approximate value and then doubled to estimate the round-trip travel time. These values were treated as indicative estimates only, not exact measurements, because they did not account for timetable frequency, delays, weekend schedules, traffic variation, or walking conditions.

For car accessibility, approximate travel times from the city centers of Malmö, Lund, and Helsingborg were checked manually using Google Maps. The destination points were based on the same public transport stops used in the public transport travel time check. The travel times were rounded to approximate values and doubled to estimate the travel time for both directions. This was done to keep the comparison between car and public transport accessibility as consistent as possible. These values were treated as indicative estimates only, not exact measurements, because traffic conditions, parking availability, exact entrance points, and walking distance from parking areas to the forest interior were not included.

This approach was used to provide a practical overview of how reachable the identified restorative forest environments may be for individuals with SRE in the three selected urban areas.

3. Results

The results are presented in three main parts. First, the literature review results are summarized to show which forest characteristics were most relevant for restorative forest environments. Second, the GIS results are presented to show how these characteristics were translated into spatial criteria and used to identify potential restorative environments in Scania. Finally, the accessibility results are presented to give an approximate overview of how reachable the identified candidate areas are by regional public transport and private car from Malmö, Lund and Helsingborg.

3.1 Literature review results

The literature review identified several stand-level forest characteristics that were repeatedly associated with restorative qualities. The most relevant variables were tree age, tree sparsity, tree height, and species composition. These variables and the main patterns found in the reviewed studies are summarized in Table 6.

Table 6. Key findings from the literature review

Variable	Main Pattern Found in Literature	Supporting Studies
Tree Age	Older and mature stands were generally perceived as more restorative than young stands	(Simkin et al. 2020; 2021)
Tree Sparsity	Low to medium density/thinned forests were generally associated with better restoration value	(Chiang et al. 2017; Stigsdotter et al. 2017; Takayama et al. 2017; Kim et al. 2021)
Tree Height	Tree height was less frequently studied, but taller trees and stronger vertical structure were linked to mature forest character and restorative quality	(Stoltz et al. 2016)

Species Composition	Species composition appeared as an additional relevant variable. Mixed stands, followed by coniferous stands, were associated with stronger restorative potential than broadleaf-only stands in the reviewed studies.	(Sacchelli et al. 2020; Liu et al. 2021a; b)
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3.2 ArcGIS analysis results

3.2.1 Forest physical characteristics and suitability

The combination of basal area, forest volume, and tree height produced a forest restorative structure suitability layer for Scania. The output showed that areas with higher structural suitability were not evenly distributed across the region but appeared as patches and clusters in different parts of Scania, as in Figure 6. However, the analysis showed a pattern of more scattered forest clusters in the southern and southwestern parts of Scania, while the northern and northwestern parts of Scania showed larger, more continuous forested areas.

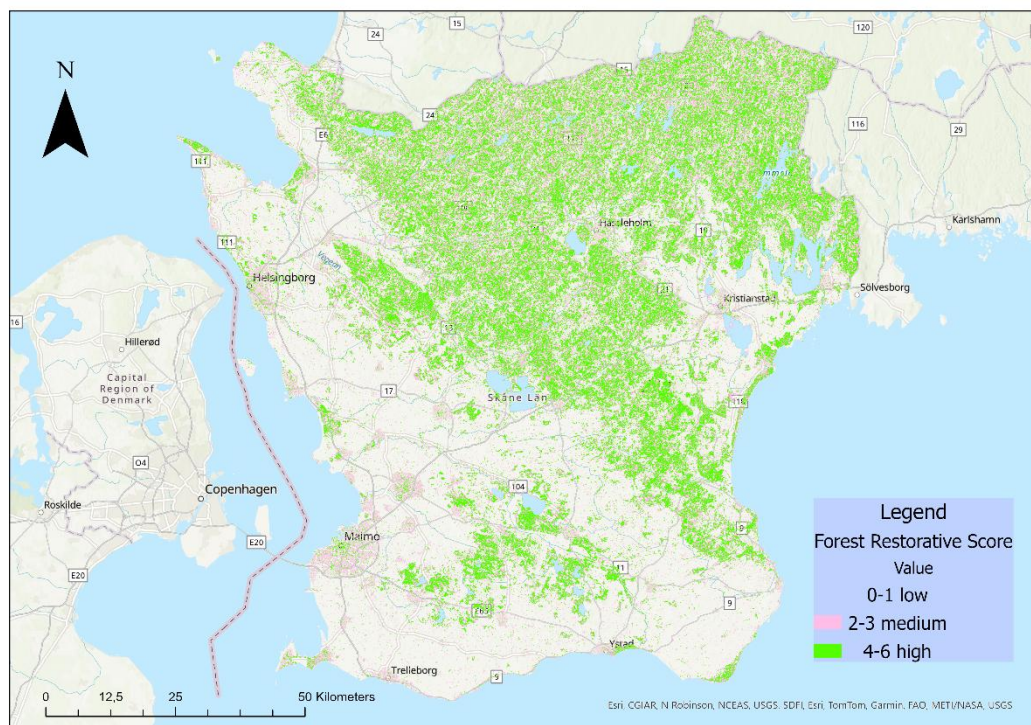


Figure 6. Areas classified as high restorative structural potential in Scania, based on the combined suitability score for basal area, forest volume, and tree height. Only the highest and medium suitability class is shown for visual clarity

3.2.2 Spatial distribution of road noise exclusion zones

The road buffer layer showed that the potential road-noise exclusion zones were mainly concentrated along the major transport corridors in Scania. The most visually affected areas were located around the Malmö-Lund region, where several motorways and national roads overlapped or occurred close to each other, as in Figure 7. A second concentration was visible around Helsingborg and the surrounding road network. In contrast, some inland and more forest-dominated areas showed fewer major road-buffer overlaps.



