



Distribution and Characteristics of Far Away Landscapes in Sweden

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Swedish University of Agricultural Sciences, SLU

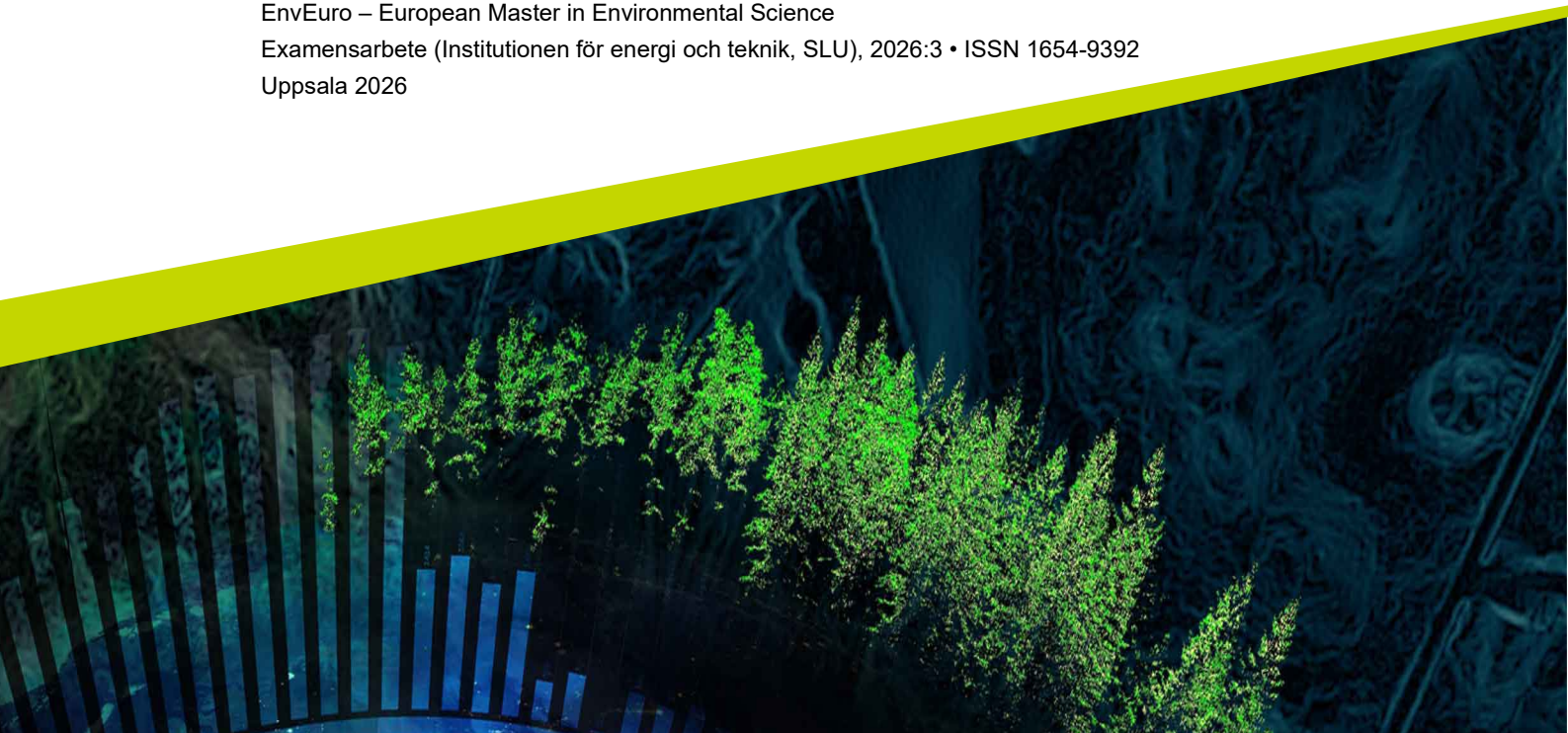
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Abstract

Landscapes far away from human infrastructure, herein "Far Away Landscapes" (FAL), hold specific ecological and socio-cultural values associated with natural and semi-natural conditions as well as with traditional rural cultures, yet in the anthropogenic world, they are rapidly disappearing or have already been lost. The purpose of this study is to map and assess FALs in Sweden, from the nemoral south to the boreal north, including subalpine and alpine regions, and evaluate the current anthropogenic pressures. FALs are defined as landscapes situated outside human infrastructure, applying three nested categories defined as >500m, >1000m, and >2000m distance from any infrastructure, as mapped by the National Land Cover (NMD) data of Sweden (layer "Artificial surface"). The results show a clear pattern, where the proportion of remote terrain drops sharply from 26.8% at >500m to just 6.8% at >2000m, explaining that infrastructure networks have efficiently occupied the majority of the landscape. A clear geographic divide was found where FALs are functionally extinct in southern and central Sweden, while over 97% of the nation's remaining deep remoteness is concentrated in the northwestern interior based on the $\geq 2000\text{m}$ distance. Case study of Norrbotten East shows that FAL availability declines rapidly with increasing distance from artificial surface, with total remaining land cover decreasing from 33.1% of the region area at $\geq 500\text{m}$ to less than 1% at 2000m. In contrast, Norrbotten West retains substantially larger and more contiguous FALs, with 79.8% of the land remaining at $\geq 500\text{m}$ and over 51% still present at 2000m. The case study of Kalmar County stands out as a unique landscape reservoir in southern Sweden, consisting of the alvar heaths, maintaining a level of structural remoteness that is nearly extinct in its neighboring regions. The results show that the extensive infrastructural footprint of industrial forestry has severely fragmented the boreal forest matrix. As a result, the last remaining large-scale remote areas are now mostly in alpine and sub-alpine terrain, not forests. These findings show that structural remoteness in Sweden is increasingly scarce and unevenly distributed.

Keywords: far away landscapes (FAL), landscape fragmentation, roadless areas, intact forest landscapes (IFL), green infrastructure, boreal forest, Scandinavian Mountains Green Belt, industrial forestry.

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Abbreviations

| Abbreviation | Description |
|--------------|--|
| BP | Before Present |
| CBD | Convention on Biological Diversity |
| EEA | European Environment Agency |
| FAL | Far Away Landscapes |
| GIS | Geographic Information System |
| HCVF | High Conservation Value Forest |
| LM | Lantmäteriet (Swedish National Land Survey) |
| MSPA | Morphological Spatial Pattern Analysis |
| NFI | National Forest Inventory |
| NLC | National Land Cover |
| NMD | National Land Cover Database (<i>Nationella Marktäckedata</i>) |
| RFI | Roadless Fragmentation Indicator |
| SCB | Statistics Sweden (<i>Statistiska centralbyrån</i>) |
| SKS | Swedish Forest Agency (<i>Skogsstyrelsen</i>) |
| SLU | Swedish University of Agricultural Sciences (<i>Sveriges lantbruksuniversitet</i>) |

Use of Artificial Intelligence

I hereby acknowledge the use of Artificial Intelligence in the preparation of this thesis, specifically the large language models Gemini and NotebookLM, which were used solely for proofreading and correcting grammatical errors. AI was not used for argument development, structural organisation, or the generation of any scientific content. All analysis, results, and conclusions are my own. I take full responsibility for the accuracy and integrity of this work.

1. Introduction

1.1 Remoteness in the Anthropocene

Human activities have so fundamentally altered the global land surface that modified landscapes now dominate over natural ones in many regions. Assessments indicate that at least 70 percent of the Earth's land surface has been significantly modified, affecting biodiversity, reducing ecosystem resilience, and diminishing the goods and services landscapes provide to people (Díaz et al. 2019; IPBES 2019). Habitat loss and landscape fragmentation are recognized as the primary threats to terrestrial ecosystems globally (Ceballos et al. 2015). Progress toward the 20 Aichi Biodiversity Targets has fallen short of what is needed, which directly impacts the related Sustainable Development Goals (Goals 12, 13, and 15) (Díaz et al. 2019; Kati et al. 2020).

Built infrastructure, including cities, roads, railways, and wind power turbines is expanding faster than at any previous point in history. According to estimates, the total amount of paved roads will grow by 14 to 59 percent globally by the year 2050 (Ibisch et al. 2016). Roads are one of the primary causes of often irreversible negative impacts on ecosystem functioning, including chemical pollution, hydrological disruption, and soil erosion (Trombulak & Frissell 2000; Ibisch et al. 2016). Additionally, roads have direct species-level effects such as wildlife-vehicle collisions, noise disturbance, and as entries and spreading networks for invasive species (Laurance et al. 2014). As a result, the areas that remain distant from human infrastructure have become critical refuges for biodiversity (Soto-Navarro et al. 2020).

To protect these areas in practice, conservation science uses the concept of Intact Forest Landscapes (IFL). These IFLs are continuous mosaics of forest and other land covers larger than 50,000 hectares (ha), displaying no evident signs of human activity or habitat fragmentation, and large enough to maintain native biodiversity and ecological functions (Potapov et al. 2013; Svensson et al. 2020). The IFL-approach acknowledges that ecological continuity and connectivity are intact on large scale (Svensson et al. 2020), thus it goes further than the protection of single patches of nature with conservation value.

Since Europe is currently considered the world's most fragmented continent with habitat fragmentation continuing (Ibisch et al. 2016), policies are being pursued to reduce further habitat degeneration and re-create habitat areas and qualities (EC 2026). Forests dominate in many European countries, including Sweden, particularly in remote hinterland regions (Svensson et al. 2020). Since the levels of forest harvesting are still high in many European countries and regions, it is urgent to locate and protect the last forest-dominated IFLs to secure globally

important environmental values such as biodiversity, carbon sequestration, freshwater supply and indigenous cultures (Potapov et al. 2008).

1.2 Transformation of the Swedish Forest Landscape

The Swedish landscape has been shaped by a long history of human exploitation, including of the boreal forest ecosystems. Gradual opening of the landscape for the cattle grazing and small-scale agricultural activities such as slash-and-burn practices occurred already in the Neolithic period (ca 5000 yr BP) (Esseen et al. 1997) and by the 17th century, it had already resulted in the deforestation of large parts of southern Sweden, the Bothnian coast and the Silurian area in Jämtland (Esseen et al. 1997).