Figure 7. Combined road-noise exclusion buffer layer in Scania. The map shows larger potential traffic-noise influence zones around main transport corridors, especially near Malmö-Lund and Helsingborg.

3.2.3 Species composition priority

The species composition analysis produced a priority layer that separated conifer-only areas from areas where volumes of coniferous and broadleaved species overlapped as represented in Figure 8. The output showed that conifer-broadleaf overlap was not evenly distributed across Scania but appeared in smaller patches and local clusters. Conifer-only areas presented the same pattern of distribution.

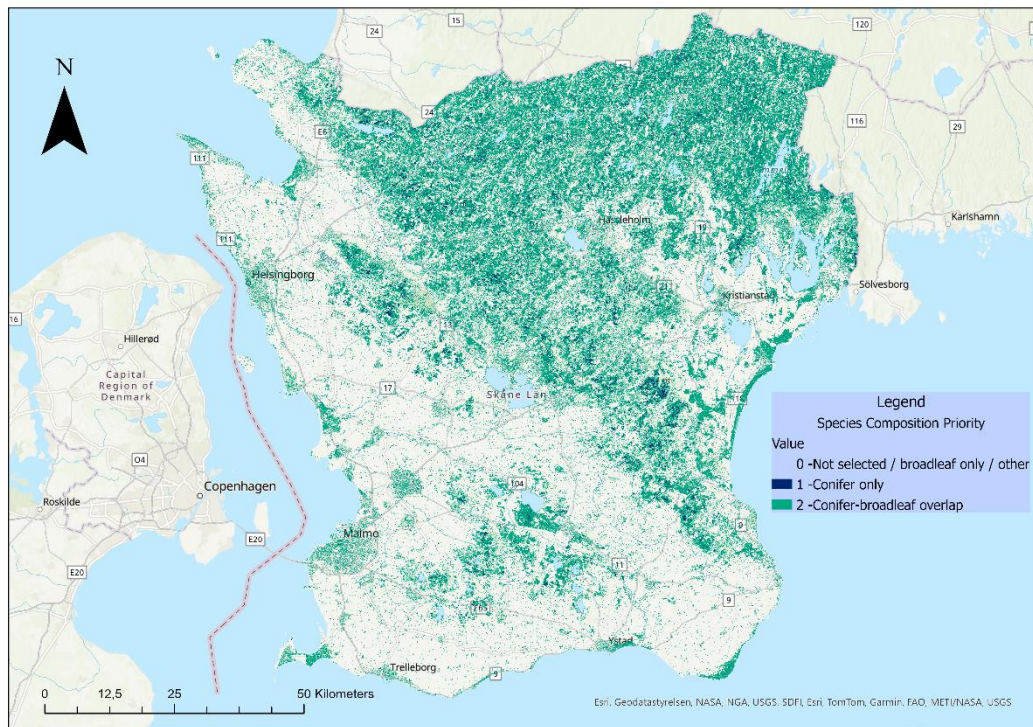


Figure 8. Species composition priority layer Scania. Value 2 represents areas where coniferous and broadleaved species volumes overlapped, while value 1 represents conifer-only areas. Value 0 represents areas not selected.

3.2.4 High-Quality Restorative Potential Forests

The combination of the forest restorative score layer, species composition priority layer (Figure 9), and a road-noise exclusion layer produced the final HQRPF candidate map (Figure 10). The road noise exclusion layer removed areas close to major roads, and this was especially visible around main transport corridors, where road buffers reduced the number of candidate areas. The results showed that the highest-quality restorative potential areas were not distributed continuously across Scania, except in the northern and northeastern parts of the region. The south and southwestern parts of the region appeared as scattered patches and local clusters.

But overall, at the regional scale, the resulting map does not show a major loss of forested areas, though some are more visible, especially in the northern parts. Most affected areas were those near the three major urban areas of interest, as seen at a zoomed-in scale.

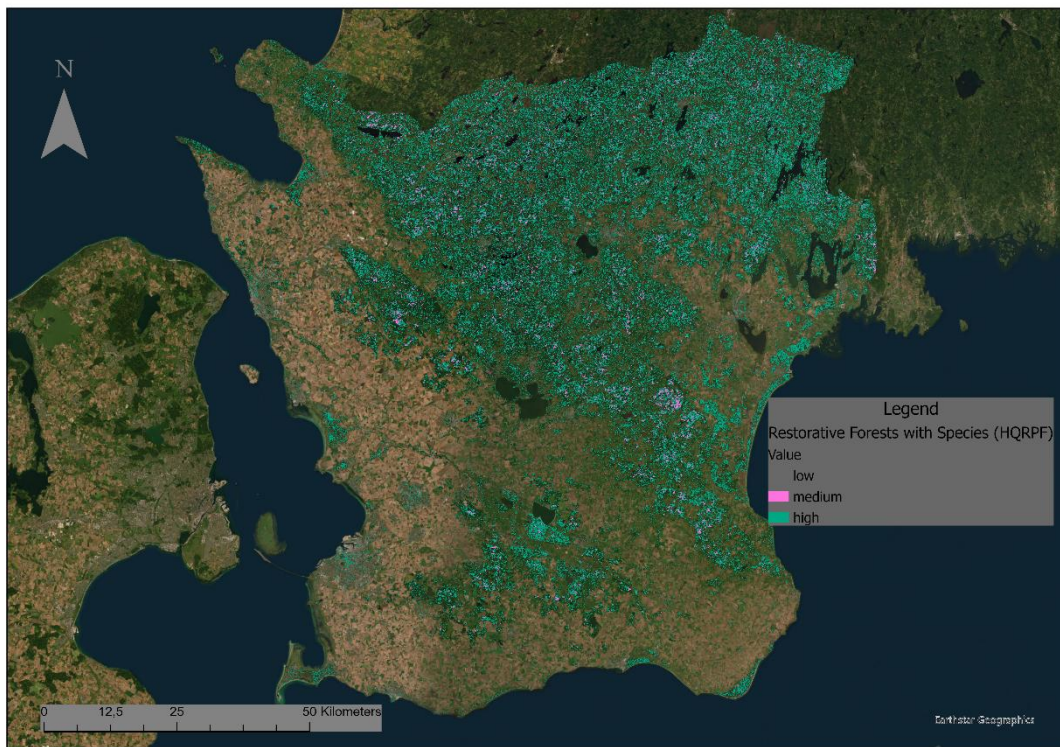


Figure 9. *Distribution of restorative forested environments with species composition across the Scania region*

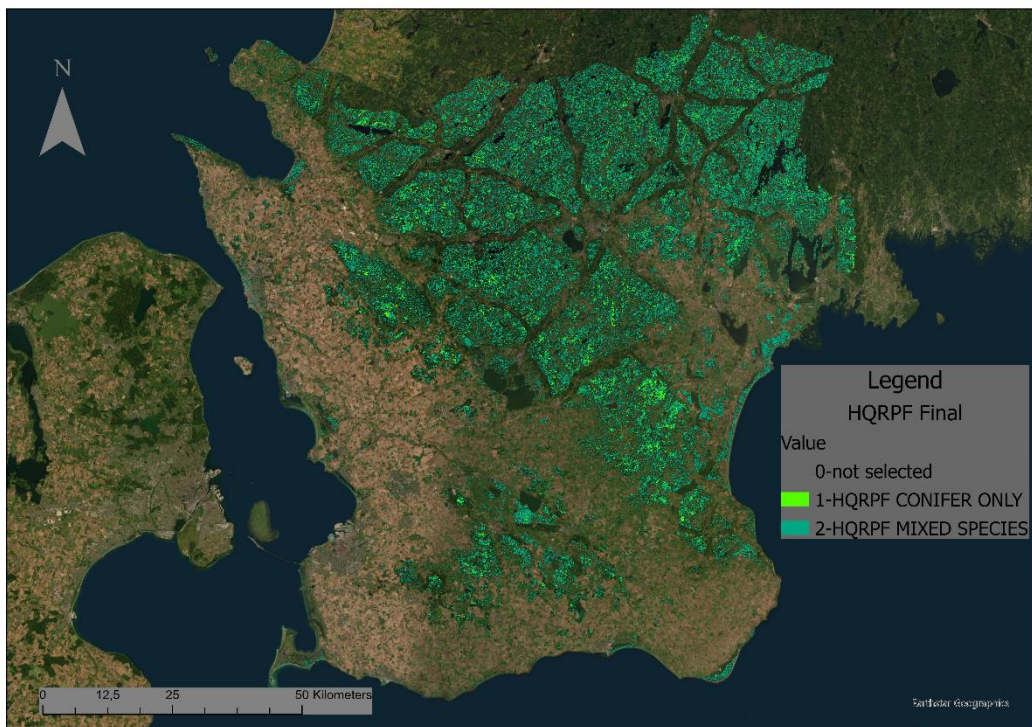


Figure 10. *Final High-Quality Restorative Potential Forests after road noise exclusion.*

3.2.5 Public transport spatial proximity

The public transport accessibility showed that regional bus and train stops were widely distributed across Scania, especially along the main settlement and transport corridors (Figure 11). However, a higher concentration of proximity to available public transport stations was clearly observable in the western part of the region, while the rest of the area had a lower concentration. Clusters in more forested- dominated inland areas appeared less directly connected to public transport.

It is important to note that the proximity of public transport was interpreted as access to the forest edge or entrance area, while the road-noise exclusion layer was used to identify quieter inner forest areas.