However, the extent of these activities was geographically concentrated. The mining industry in central Sweden grew rapidly during the 17th and 18th centuries. Large amounts of charcoal and timber were required, which periodically led to local overexploitation, and ultimately required expansion of settlement into the northern interior by the end of the 18th century to sustain wood provisioning to the forest industries (Östlund et al. 1997). The production of tar, particularly of large Scots pine trees (*Pinus sylvestris*), was at its high point around 1850 and had an effect on forest environments even within a sparsely populated area (Esseen et al. 1997). This phase of early industrialized forest harvesting was focused on high-grading, the selective extraction of high-quality pine and Norway spruce (*Picea abies*) trees of large diameter (Wastenson 1990) with most timber transported in Sweden to mills and markets by rivers (Törnlund & Östlund 2006). The method of river driving of logs allowed forest harvesting into hinterlands that could not be reached before (Wastenson 1990). As a result, by the late 19th century, a majority of old-growth forests in Sweden had been harvested at least once to meet the growing demands of sawmill markets (Esseen et al. 1997).

Since 1903, forestry has been legally regulated to ensure the regeneration of forests and the long-term provisioning of forest resources (Lindahl et al. 2017). After the ban on selective logging on the state lands in 1950, a shift towards mechanised rotation forestry operations took place. This standardized industrial forestry system transformed the natural and multi-aged forest matrix to even-aged production stands, a limited number of tree species, with straight and artificial linear boundaries, with little resemblance to patterns that can be found in the natural landscapes (Axelsson 2001; Appelstrand 2012). To facilitate the intensive wood extraction, an extensive network of forest roads and drainage ditches, built since the 1950s, systematically affected the landscape continuum and opened access to remote forest lands (Östlund et al. 1997). Lower elevation wetlands and water bodies were also heavily altered to sustain timber production (Björklund

1984; Linder & Östlund 1998). Ditching was used to drain large tracts of wetlands and wet forests to enhance the growth of trees, and this altered the local hydrology (Östlund et al. 1997).

Recent retrospective studies have shown that only approximately 3 percent of the productive forest land in Sweden has escaped this modern era of intensive forestry (Östlund et al. 1997). As a result, remote and intact forest landscapes with no evident signs of forestry are scarce (Moen et al. 2014; Svensson et al. 2019; Ahlström et al. 2022). As the forest matrix was subjected to systematic industrialization, the trajectory for subalpine, alpine and other open lands, wetlands (if not drained for agricultural, peat excavation, or forestry purposes), and larger inland water bodies (if not modified for more effective log floating transport and later by hydropower facilities) have remained more intact and currently form the core of remote areas in Sweden. This is directly reflected in the distribution of protected areas in Sweden, where the share of protected subalpine woodland (57%), open alpine environment (47%), lakes and watercourses (27%) and open wetlands (22%), by far exceed the share of protected forests (9%) (Statistics Sweden 2025).

1.3 Sweden's Landscape

Centuries of farming and urbanization in southern and central Sweden have left natural ecosystems as small, isolated fragments within a landscape dominated by human land use (Götmark & Nilsson 1992). Meanwhile, the northern interior, specifically the Scandinavian Mountain range areas, represents one of the last large, continuous intact forest landscapes in Europe (Potapov et al. 2013; Svensson et al. 2020). This region is a key area for biodiversity, with the Scandinavian Mountains Green Belt maintaining ecological connectivity and original habitats that have been lost across the lowlands and coastal areas (Svensson et al. 2020).

Unlike the boreal forests, alpine and sub-alpine environments, often classified as "Other Open Land" in the Swedish National Land Cover Database (SEPA 2020) have historically been more resistant to fragmentation because of their harsh climate, difficult terrain, and low biological productivity. These conditions have also made them unsuitable for commercial forestry and restricted road expansion (Esseen et al. 1997; Svensson et al. 2019).

Despite this historical resistance, these northern landscapes now face cumulative pressures from both industrial forestry (Korosuo et al. 2014) and the modern expansion of renewable energy infrastructure (Marin 2025). For indigenous reindeer husbandry, the quality of winter grazing sites has already been severely degraded by the extensive network of forest roads, which disrupts the continuity

of lichen-rich old forests (Sandström et al. 2016; Svensson et al. 2019). Furthermore, large-scale wind farms are now frequently constructed in high-elevation alpine habitats, introducing new infrastructure and disruption into the exact areas that historically provided the last undisturbed grazing grounds for reindeer herds (Marin 2025).

1.4 Policy Implications and the Necessity of Spatial Conservation

Recent European policies, such as the newly adopted EU Nature Restoration Regulation (EC; NRR 2024) and the Biodiversity Strategy 2030 (EC 2020), are aiming to restore the ecological connectivity across all EU Member States. However, implementing these goals in Sweden is proving difficult (Svensson et al. 2025). Sweden's current national strategy is preferring the minimum compliance, proposing the use of historical 1995 habitat baselines rather than modern scientific evidence to define what needs to be protected (Svensson et al. 2025). Because industrial forestry has already transformed the Swedish landscape, relying on these outdated baselines threatens to leave the remaining remote areas unprotected. To actually meet these targets, there must be an urgent shift toward landscape-level planning that uses current spatial data to identify, prioritize, and protect these remote areas (Angelstam et al. 2011; 2026; Svensson et al. 2025; Wang et al. 2025).

One way to effectively prevent further decline of remote landscapes is to implement the "Roadless Rule" that legally protects remaining landscapes from new industrial expansion and road building (Kati et al. 2020). Studies confirm that road avoidance is a key factor of wildlife distribution; therefore, preventing road expansion into intact habitats is one of the most effective ways to minimize human disturbance, reduce poaching, and secure ecological continuity (Laurance et al. 2014; Ibisch et al. 2016; Kati et al. 2020).

In Sweden, existing legal frameworks, such as the Swedish Environmental Code (Miljöbalken) (1998:808; SEPA 2020), have failed to prevent the expansion of forest roads and wind energy infrastructure (Marin 2025). This ongoing expansion is particularly dangerous for the Scandinavian Mountains Green Belt and other remote and intact nature areas that function as vital refuges for biodiversity and support species adaptation to climate change (Elmhagen et al. 2015; McGuire et al. 2016). If combined pressures from land-use and climate change exceed a critical threshold, the region risks an irreversible "sledgehammer effect" resulting in permanent ecological damage (Svensson et al. 2020).

Given these threats, current research shows that immediately strictly protecting the remaining intact old-growth forests and remote areas is both economically and

ecologically more efficient than attempting the massive and costly task of restoring heavily degraded production lands in the future (Watson et al. 2018; Svensson et al. 2025).

1.5 Definitions of Intact and Remote Landscapes

The terminology and theoretical frameworks of remoteness and intactness include terms such as, for example, wilderness, intact areas, roadless regions, and low-impact zones, all describing a low or lack of human structures (Pérez-Hämmerle et al. 2022). There are several current definitions that are characterized by a variety of overlapping terminology. Table 1 above lists definitions utilized in this research to describe intactness and remoteness.

Table 1: Examples of Existing Definitions

| Term | Definitions | Author/Agency |
|-------------------------------|--|--|
| Wilderness/Protected Places | An area governed by natural processes and it is unmodified or only slightly modified and without intrusive or extractive human activity, settlements, infrastructure or visual disturbance. | (European Commission 2013) |
| Roadless areas | Natural and semi-natural regions largely devoid of roads. | (Ibisch et al. 2016; Kassara et al. 2022) |
| Wilderness Areas | Category Ib protected areas [i.e.wilderness areas] are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition. | (Dudley 2008; IUCN 2020) |
| Functional Remoteness | A finite and non-renewable resource defined by the absence of human footprints, essential for species retention and large-scale carbon storage (e.g., storing 35% of global terrestrial carbon). | (Svensson et al. 2020; Pérez-Hämmerle et al. 2022) |
| Intact forest landscape (IFL) | A seamless mosaic of forest and naturally treeless ecosystems with no remotely detected signs of human activity and a minimum area of 500 km ² . | (Potapov et al. 2013) |

Note: The text here comprises excerpts only. The full definitions are in some cases much longer. Additionally, some of the definitions presented here may not represent the original sources of these terms and build on the previous ones. Rather, they have been extracted from the cited papers to illustrate how these concepts are defined and applied in recent literature.

1.6. Study Justification

While the above established definitions (Table 1) are essential for understanding the Swedish hinterlands and provide a strong foundation for their protection, current conservation efforts often remain restricted to smaller, isolated patches (Orlikowska et al. 2020). Building on this foundation, this study seeks to broaden the perspective by identifying remaining areas at distance from roads and other built infrastructure.

Our approach is strictly based on arbitrary, regular distances, and not on literature-based disturbance zones for human amenities, species sensitivity or ecological intactness, since personality, trait, life cycle phase, cumulative premises, etc., are the factors that determine the actual distance zone where remoteness matters. This implies that distances are both numerous and variable depending on focal species, aspect, seasonality, etc. This “Far Away Landscape” (FAL) approach is thus similar to the definition of roadless areas, but broader, to allow further target-specific adjustment to focal species or other matters of concern.

As an approach, FALs is a way forward to contribute a high-resolution spatial mapping of continuous center-to-periphery assessment for informed planning and decision-making on sparing or sharing of remaining FALs. Sweden as a case offers broad biogeographical and socio-economic gradients from north to south and west to east, but also a legacy of intense industrial use of forests as being the dominating land cover type, unbalanced nature protection and human population distribution, expanding wind power and other land-use, and on-going conflicts on sustainable land use.

1.7 Aim and Objectives

In Sweden, as in many other countries and regions globally, FALs are rapidly disappearing or have already been lost. To assess these areas, this study presents nested distances from "Artificial surfaces" such as roads, railways, and buildings as documented in the Swedish National Land Cover database (SEPA 2018).

The aim of this study is to identify, map, and assess the distribution of FALs across Sweden from the nemoral south to the boreal north, including subalpine and alpine regions, to provide a quantitative baseline of landscape remoteness and examine current built infrastructure pressure. To fulfil this aim, the study addresses the following specific objectives:

1. Map the occurrence of FALs across the Swedish land base using nested distance thresholds (>500m, >1000m, and >2000m) from human infrastructure to define the extent of landscape remoteness.