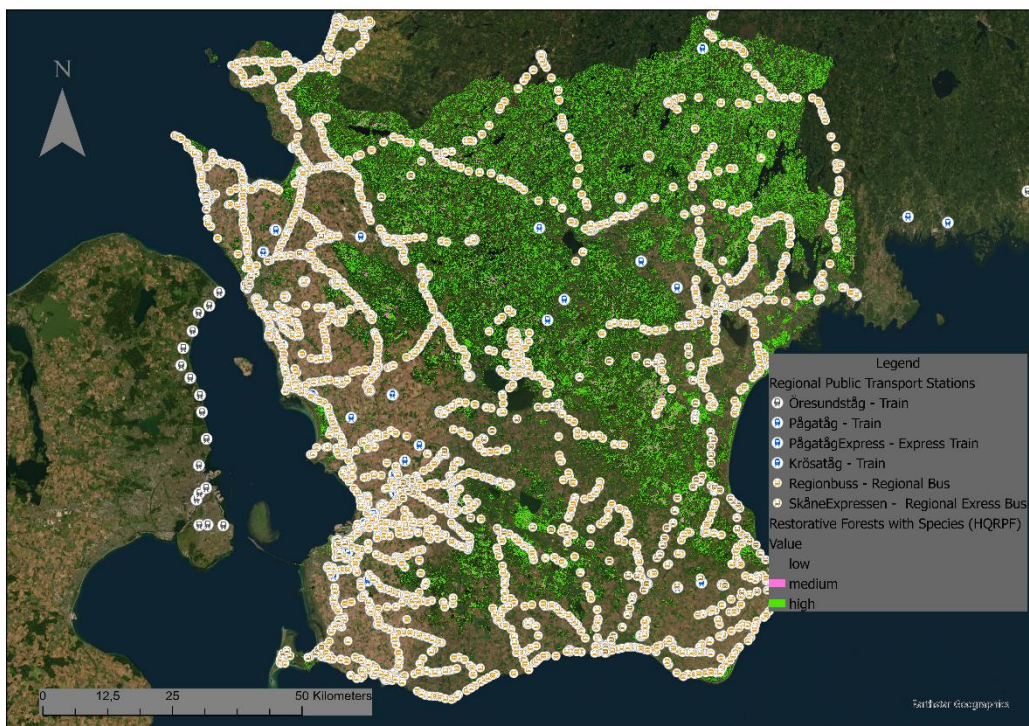


Figure 11. General overview of public transport proximity over the region of Scania in relation to identified restorative forested areas represented in Figure 8.

The public transport accessibility analysis showed the overall spatial relationship between forest edges and the regional public transport stops. At the regional scale, the 300m and 700m accessibility zones were not clearly visible as identified zones around the public transport stops, but at a zoomed-in view, the analysis became more relevant. In Figure 12, in addition to the overall regional view, an in-map of the closest visually identified zone around the city of Malmö provided a clearer understanding of the result. The identified geographical areas for the in-map were Torup-Bokskogen, national road 108, and Eksholm nature reserve, where the

accessibility pattern became more visible in detail. The area between road 108 and the Ekholm nature reserve resulted in some compatible public transport stations with a proximity of 300m , while Torup-Bokskogen resulted in a single public transport station in the proximity of 300 m.

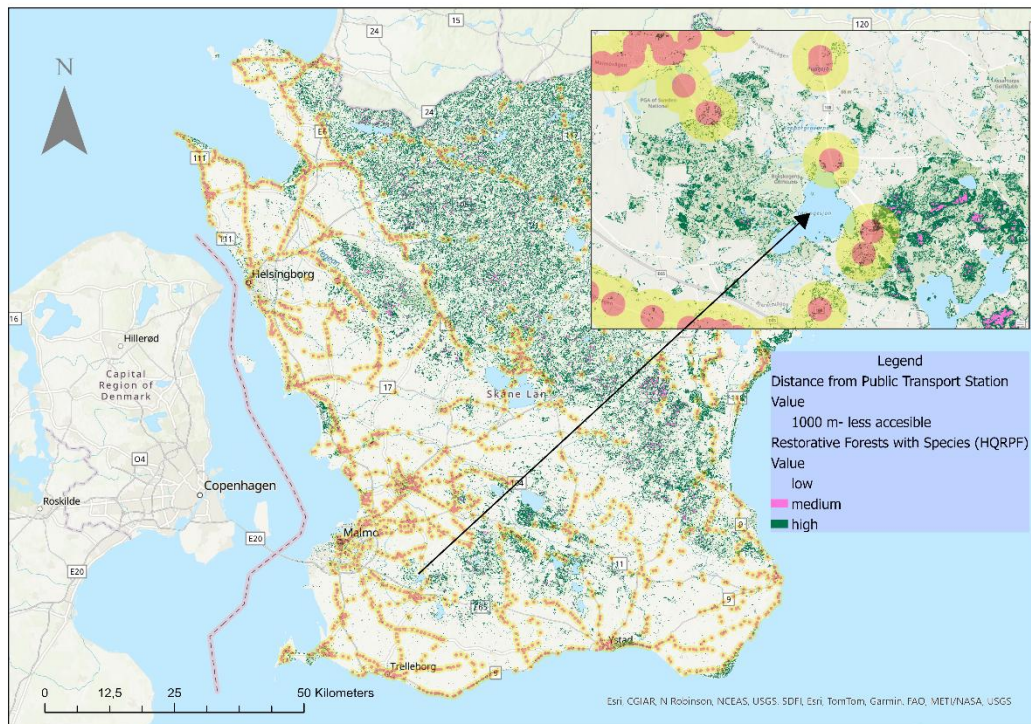


Figure 12. Public transport within 300-700 m of the forest edges. The inset map shows a detailed example of the area around Torup-Bokskogen, road 108, and Ekholm Naturreservat.