2. Analyse the land-cover distribution within identified FALs to determine different land-cover types, specifically forest, wetland, water, arable land, and open land, that constitute the core of Sweden's remaining remote areas.
3. Assess the fragmentation of the landscape based on geographic regions by comparing FAL persistence among the "mountainous" counties vs. the "non mountainous" counties, quantifying the north-south divide in structural integrity.

2. Materials and Methods

2.1 Study Area

This study focuses on the distribution and characteristics of FALs across the entire terrestrial territory of Sweden, i.e. the entire range of Sweden's natural environments, extending from the nemoral vegetation zones in the south to the extensive boreal forests and alpine regions in the north (Gustafsson & Ahlén 1996). While the assessment is national in scope, the analysis deals with the heterogeneity of the Swedish landscape by reorganizing the 21 administrative counties into 23 regions (Fig. 1). This modification involves subdividing the large northern counties of Norrbotten and Västerbotten into "West" (alpine/interior) and "East" (coastal) regions, following, e.g., Svensson et al. (2020). This prevents the western mountain regions data from overshadowing the data of the more urbanized eastern coastal zones, allowing for a robust national assessment. The resulting 23-region subdivision ensures that the remoteness and land-cover data represent the landscape evenly, providing a much more reliable basis for the analysis.

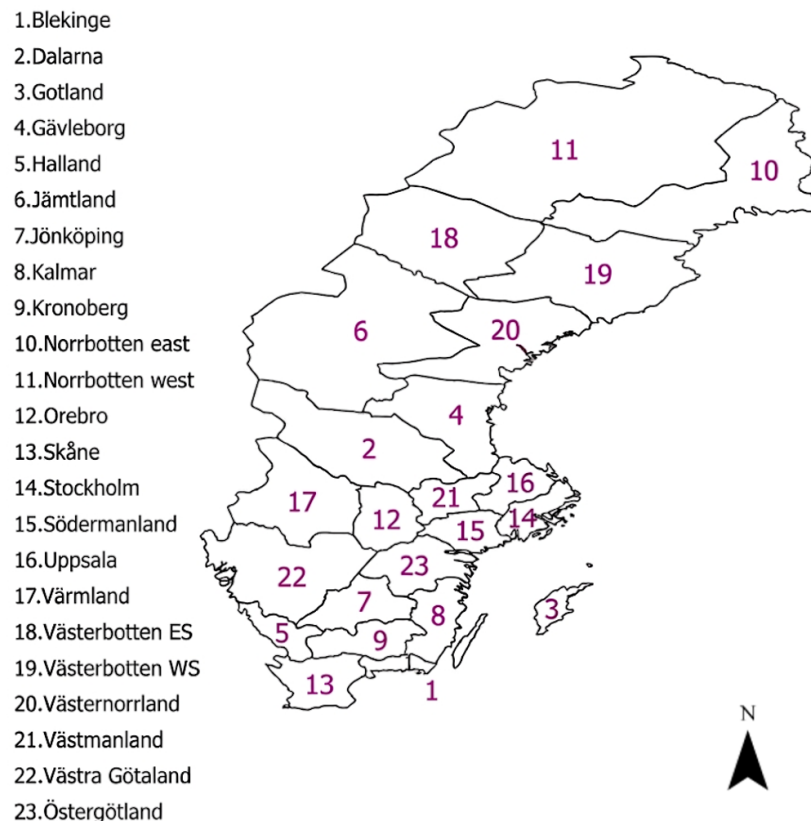


Figure 1: Map of Sweden showing the 23 regions used in the Far Away Landscapes (FAL) assessment.

2.2 Data Description and Sources

Data sources were selected based on their relevance for mapping land cover, infrastructure density, and anthropogenic pressure. The primary dataset serving as the foundation for this analysis is the National Land Cover Database of Sweden (SEPA 2018; 2025).

2.2.1 National Land Cover Database (NMD)

The National Land Cover Database (SEPA 2018) produced by the Swedish Environmental Protection Agency and Metria land survey (SEPA 2020), with high-resolution geospatial inventory, provides a complete coverage of Sweden at a 10×10m spatial resolution. The map is provided as a standard GeoTiff file and classifies land cover using Sentinel-2 satellite imagery captured between 2017 and 2019 (SEPA 2020). For the analysis, the NMD Base Map from the 2018 was selected (SEPA 2020) as the most consistent and reliable baseline for a national-scale analysis. While a newer 2023 version is partially available, it was still incomplete for certain regions during data acquisition.

The classification system organizes land cover into 23 categories across three levels (Fig. 1), based on a Swedish adaptation of the CORINE Land Cover standard (SEPA 2020). To maintain spatial accuracy across Sweden, all analyses were conducted using the data's native SWEREF 99 TM coordinate system.

In this study, the NMD Base Map was used to identify both the Artificial Surfaces used as the origin points for disturbance buffers and the ecological land-cover classes that characterize the FALs. Since the original data is provided in Swedish as separate county-level files, these regional datasets were first merged into a single national layer, and all attributes were translated into English to ensure the analysis is internationally accessible.

The overview below (Fig. 2) illustrates the structure of the NMD hierarchical classification, where all land-cover types are organized into six top-level classes applied in this study: Forest (1; with two major classes: on wetland and not on wetland), Open Wetland (2), Arable Land (3), Other Open Land (4), Artificial Surfaces (5), and Water (6).

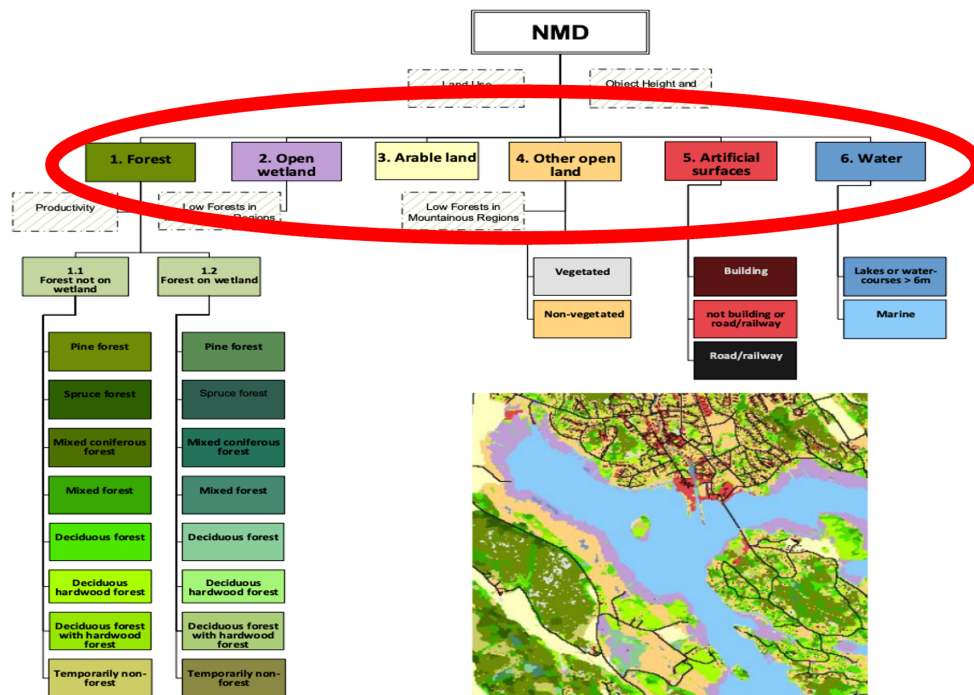


Figure 2: Conceptual overview of the Swedish National Land Cover Map (NMD) classification system, highlighting the six primary land-cover categories used in the Far Away Landscapes (FAL) analysis (modified from SEPA, 2020).

To define the concept of Infrastructure, this study uses the specific Artificial Surfaces classes from the NMD. These layers represent the direct footprint of human activity, encompassing transportation networks, buildings, and industrial sites. Following the NMD product description (SEPA 2020), the classes were extracted to create the binary infrastructure mask included (Appendix Table A1); artificial surfaces, building (class 51); artificial surfaces not building or road/railway (class 52), and artificial surfaces, road/railway (class 53).

2.3 Data Preparation and Categorical Simplification

Before the spatial analysis, extensive data preparation was needed to correct topological errors and simplify the classification.

2.3.1 Data Integrity and Geometry Repair

Before running the spatial analysis, the compiled national dataset required a standard integrity check. The Repair Geometry tool in ArcGIS Pro (Version 3.6, Esri Inc. 2024) was used on the Artificial Surfaces layer to identify and correct geometric errors, such as self-intersections or null geometries. This step was necessary to prevent errors in the subsequent buffer analysis. All spatial analyses were performed in ArcGIS Pro software (Version 3.6, Esri Inc. 2024).

2.3.2 Reclassification of Land Cover

The original NMD classification system contains 23 detailed sub-categories (Fig. 2; SEPA 2020). For the purposes of this study, the FAL-approach focuses exclusively on the five ecologically dominant categories (circled in red): Forest, Open Wetland, Arable Land, Other Open Land and Water. These classes collectively define the natural and semi-natural landscape matrix most relevant for assessing landscape permeability, remoteness, ecological integrity and patterns, to enhance interpretability. The fifth class Artificial Surfaces represents human impact. The primary land-cover categories include:

1. Forest Land (Class 1(111-118, 121-128)): Aggregating coniferous, deciduous, and mixed forests, as well as temporarily non-forested areas (e.g., clear-cuts).
2. Open Wetland (Class 2): Defined as open land where water is close to the surface.
3. Arable Land (Class 3): Representing agricultural production areas.
4. Other Open Land (Class 4 (41, 42)): Including alpine meadows, heaths, and bare rock.
5. Artificial Surfaces (Class 5 (51, 52, 53)): Used strictly as the origin boundary for infrastructure influence.
6. Inland Water (Class 6 (61, 62)): Lakes and watercourses.

Marine waters were excluded from the analysis using a terrestrial boundary mask to keep the study strictly focused on terrestrial environments. Ultimately, this simplified five-category approach (Fig. 2 and 3) makes the national data possible to interpret while still capturing the core land cover types that shape ecological variation and remoteness across Sweden.