3.2.6 Approximate travel time accessibility by public transport and car.

The overview of approximate travel times showed clear differences in terms of accessibility between car and public transport, as shown in Figure 13. Car travel times were generally shorter, while public transport often required longer two-way trips and, in several cases, one or more transfers. Some candidate areas could be reached within approximately one to two hours, round-trip travel time, while more distant areas required longer journeys. An overview of the selection of areas, travel times, and their relation to the restorative forests is summarised in Appendix 1.

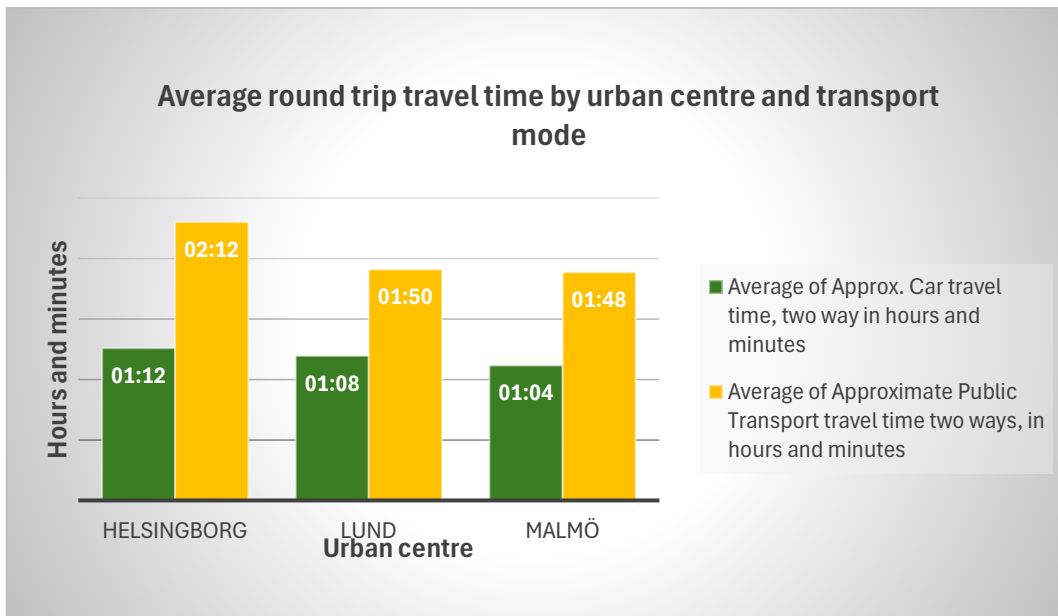


Figure 13. Comparison of travel time between public transport and private car in order to reach the closest restorative forested areas from the three major urban areas, Malmö, Lund, and Helsingborg

4. Discussion

This study aimed to identify restorative forest environments in Scania, evaluate their availability and accessibility for people with SRE syndrome, and analyze how reachable these areas are for residents of Malmö, Lund, and Helsingborg. Findings indicated that the restorative potential of forests depends not only on their presence but also on factors such as forest structure, species diversity, noise pollution, and ease of access. This is important because a forest might have excellent ecological qualities yet remain challenging to use if it is distant, poorly connected by public transportation, or affected by traffic noise.

The literature review revealed that several physical forest characteristics are relevant for restorative qualities, such as older or more mature forests, forests with low to medium density, taller trees, and certain species compositions, which were repeatedly described as important. A forest with tall trees but a very dense structure may not provide the same restorative experience as a forest with mature trees and some visual openness, due to a feeling of unsafety or a sense of refuge (Gatersleben & Andrews 2013). In the same way, a forest with low density may not be restorative if it is young, fragmented, or lacks developed structure (Simkin et al. 2020). Species composition enhances understanding of restorative forest environments, as the reviewed studies indicate that mixed, broadleaf, and conifer forests are perceived as most restorative, with conifer forests following (Liu et al. 2021b; Zhu et al. 2021). Mixed forests were described as providing a more varied visual structure and, although more complex, still offering a sense of naturalness. At the same time, although they were treated as a second candidate with high potential for restorativeness, coniferous forests only can still have strong psychological restorative effects. Coniferous species were a common attribute of both classes of restorativeness, possibly related to their specific sensory qualities and benefits, such as evergreen character or the presence of volatile organic compounds or phytocides released by trees (Zorić et al. 2021).

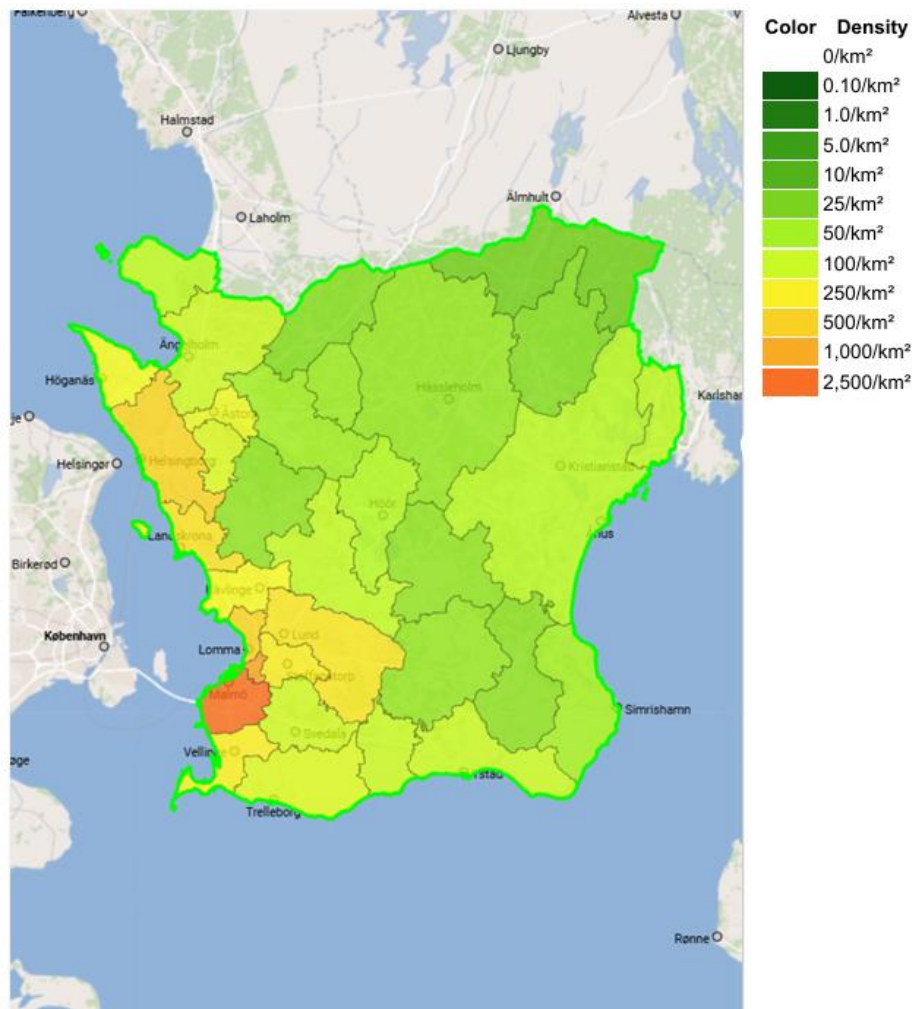
The first important pattern observed in GIS analysis was the large-scale spatial division of Scania. Forested areas were not randomly distributed but followed a broader landscape gradient. The southern, southwestern, and western parts of Scania appeared more open, fragmented, and agriculturally dominated, while the northern, northeastern, and eastern parts contained larger, more continuous forest areas. This pattern can be understood in relation to Scania's position in southern Sweden, where the landscape is influenced by the border between the south and the northern European continent, with both nemoral and boreal forest conditions (Tyler et al. 2020). This large-scale pattern is important because it situates the GIS

findings within a broader landscape context. Malmö, Lund, and Helsingborg are located in the southwestern part of Scania, where forest areas are generally more fragmented, meaning that the largest urban populations in the study area are not located closest to the most continuous forest landscapes. At the same time, these cities are historically linked to coastal locations, ports, and transport corridors (Anderson 2014; Sumner 2021). The location of Malmö, Lund, and Helsingborg along the coast and close to important transport and port functions has likely contributed to the concentration of people, infrastructure, and urban pressure in this part of the region. Therefore, in the first instance, the region of Scania faces a planning challenge because areas where many people live are not necessarily the same areas where the most continuous restorative forest environments are found.

However, the findings after the first forest structure analysis did not show a completely new or unexpected pattern. The areas with higher restorative structural potential mainly followed the existing forested parts of Scania. In other words, the combination of basal area, forest volume, and tree height helped identify structurally suitable forest areas, but it did not strongly change the regional picture. More important changes emerged when species composition and road-noise exclusion were added to the analysis. An important observation in species composition analysis is that conifer-broadleaf overlap occurred across large parts of the forested landscape, especially in the more forest-dominated areas of the region. This suggests that species composition is also part of the larger landscape shaped by agriculture, urbanization, and historical land use.