Categories 1-4 and 6 (Fig. 2 and 3) capture the primary environments of Sweden and provide a clear foundation for evaluating human influence and landscape remoteness. Forests, which dominate the boreal and sub-alpine north, make up most of the country's land surface. Open wetlands, Other Open Lands and Inland Water are distributed across the country, whereas arable lands highlight the intensive agriculture.

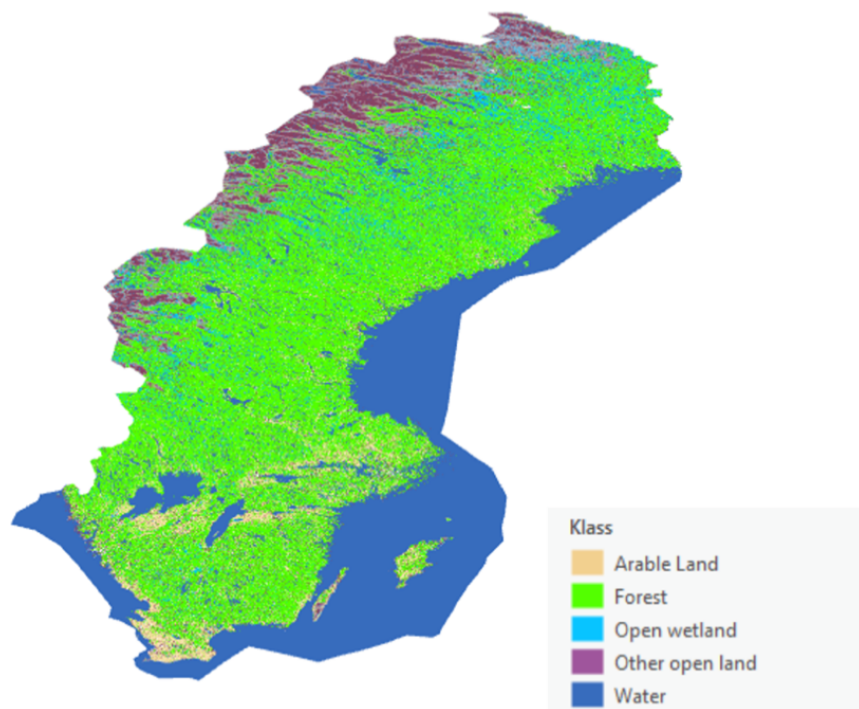


Figure 3: National Land Cover Map (NMD) of Sweden classified into the five primary land-cover categories used in the Far Away Landscapes (FAL) analysis. The map displays Sweden's terrestrial landscape, aggregated into five main classes: Forest (1), Open Wetland (2), Arable Land (3), Other Open Land (4), and Water (6).

2.3.3 Terrestrial Masking and Exclusion of Major Lakes

In the reclassification workflow to define the study area, a standard terrestrial boundary mask from the National Land Cover Database (SEPA 2018) was applied. While the primary objective was to filter out Marine Waters (Class 62) and keep the analysis focused strictly on land, this mask also removed Sweden's four largest inland lakes (Vänern, Vättern, Mälaren, and Hjälmaren) because they were not mapped in the terrestrial map from NMD. Consequently, although the Inland Water FAL-category (Class 61) successfully captures the smaller lakes and rivers, these four major lakes are excluded from the baseline. The implications of omitting these extensive lake systems from the dataset are addressed in the Discussion (Section 4.3.5).

2.4 Delineation of Far Away Landscapes (FALs)

The core analytical process involved delineating FALs through a Zone of influence buffer analysis within ArcGIS Pro (version 3.6, Esri Inc. 2024).

2.4.1 Buffer Analysis

The ArcGIS Pro Multiple Ring Buffer tool, was utilized to model infrastructure influence. Using the aggregated NMD Artificial Surfaces (*Class 5 (51,52, 53)*) layer as the input, concentric buffer polygons were generated at three distinct spatial thresholds to represent varying degrees of remoteness (Fig. 4):

- **≥500m (500m-999m) distance from Artificial Surface:** Representing the immediate zone of influence (Fig. 4B).
- **≥1,000m (1000m-1999m) distance from Artificial Surface:** Representing a moderate zone of influence (Fig. 4C).
- **≥2,000m distance from artificial surface:** Representing an extended zone of influence (Fig. 4D).

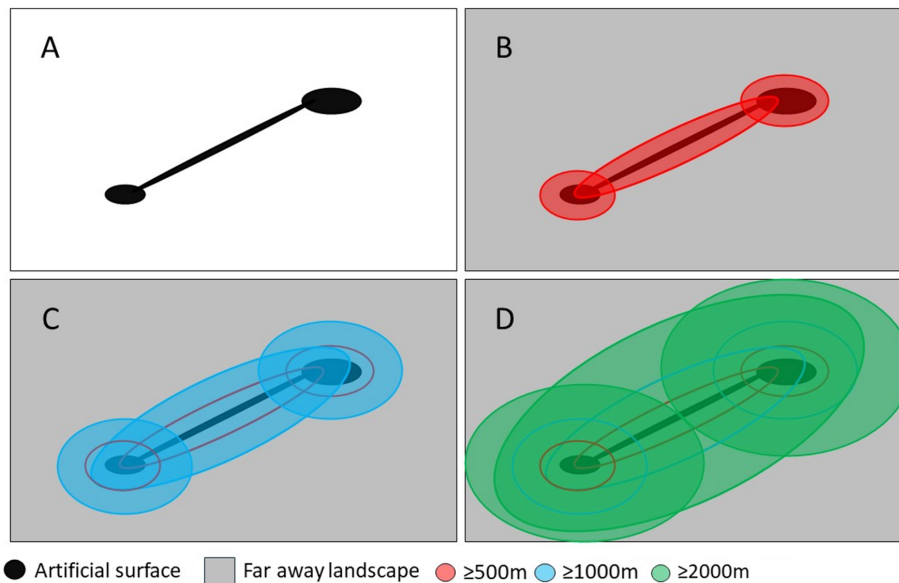


Figure 4: Illustration of the methodological approach to map Far Away Landscapes, showing an imaginary built infrastructure in an imaginary landscape (A), to which a $\geq 500\text{m}$ (B), $\geq 1000\text{m}$ (C), and $\geq 2000\text{m}$ (D) zone was added to stepwise map parts of the landscape $\geq 500\text{m}$, $\geq 1000\text{m}$ and $\geq 2000\text{m}$ on distance from the infrastructure.

FAL-areas are nested, i.e. the $\geq 1000\text{m}$ FAL includes the $\geq 500\text{m}$ FAL, and the $\geq 2000\text{m}$ FAL includes both, where each distance threshold represents a progressively more remote tier. Because each threshold is nested within the next, a point qualifying at $\geq 2000\text{m}$ also qualifies at $\geq 1000\text{m}$ and $\geq 500\text{m}$ (Fig. 4). The $\geq 500\text{m}$ FAL encompasses the broadest extent of land free from immediate anthropogenic pressure, while the $\geq 1000\text{m}$ FAL and $\geq 2000\text{m}$ FAL represent progressively isolated subsets of that initial area. The nested approach allows us to track how the structural core of Sweden's remaining remote areas changes with increasing distance from infrastructure. Because any point situated at least

$\geq 2000\text{m}$ from infrastructure must, by definition, also be at least 1000m and 500m distant, the $\geq 2000\text{m}$ FAL acts as the inner ecological nucleus of the FALs. This allows the study to move beyond a binary roadless distinction and instead model the spatial decay of infrastructure influence moving deeper into the nested tiers.

To ensure the completeness of this approach, a critical validation phase was conducted regarding renewable energy infrastructure, specifically wind and solar power installations. Spatial analysis using data from the Wind Farm map service (Swedish Energy Agency 2025), extracted April 20, 2025) and national solar registries (Swedish Energy Agency 2025) confirmed that these features cover 1.4% and 0.8% of Sweden's land area, respectively, and were already spatially encompassed within the primary NMD Artificial Surfaces dataset. Therefore, a separate step to map renewable energy was unnecessary for defining the final Far Away Landscapes (Appendix Fig. A1). To illustrate the actual spatial reach of anthropogenic influence, Skåne County is used as an example in Fig. 5, where the FALs decrease step by step and vanishes at $\geq 2000\text{m}$.