The road-noise exclusion step revealed the spatial differences clearer and identified the best candidate areas for high-quality restorative forested areas. After the road buffers were applied, it became clear that the Malmö-Lund area and the area around Helsingborg are not only close to major roads but are also surrounded by several overlapping transport corridors. This indicates that the most urbanized and accessible parts of Scania are also the areas where potential traffic-related disturbance is strongest overall, not only relative to forested environments. In terms of forest loss areas, the road noise exclusion was visually more noticeable in the northern and northeastern parts of Scania, where larger forest areas were fragmented by the main roads. However, this did not completely change the regional pattern, as many large, forested areas still remained in that part of the region. The more important issue appeared around Malmö and Lund, where the remaining candidate areas became somewhat smaller and more scattered after the buffer was applied. This suggests that the urban populations closest to these cities may have fewer nearby options for larger, quieter, and more continuous restorative forest environments. Another important aspect to mention is that the Malmö, Lund, and Helsingborg area, with close surroundings, has a high

population density (Figure 14), which means that even if the analysis findings show some scattered clusters of restorative forest environments near these cities, these areas may be relatively limited in relation to the size of the urban population in general.



© Thomas Brinkhoff,
https://www.citypopulation.de/en/sweden/admin/12__sk%C3%A5ne/

Figure 14. Population density in Skåne County by municipality. Reproduced from CityPopulation.de, © Thomas Brinkhoff. Population data source: Statistiska Centralbyrån. (Skåne (County, Sweden) - Population Statistics, Charts, Map and Location n.d.)

This indicates that the remaining nearby forest patches could be under strong recreational pressure, especially if they are among the few areas that combine accessibility with restorative qualities. For individuals with stress-related exhaustion, although the map shows that some candidate restorative forest areas exist near the Malmö Lund region, these areas may already be exposed to general recreational pressure because of the large number of residents living nearby.

However, the Helsingborg area may offer a slightly better situation in this aspect as it's located further north and outside the strongest Malmö-Lund urban pressure. Therefore, the issue is not only whether restorative forest patches exist near the cities, but whether they are large, quiet, and continuous enough to function as meaningful restorative environments for a large urban population.

The public transport proximity findings add another important aspect to the accessibility question. At the regional scale, the selected regional bus and train stops were mainly concentrated around the larger settlements and transport corridors, especially in the Malmö-Lund area and around Helsingborg. The western part of Scania is generally better connected by regional public transport, but the more forest-dominated inland areas, especially towards the north and northeast, appear less evenly connected. Although public transport stops exist in these areas, there are more scattered and large forested areas that do not seem to have the same level of direct public transport coverage. This creates an important tension between forest quality and public transport accessibility because the areas with larger and more continuous restorative potential are often located farther from the strongest public transport network. The areas closer to Malmö, Lund, and Helsingborg are better connected but more fragmented and more affected by roads and urban pressure. For individuals with stress-related exhaustion, it is also important whether the stop is close enough to the forest edge, whether the journey is simple, and whether the person can reach the forest without using too much energy before the restorative experience even begins, because the overall cognitive function of these individuals is deeply affected (Ellbin et al. 2018).

The approximate travel-time findings for both public and private transport, together with forest restorative environments findings, gave a more practical answer to the research question: How accessible are these restorative forest environments for residents of Malmö, Lund, and Helsingborg? The results showed a clear difference between access by private car and access by public transport. In general, the selected candidate areas were easier to reach by private car, while public transport often required longer travel times and, in many cases, at least one change. In the selected forested geographical areas, the findings revealed that the most accessible areas are not necessarily those with the strongest or most continuous restorative potential. For private car travel, the selected candidate areas had an estimated round-trip time between 40 minutes and 1 hour 30 minutes, with an average of about 1 hour 10 minutes. The shortest car travel times were found for nearby areas such as Torup/Bokskogen, Skrylle, and Ekholm/Yddingsjön, while more distant areas such as Snogheholm and Kullaberg required around 1 hour and 30 minutes for a round trip. Public transport findings showed a different pattern where the average round trip time by public

transport was close to two hours, and several areas required considerably longer journeys. The shortest public transport route was found for the southeast of Åstorp from Helsingborg, with an estimated round-trip time of about 50 minutes. However, other areas, especially the midpoint between Åstorp and Söderåsen, Söderåsen from Helsingborg, Fulltofta from Lund, and Snogeholm from Malmö/Lund, required between approximately 2 hours 30 minutes and 3 hours for a round trip.

When these travel time results are compared with all other findings, an important pattern becomes visible. Some of the more compact and continuous candidate forest areas, such as Härkeberga, Vomb, Snogeholm, Fulltofta, and Söderåsen, were the most difficult to reach, especially by public transport. Longer trips of two to three hours, especially when they include transfer wait times or crowded transport conditions, may reduce the practical usefulness of this forest as a recovery environment. Even though the areas closer to the main urban centers, such as Skrylle, Torup/Bokskogen, Ekholm/Yddingesjön, Åstorp SE, and the south-eastern part of Veberöd, had shorter estimated round-trip times, they may still represent a challenge for individuals with SRE. A round trip of around one hour, which may seem relatively short for the general population, can still represent a challenge for people with limited cognitive and physical energy. This shows that the relevance of restorative environments in general is not only a question of spatial location, but also a question of how realistic it is for people with limited energy to use them as part of recovery or everyday stress prevention. Access to calm outdoor environments may help reduce everyday stress responses and support recovery before stress develops into more serious health problems (Kondo et al. 2018). However, stress-related exhaustion is not only connected to the availability of restorative environments, but also shaped by work related demands (Maslach et al. 2001), stressful events and pressures in private life (Grebner et al. 2004), and broader economic insecurity (Catalano 1991).