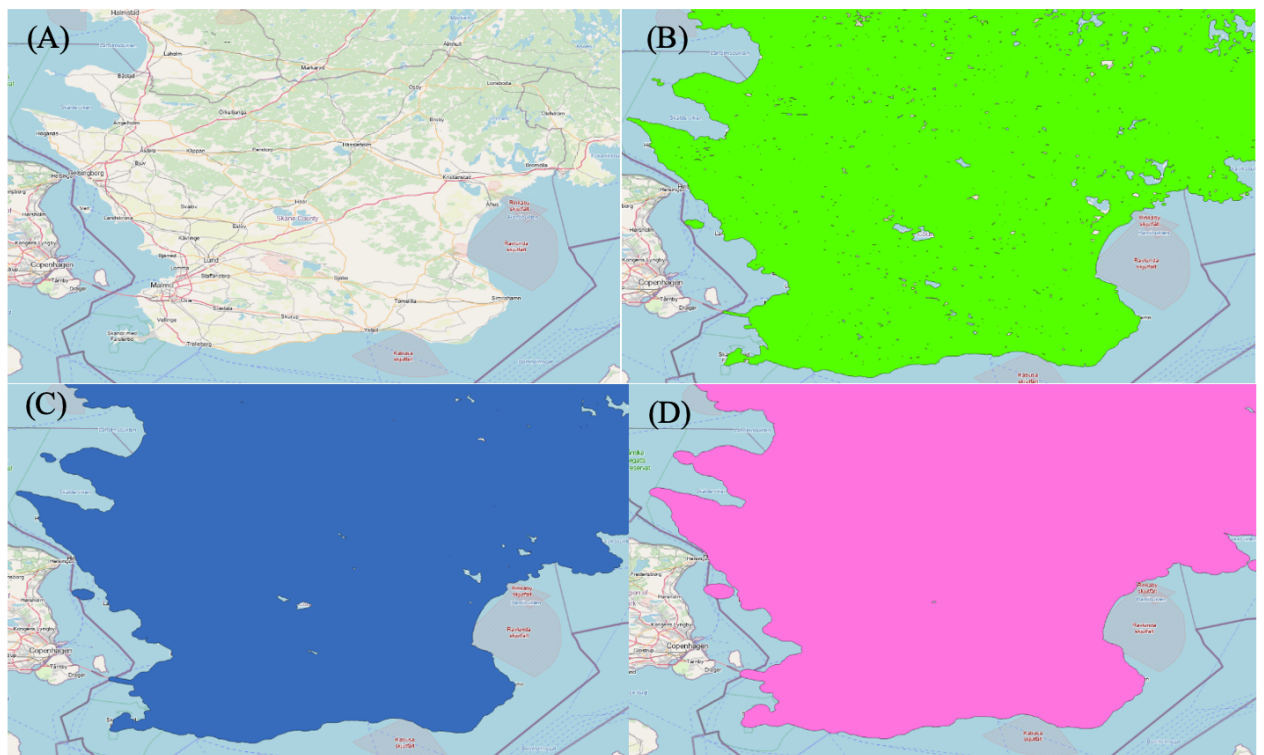


Figure 5: Functional extinction of remoteness in Skåne County. A) Baseline terrestrial land base of Skåne, B) $\geq 500\text{m}$ distance (green), C) $\geq 1000\text{m}$ distance (blue), D) $\geq 2000\text{m}$ threshold (pink).

These buffered zones were merged to create a unified polygon layer representing the area of anthropogenic influence. This layer served as the exclusionary mask for the subsequent spatial extraction process, where the Erase tool was employed

to subtract the buffered infrastructure zones from the total terrestrial land area of Sweden to isolate the potential Far Away Landscapes (FALs).

2.4.2 Spatial Extraction

To isolate the FALs, the ArcGIS Pro Erase tool was used. The distance zones were subtracted from a master polygon representing the total terrestrial land area of Sweden (excluding marine waters). This process generated distinct feature classes for each threshold (e.g., $\geq 500\text{m}$ FAL, $\geq 1000\text{m}$ FAL), representing the terrain away from infrastructure.

2.4.3 Quantification

The total area of each FAL polygon was calculated using the ArcGIS Pro Calculate Geometry Attributes tool. These results were aggregated by the reclassified land cover types as in Fig. 3 and the 23 analytical regions (Fig. 1). The percentage of land constituting a FAL was derived by comparing these values against the total terrestrial land area of Sweden.

2.4.3.1 Quantitative Analysis

To standardize the results and facilitate comparisons across different buffer thresholds, the relative extent of Far Away Landscapes was calculated as a proportion of the total national land base. The percentage of terrestrial Sweden classified as FAL for each distance category P_{FAL} was derived using Equation 1:

$$P_{FAL} = \left(\frac{A_{FAL}}{A_{Terra}} \right) * 100$$

Where:

- P_{FAL} : The percentage of terrestrial land qualifying as a Far Away Landscape at a specific buffer threshold (e.g., ≥ 500 m).
- A_{FAL} : The total summed area (ha) of the FAL polygons remaining after the spatial erase operation, or the area that remains after the buffered infrastructure is removed.
- A_{Terra} : The total land area of Sweden (ha), excluding marine waters.

This calculation was performed for each of the three defined remoteness thresholds ($\geq 500\text{m}$, $\geq 1000\text{m}$, and $\geq 2000\text{m}$) to generate the national distribution statistics reported in the results.

2.5 Comparative Analysis and Case Studies

Next, to understand what kinds of environments actually comprise these remote areas, the FALs were broken down into the five main land-cover categories

(Forest, Open Wetland, Arable Land, Other Open Land, and Inland Water). This was done by a "funnel analysis" that tracked how the different land covers contributed step-wise to the FALs.

To explore how remoteness varies across the country, the four "mountainous" counties (Norrbotten West, Västerbotten West, Jämtland, and Dalarna) were compared directly against the remaining "non-mountainous" counties. Finally, the study includes two specific regional case studies; Norrbotten County, where extended buffers (up to 16 km) were applied to test extreme remoteness in the alpine interior, and Kalmar County, to examine how isolated patches manage to persist in the developed southern Sweden.

3. Results

3.1 Distribution and Land-Cover Composition of FALs

The FAL analysis reveals a clear pattern as the required distance from human infrastructure increased (Fig. 6). At the minimum distance of $\geq 500\text{m}$, 26.8% of Sweden's terrestrial area qualifies as FAL; equal to approximately one third of the surface. When the distance is extended to $\geq 1000\text{m}$, the proportion of FAL drops to 15.4%, whereas at $\geq 2000\text{m}$ only 6.8% of Sweden's terrestrial area remains. The total FAL-area decreases by 75% between the $\geq 500\text{m}$ and $\geq 2000\text{m}$ distance thresholds (Fig. 6). Across all evaluated distances, the mountain region contains the highest concentration of remaining FAL-area.

Table 2: Far Away Landscapes (FALs) Values per County Across Three Distance Thresholds, Percentage

| ID | County | $\geq 500\text{m}$ FAL | $\geq 1000\text{m}$ FAL | $\geq 2000\text{m}$ FAL |
|----|------------------|------------------------|-------------------------|-------------------------|
| 1 | Norrbottn west | 79.8 | 67.1 | 51.3 |
| 2 | Norrbottn east | 33.1 | 9.1 | 0.9 |
| 3 | Västerbottn west | 63.0 | 44.4 | 28.1 |
| 4 | Västerbottn east | 17.5 | 1.8 | 0 |
| 5 | Jämtland | 41.9 | 25.9 | 14.9 |
| 6 | Västernorrland | 13.5 | 0.8 | 0 |
| 7 | Gävleborg | 8.8 | 0.7 | 0.1 |
| 8 | Dalarna | 22.3 | 8.3 | 3.1 |
| 9 | Värmland | 12.1 | 1.2 | 0 |
| 10 | Uppsala | 5.0 | 0.3 | 0 |
| 11 | Stockholm | 4.0 | 0.2 | |
| 12 | Västmanland | 6.1 | 0.6 | 0 |
| 13 | Örebro | 6.4 | 0.6 | 0.1 |
| 14 | Södermanland | 4.2 | 0.3 | |
| 15 | Västra Götaland | 5.0 | 0.8 | 0.2 |
| 16 | Östergötland | 4.7 | 1.1 | 0.2 |
| 17 | Jönköping | 3.7 | 0.6 | 0.0 |
| 18 | Kalmar | 3.8 | 1.1 | 0.3 |
| 19 | Gotland | 9.4 | 0.7 | |
| 20 | Halland | 2.0 | 0.2 | |
| 21 | Kronoberg | 4.8 | 1.1 | 0.1 |
| 22 | Blekinge | 0.4 | | |
| 23 | Skåne | 1.7 | 0.3 | 0 |

Note: The value 0 (zero) shows presence $<0.1\%$. No value shows no presence

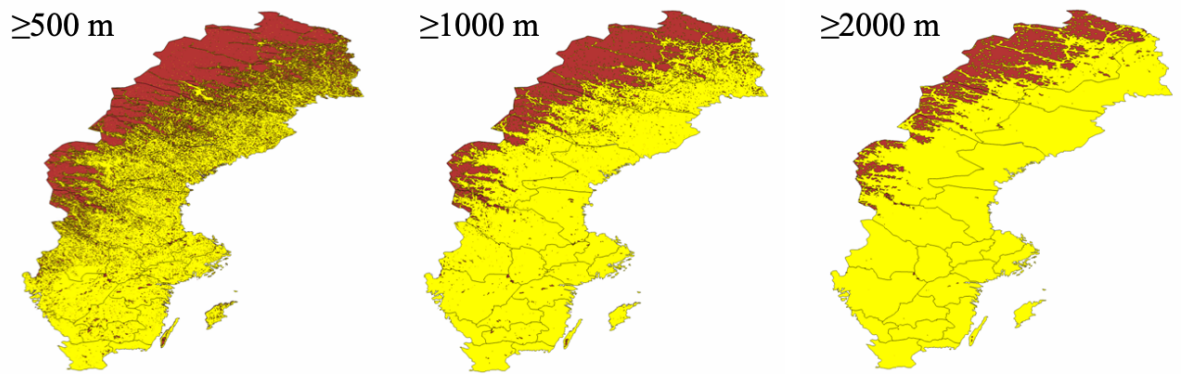


Figure 6: Sweden's Far Away Landscapes (FALs; red color) mapped using three distance-from-artificial surfaces (≥ 500 m FAL (left), ≥ 1000 m FAL (middle), and ≥ 2000 m FAL (right)).

The ≥ 500 m distance shows relatively dispersed FAL across much of northern and central Sweden, whereas the ≥ 2000 m distance reveals FAL almost exclusively confined to the northern counties of Norrbotten, Västerbotten, and Jämtland. FAL beyond ≥ 2000 m from infrastructure is close to absent in central and south Sweden.

While FALs contain a diverse mix of land-cover types, the most remote regions are heavily dominated by Other Open Land (Fig. 7). This reflects the high persistence of alpine meadows, heaths, and bare mountain terrain located above the tree line.

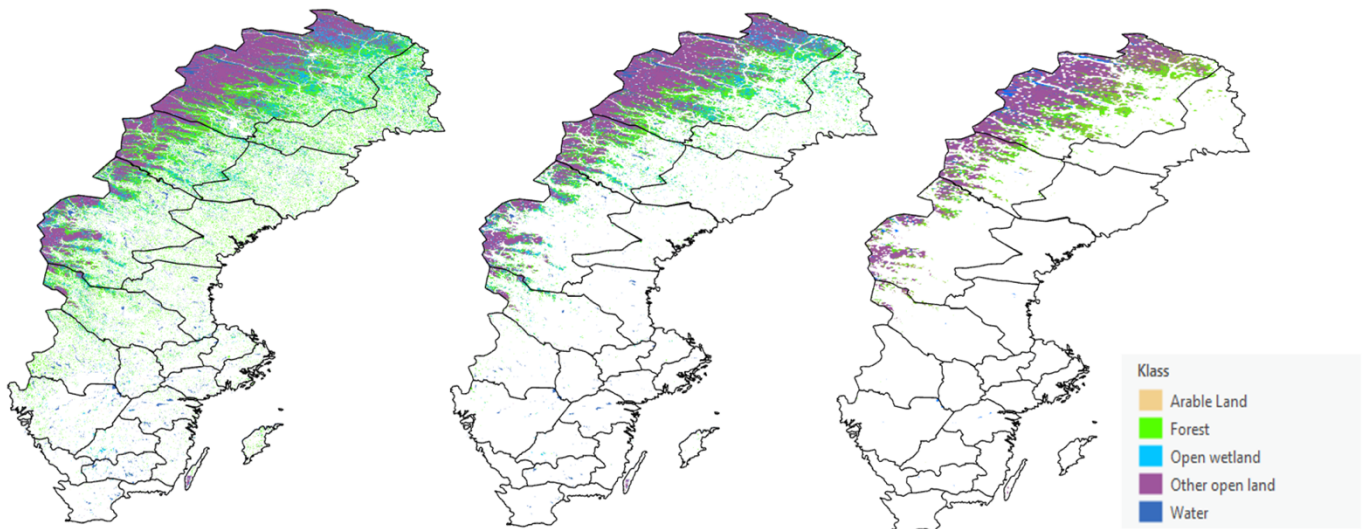


Figure 7: Geographic distribution of the Far Away Landscapes, by land-cover types, across different distances from artificial surfaces: (left) ≥ 500 m distance size, (center) ≥ 1000 m distance size, and (right) ≥ 2000 m distance size. Colors represent different land cover types: green (Forest), cyan (Open Wetland), yellow (Arable land), purple (Other Open land), and blue (Inland Water). Regional boundaries are overlaid in black.

The area of the Other Open Land FAL land-cover type declines progressively with increasing distance (Appendix Table A2-A4). At the national level, the total inventory of remote terrain contracts from 13.3 million ha at the initial $\geq 500\text{m}$ threshold, to 8.1 million ha at $\geq 1000\text{m}$, leaving a final remnant of just 5.3 million ha at the strictest $\geq 2000\text{m}$ distance (Fig 7).

Figure 8 below visualizes the progressive reduction in FAL area as the distance from infrastructure increases, with areas grouped into Forest, Open Wetland, other Open Land, and Water; from broad and expansive at $\geq 500\text{m}$, narrowing substantially at $\geq 1000\text{m}$, and tapering to a small remnant at $\geq 2000\text{m}$ (Appendix Table A5). At the initial $\geq 500\text{m}$ distance, Forest Land represents the largest component at 40.4% (5.41 million ha), followed by other Open Land at 33.4% (4.4 million ha), with Open Wetland and Water accounting for 15.9% and 10.1% respectively. In the $\geq 1000\text{m}$ distance, a compositional shift takes place; the share of forest FAL drops to 27% (2.2 million ha), while other open land becomes the dominant category, rising to a 50.2% share (4.1 million ha). At the largest $\geq 2000\text{m}$ distance, Other Open Land, dominated by alpine meadows and bare rock, becomes the main component at 62.6% (3.3 million ha), while the share of forest land decreases to 18.9% (1 million ha), i.e. a 81% reduction compared with in the $\geq 500\text{m}$ distance. The remainder of this remote zones consists entirely of Open Wetland (12.4%) and Inland Water (6.1%), with Arable Land completely absent (0%).



Figure 8: Change in the Far Away Landscape (FAL) area across major land-cover types at three distance thresholds ($\geq 500\text{m}$, $\geq 1000\text{m}$, and $\geq 2000\text{m}$) from the Artificial Surfaces. Arable land occurs only as 20,195 ha in the $\geq 500\text{m}$ distance.

The stacked bar chart (Fig. 9) reveals substantial regional variation in both the total coverage and the land-cover composition of the FALs across Sweden at different distance thresholds. At the initial $\geq 500\text{m}$ (Fig. 9 (a)), Northern counties demonstrate the highest overall FAL coverage, with Norrbotten West leading at 79% of the region area, followed by Västerbotten West (63%) and Jämtland (42%). When looking at these interior counties, the remote areas are mostly made up of Open Land (38.9% of the region area) and Forest Land (22.6%).

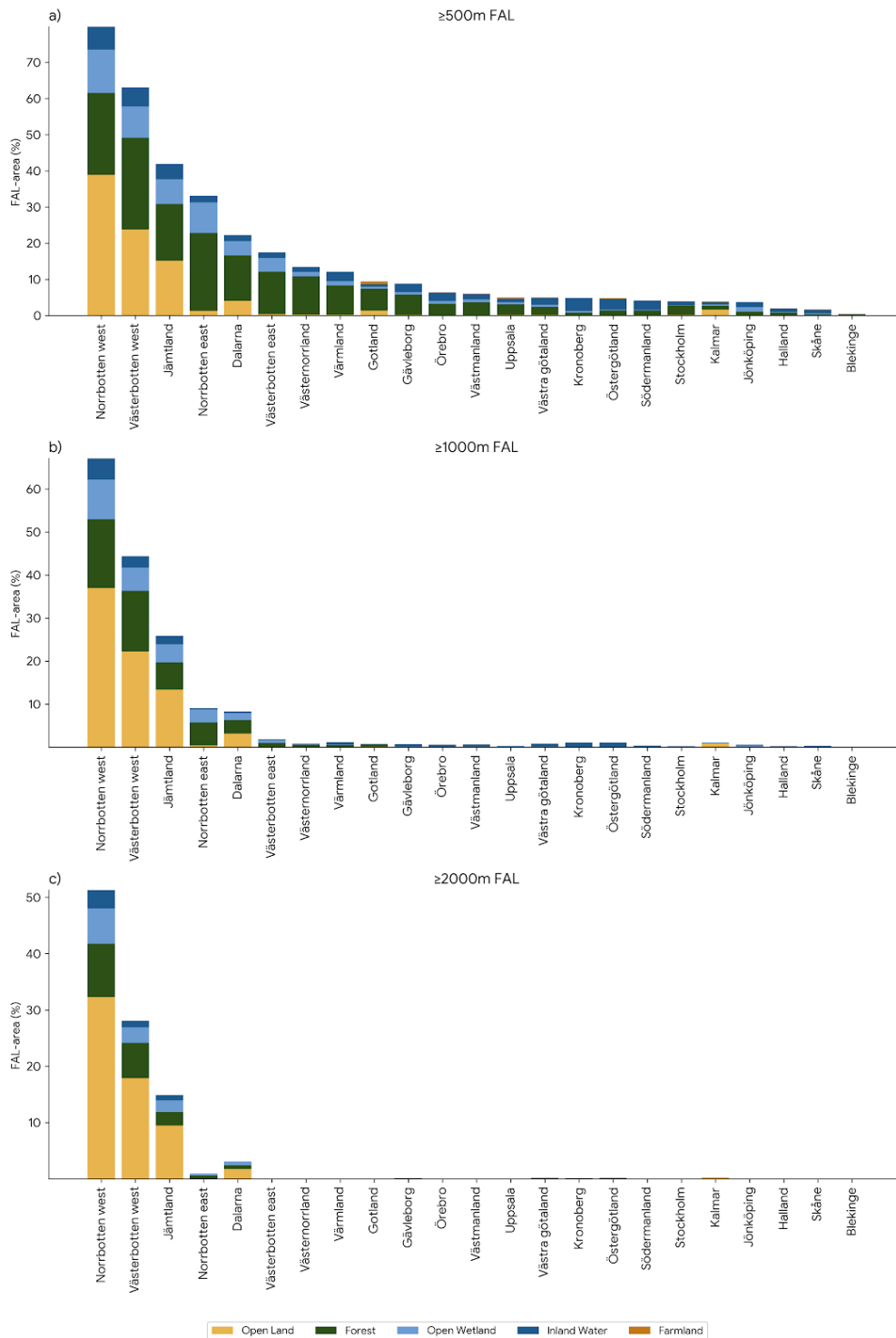


Figure 9: Land cover type composition of the Far Away Landscapes (FAL) at $\geq 500m$ (a), $\geq 1000m$ (b) and $\geq 2000m$ (c) distance from Artificial Surfaces, expressed as percentage of total region area.

In contrast, the coastal eastern counties have a different land-cover compositional mix. Norrbotten East has much lower total FAL coverage (33.1%), and its remote land mostly consists of Forest Land (21.5%) and Open Wetland (8.4%), with

Open Land making up only 1.3%. A similar difference is visible between Västerbotten West, where Forest and Other Open Land are the main land covers, and Västerbotten East, where the remaining FALs is mostly limited to Forest Land and Open Wetland.

Southern and central counties have much less FAL coverage and almost no Open Land. Counties such as Blekinge (0.43%), Skåne (1.69%), and Halland (1.95%) have very few FAL's left. Within these small remaining areas in the south, Forest Land and Inland Water are the primary surviving land covers. Additionally, Kalmar County stands out as a notable outlier in southern Sweden, retaining 3.8% FAL coverage substantially higher than neighboring southern counties and comparable to mid-Sweden counties such as Jönköping (3.7%) and Stockholm (3.9%).

At $\geq 1000\text{m}$ FAL (Fig. 9 (b)), the densely populated Mälardalen region (including Stockholm, Södermanland, and Västmanland) and southernmost counties show almost no remote terrain remaining beyond $\geq 1000\text{m}$, with Blekinge dropping to exactly 0ha. As distance increases to $\geq 2000\text{m}$ threshold (Fig. 9 (c)), FALs sustained primarily by Other Open Land, while its remote Forest Land drops to just 9.5%. Conversely, the coastal Norrbotten East region collapses to less than 1% FAL coverage at this distance. In southern Sweden, Kalmar County continues to act as a unique outlier by preserving a core of 3,114 ha at $\geq 2000\text{m}$; however, its forest cover collapses to a mere 19 ha, leaving Other Open Land (the alvar heaths) as the primary surviving remote landscape.