This study has several limitations. First complete vector data for forest stands across Scania was not available, so raster data were used to represent forest structure and species composition. In addition, the raster datasets had different cell sizes, which may have affected the spatial precision of the combined outputs, particularly along patch boundaries. This allowed a regional analysis but reduced the precision of the results. For example, stand boundaries, forest entrances, paths, system, understory structure, visibility, actual tree age, and local management conditions could not be fully included. Second, the species composition analysis was based on raster overlap of species volumes and should not be interpreted as a formal mixed-forest stand classification. Similarly, the road noise layer was based on buffer zones around major roads and should not be understood as an exact

noise pollution map. Accessibility was treated in a simplified way. Analysis focused on proximity to regional public transport stops and approximate travel time by public transport and private car. It did not include parking availability, exact walking distance to the forest interior path, quality, slope, safety, service frequency, waiting time, or individual differences in mobility and energy level. Finally, the identified areas were not validated through field visits or user-based evaluation with individuals experiencing stress-related exhaustion. Therefore, the results should be interpreted as potential restorative forest environments, not confirmed restorative environments. Future studies should combine GIS analysis with field assessment, sound measurements, and direct evaluation by the target group.

5. Conclusions

The answer to the research question is not that restorative forest environments are completely inaccessible, but that their accessibility is limited and uneven in terms of travel time, proximity to a public transport station, and availability of compact forested areas near the urban cities of interest. The initial working hypothesis of this study is partially supported by the findings. The most continuous forested areas are often located farther from the largest urban centers, while forested areas that are closer to the cities are generally more fragmented, more affected by traffic-related noise pollution, and the required level of travel effort may still be considered demanding. Even with the limitations of the available GIS data and the approximate travel analysis, the study highlights an important planning issue. The Malmö-Lund area and the area around Helsingborg are strongly shaped by transport corridors, urban expansion, and fragmented forest distribution. The findings in this study also suggest that future spatial planning should pay more attention to the connection between urban growth, preventive health, and access to low-stimulation natural environments, not only at the regional scale but also from an urban perspective. If urban populations continue to grow and densification increases, access to quiet, restorative forest environments may become even more important, as urban green spaces themselves may become more crowded and therefore less restorative. This is relevant not only for individuals already affected by stress-related exhaustion, but also from a preventive health perspective, since access to low-stimulation outdoor environments may help reduce everyday stress, before it develops into more serious conditions. In this sense, the protection of mature, continuous, and relatively undisturbed forest environments becomes more important, alongside their already recognized ecological and climate-related importance.

However, restorative environments alone cannot explain or solve stress-related exhaustion, even if a city with well-designed urban green spaces and good access to nearby forests still needs to address wider social and work-related factors. Work pressure, private life stress, economic insecurity, and the organization of everyday life may all influence the risk of developing stress-related exhaustion. Therefore, future research and planning should focus not only on where restorative environments are located but also on how urban life, work life, and access to recovery opportunities interact. In this sense, restorative forest environments should be seen as one part of a broader preventive approach, not as a single solution.

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Appendix 1

Table 7. Approximate travel time by public transport and private car to selected candidate forest areas.

Urban Center	Candidate forest area / cluster	Route end point used	Approx. Car travel	Approximate Public	Notes
Malmö	Torup / Bokskogen	Forest edge	00:40	01:10	Close to Malmö; candidate areas very scattered
Malmö	Skrylle	Forest edge	01:00	01:20	Relevant candidate area between Malmö and Lund
Malmö	Ekholm / Yddingesjön area	Forest edge	00:40	01:40	More compact clusters east of road 108
Malmö	Häckeberga area	Forest edge	01:10	01:50	Larger area with more compact clusters
Malmö	Veberöd SE	Forest edge	01:10	02:20	Good relevant clusters
Malmö	Vomb area	Forest edge	01:20	01:50	Very good candidate area but farther from Malmö
Malmö	Snogeholm	Forest edge	01:30	02:30	More distant candidate area
Lund	Ekholm / Yddingesjön area	Forest edge	01:00	01:00	Relevant compact clusters east of road 108
Lund	Häckeberga area	Forest edge	01:00	01:40	Larger area with compact clusters
Lund	Veberöd SE	Forest edge	01:10	01:50	Good relevant clusters
Lund	Vomb area	Forest edge	01:20	01:10	very good candidate area
Lund	Snogeholm	Forest edge	01:30	02:40	More distant candidate area
Lund	Skrylle	Forest edge	00:40	01:40	Relevant candidate area close to Lund
Lund	Fultrofta	Forest edge	01:00	02:40	Relevant for the northeastern accessibility from Lund
Lund	Söderåsen	Forest edge	01:30	02:00	Relevant for the northwestern accessibility from Lund
Helsingborg	Åsorp SE	Forest edge	00:50	00:50	Closest selected clusters from Helsingborg side
Helsingborg	Mid-point Åsorp-Söderåsen	Forest edge	01:10	03:00	Intermediate candidate area
Helsingborg	Söderåsen area	Forest edge	01:20	02:40	Larger area with more compact clusters
Helsingborg	Kullaberg	Forest edge	01:30	02:20	Good relevant clusters

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