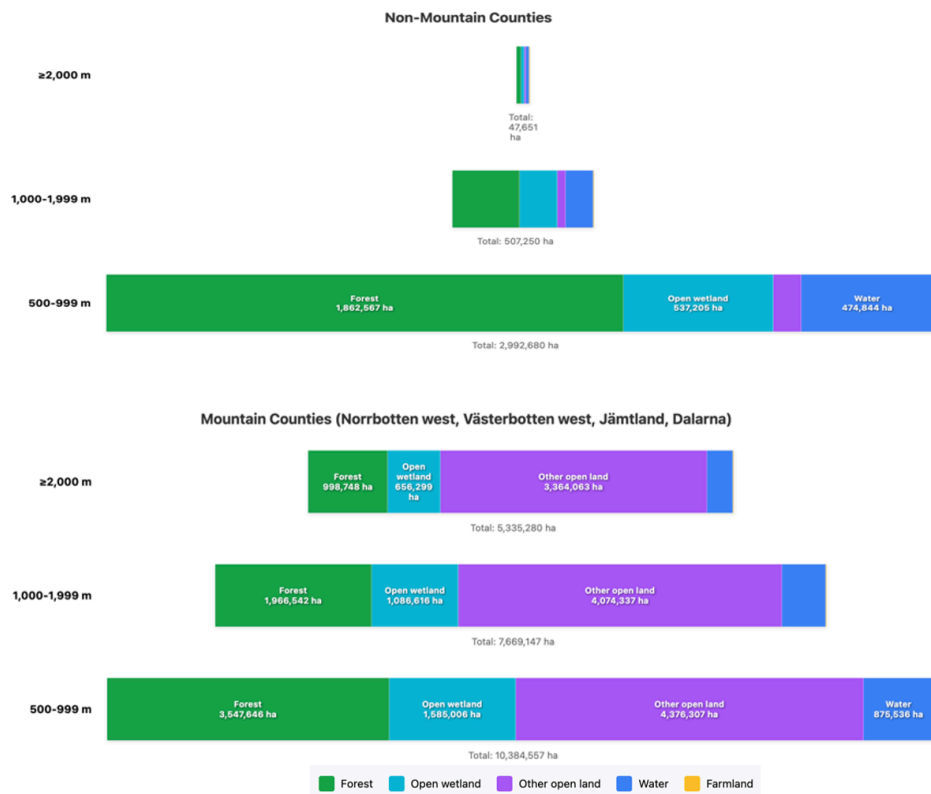


Figure 10: Comparative Funnel Analysis of Far Away Landscapes (FAL) between Mountainous vs. Non-Mountainous Counties.

Figure 10 compares the spatial decline of landscape integrity across Sweden's major geographic divisions. Away from the mountainous region, i.e. Norrbotten west, Västerbotten west, Dalarna and Jämtland, FAL represents only 3 million ha (≥ 500 m distance), representing just 22% of the national FAL area. Within these regions, forest land is the dominant cover type, accounting for 1.9 million ha (62%), followed by Open Wetland (0.5 million ha, 17.9%) and Inland Water (0.4 million ha, 15.9%). As the distance increases (≥ 1000 m), it shrinks to just 0.5 million ha (6.2% of the national FAL inventory). Forest Land remains the largest regional component but drops substantially to 0.2 million ha (48.3%), followed by Open Wetland at 0.1 million ha (26.9%). At the ≥ 2000 m, only 47,400 ha remains, less than 0.9% of Sweden's total deep remoteness. Even within this tiny remnant, Forest Land maintains a relative dominance with a 39.7% share (18,800 ha), followed by Open Wetland at 26.7% (12,700 ha).

However, the mountainous counties specifically Norrbotten West, Västerbotten West, Jämtland, and Dalarna contain 77.6% of Sweden's total FAL area (10.4 million of 13.4 million ha) at the ≥ 500 m distance, land-cover is dominated by Open Land (alpine/tundra), which constitutes 4.4 million ha (42%) of the total

area at the $\geq 500\text{m}$ FAL, while Forest land comprises 34%, and Open Wetland at 15.3%. At $\geq 1000\text{m}$ threshold the pattern changes, they retain 7.6 million ha (93.8%) of the national FAL inventory, the share of Forest Land drops to 25.6% (1.9 million ha), while Open Land exhibits remarkable stability, rising to represent 53.1% (4 million ha), with Open Wetland accounting for 14.2% (1.09 million ha).

While forested FAL area declines across the gradient, the stability of the alpine environments allows these mountainous counties to retain 5.34 million ha at $\geq 2000\text{m}$ distance. This accounts for 97.1% of the entire national land base. At this terminal stage, the ecological core of the mountains is heavily concentrated in Open Land at 63.0% (3.3 million ha), whereas Forest Land collapses to just 18.7% (1 million ha) and Open Wetland constitutes 12.3% (0.6 million ha).

3.2 Case Study Norrbotten County

Norrbotten was selected for detailed analysis because it serves as the core region for FALs; this single region accounts for 62% ($\geq 500\text{m}$) to 68% ($\geq 2,000\text{m}$) of the entire national FAL area.

The land-cover composition of FALs in Norrbotten undergoes a clear shift as the distance increases. To provide a reference point for this shift, the total National Land Cover (NMD) composition was included in the visual analysis (Fig. 11), representing the regional baseline before any Artificial Surface is subtracted. Comparing this baseline against the nested FAL thresholds highlights the proportional decline of each land cover type.

At the $\geq 500\text{m}$ distance, the landscape is a heterogeneous mix of Other Open Land (2.7 million ha) and Forest (1.6 million ha). However, as the distance increases to $\geq 2000\text{m}$, forest area drops precipitously to 0.6 million ha, while Open Land remains comparatively stable at 2.3 million ha. This disparity illustrates that the deepest remoteness in the Swedish landscape is found above the tree line in alpine environments (Appendix Table A6)

Norrbotten West (Fig. 11), retains substantially larger and more contiguous FALs, with 79% of the land remaining at $\geq 500\text{m}$ and over 51% still present at $\geq 2000\text{m}$. Increasing remoteness is associated with a pronounced decline in forest cover, particularly in Norrbotten West, where forest decreases from approximately 22% at $\geq 500\text{m}$ to 9% at $\geq 2000\text{m}$. In contrast, in Norrbotten East, FAL area declines rapidly with increasing distance, from 33% of the region area at $\geq 500\text{m}$ to less than 1% at $\geq 2000\text{m}$ (Fig. 11).

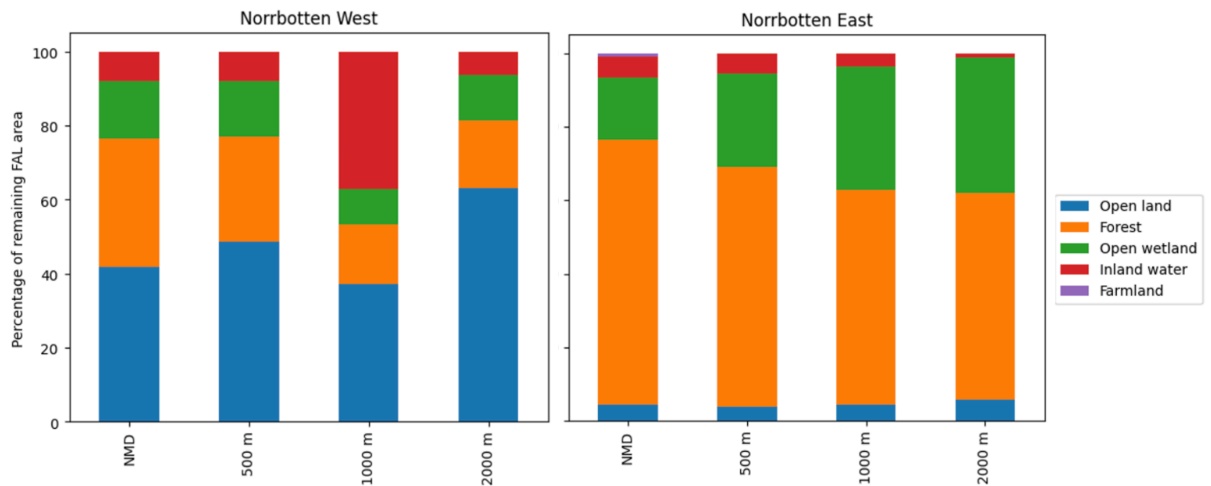


Figure 11: Land-cover composition of Far Away Landscapes (FALs) in Norrbotten West (interior/alpine) and Norrbotten East (coastal) across increasing distances from artificial surfaces (NMD, $\geq 500m$ FAL, $\geq 1000m$ FAL, and $\geq 2000m$ FAL). Values are expressed as percentages of the total remaining FAL area within each distance from Artificial Surfaces.

The multi-panel visualization below (Fig. 12) highlights Norrbotten West as Sweden's primary FAL-region, showing how structural remoteness persists as across FAL-distances. Panel (A) shows the $\geq 500m$ zone of influence emanating from artificial surfaces, which covers approximately 20%. Panel (B) represents the $\geq 2000m$ zone of influence, revealing that the infrastructure in the northern interior is largely restricted to specific corridors rather than broad-scale saturation. Panel (C) displays the resulting nested FAL remnants across three distances, yellow ($\geq 500m$), orange ($\geq 1000m$), and red ($\geq 2000m$) demonstrating that the interior zones remain largely contiguous and connected. Finally, panel (D) stratifies the land-cover composition of these remote areas at $\geq 500m$, showing a shift in dominance as distance increases.

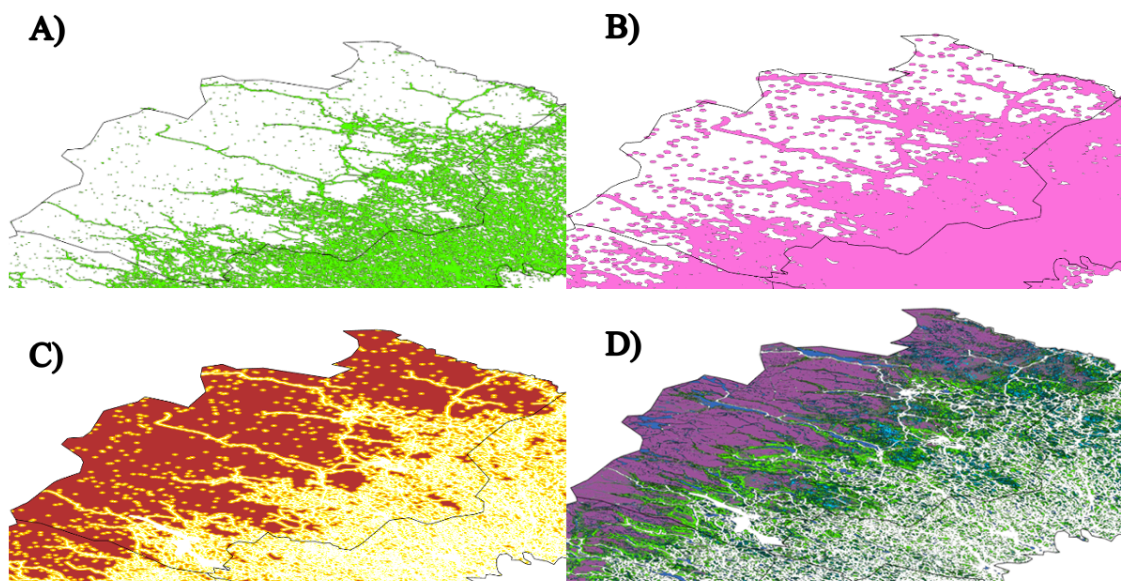


Figure 12: Multi-Scale delineation and persistence of the northern interior (Norrbotten West) A) $\geq 500\text{m}$ distance size from Artificial Surface, B) $\geq 2000\text{m}$ distance size from Artificial Surface, C) resulting FAL remnants categorized by progressive distance thresholds, yellow ($\geq 500\text{m}$), orange ($\geq 1000\text{m}$), and red ($\geq 2000\text{m}$), D) land cover type stratification of the FAL at $\geq 500\text{m}$ aggregated into main classes: Forest (green), Open Wetland (cyan), Arable Land (yellow <1%), Other Open Land (purple), and Water (Navy blue) .

Forest Land is prominent at the initial $\geq 500\text{m}$ distance with 1.6 million ha, it is the Other Open Land (Alpine) category that forms the stable core of Sweden's deep remoteness, retaining 2.3 million ha even at $\geq 2000\text{m}$ threshold. This sequence provides a spatial baseline for understanding the Scandinavian Mountains Green Belt as a finite ecological resource where distance itself serves as a primary conservation value.

3.3 Case Study: Kalmar County

Kalmar County stands out in southern Sweden. While the majority of southern and central counties, such as Blekinge, Skåne, and Stockholm, exhibit negligible amounts of FALs beyond the $\geq 500\text{m}$ distance, Kalmar retains a substantial 42,391 ha ($\geq 500\text{m}$; equal to 3.8% of the county terrestrial area), 11,927 ha (1.1% at $\geq 1000\text{m}$), and 3,114 ha (0.3% at $\geq 2000\text{m}$) of land free from immediate anthropogenic influence. (Appendix Table A7).

In Kalmar County (Fig. 13) at the $\geq 500\text{m}$ distance, the landscape is ecologically diverse, comprising 17,636 ha of Open Land and 11,728 ha of Forest Land. However, at $\geq 2000\text{m}$, Forest Land area decreases substantially to 19 ha, while Other Open Land remains the primary contributor with 2,767 ha. This highlights that even in the southern Swedish context, the deepest remaining remoteness is

not found within the forest matrix, which is heavily bisected by infrastructure but is instead concentrated in open environments. In Kalmar County, they are associated with the grassland-dominated alvar heaths on the island of Öland and maintained open by cattle grazing and protected as a UNESCO World Heritage site.

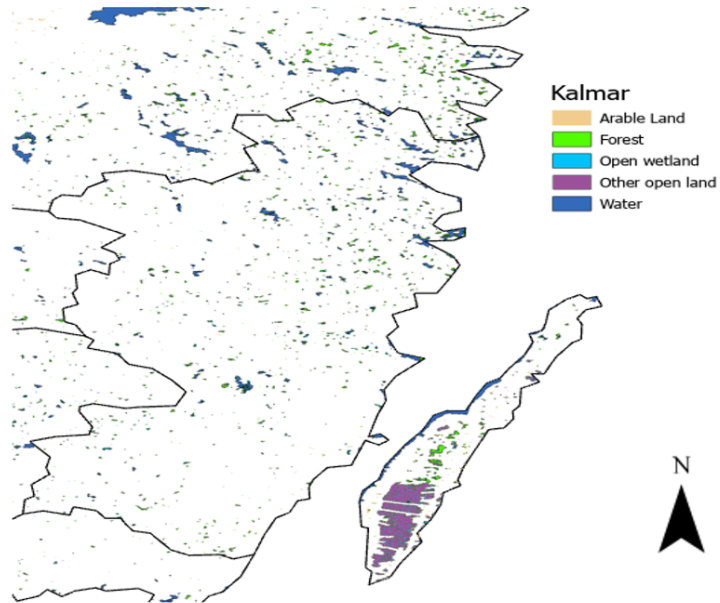


Figure 13: Land cover type composition of the Far Away Landscapes (FAL) in Kalmar County at $\geq 500\text{m}$ distance from artificial surfaces.

4. Discussion

This results maps the current distribution of remote areas across Sweden's terrestrial surface. The results show a clear pattern, indicating how rapidly remote areas disappear as the distance from infrastructure increases, with the total FAL area drops sharply from 26.8% at the $\geq 500\text{m}$ distance to just 6.8% at $\geq 2000\text{m}$. It also reveals which specific environments actually survive at these distances; while remote Forest Land drops by 77% across the distance thresholds, Other Open Land decreases by only 18%, ultimately comprising 62.6% (3.3 million ha) of the remaining remote terrain at the $\geq 2000\text{m}$ distance.

4.1 The Geographic Distribution

The findings confirms a steep north-south gradient in landscape remoteness. In counties such as Skåne, Blekinge, and the Lake Mälaren Valley region of central-east Sweden, FALs are functionally non-existent. This confirms that in the nemoral and hemi boreal zones, nature exists almost exclusively as small, fragmented patches embedded within a dense matrix of agriculture and infrastructure (Nilsson & Götmark 1992; Orlikowska et al. 2020). The one exception in the south is Kalmar County. Kalmar retains over 3,100 ha of remote land at the maximum distance of $\geq 2000\text{m}$. However, this is mainly due to the unique alvar heaths on the island of Öland which are maintained by traditional cattle grazing and protected as a UNESCO World Heritage site (UNESCO 2000). Aside from these specific geomorphological refuges, remoteness in the south is scarce or absent.

However in the north, the results shows that over 97% of the nation's remaining remoteness ($\geq 2000\text{m}$) is concentrated in the northwestern interior, specifically in the Norrbotten West, Jämtland, and Västerbotten West. Norrbotten West region alone contains 5.6 million ha of FALs at the $\geq 500\text{m}$ threshold, an area approximately 294 times larger than the total FAL area of Skåne. This also demonstrates that the Scandinavian Mountains Green Belt (Svensson et al. 2020) is the last remaining contiguous reservoir of remote areas in Sweden.

4.2 Land Cover FAL Distribution

A key finding of this study is how the land-cover type composition of the FALs changes as the remoteness increases. The analysis has shown that Forest Land decreases rapidly, while Other Open Land (alpine and sub-alpine environments) displays higher stability and characterizes the nature at the longest distance from infrastructure.

Between the $\geq 500\text{m}$ and $\geq 2000\text{m}$ thresholds, Forest Land FALs drop by 77%. This severe decline can be interpreted as a result of the well-developed industrial forestry road network. The widespread network of forest roads built since the

1950s has systematically divided the landscape to make timber extraction easier (Svensson et al. 2019; 2020; Ahlström et al. 2022), leaving mostly small remnants of high conservation value forests embedded in a heavily modified matrix (Jongman 2002; Svensson et al. 2019).

This fragmentation is visible when comparing the remaining FALs against the total National Land Cover (NMD) baseline, in Norrbotten West (Fig. 11), total forest cover accounts for 34.6% of the NMD baseline, but this drops to just 9.5% at the $\geq 2000\text{m}$ threshold. Open Wetlands show a 69% decline across the gradient, while Inland Water remains comparatively substantial at $\geq 2000\text{m}$ (327,629 ha) due to the presence of large, remote mountain lakes. Conversely, Arable Land drops from 20,195 ha at the $\geq 500\text{m}$ threshold to 0 ha at $\geq 2000\text{m}$, confirming that agricultural fields in Sweden are almost road-adjacent everywhere. This shows that while Sweden is a heavily forested nation, remote forests defined here as forests located $\geq 2000\text{m}$ from infrastructure are incredibly rare mostly outside the protected mountain foothills landscape (Aksenov et al. 1999; Svensson et al. 2020; Ahlström et al. 2022).

In contrast, the "Other Open Land" category decreased by only 18% across the FAL distance thresholds. This stability shows that Sweden's most remote landscapes are alpine environments. These areas remain remote largely because of their difficult topography, high altitude, and harsh weather which have historically stopped forestry expansion and human settlement (Götmark & Nilsson 1992; Nilsson & Götmark 1992).

4.3 Ecological and Socio-Cultural Significance

The numbers in this study measure distance, not ecological condition. But the two are related. Remote areas, those far from roads, buildings, and railways are more likely to retain intact vegetation structure, lower noise levels, lower chemical inputs, and undisturbed wildlife behaviour (Trombulak & Frissell 2000; Kati et al. 2020). Furthermore, these landscapes hold socio-cultural significance. For the Sámi people, the significance is more direct. Traditional reindeer herding depends on continuous, connected terrain across which animals can migrate seasonally and access lichen-rich winter grazing grounds. The fragmentation documented here particularly the loss of remote forest cover in the boreal zone has a documented negative effect on the accessibility and continuity of these grazing routes (Sandström et al. 2016; Marin 2025).

However, when interpreting the preservation of these values, the mapped FALs represent areas of geographic isolation based on geometric distances from Artificial Surfaces, not absolute boundaries of ecological silence. In reality, actual disturbance footprints such as noise pollution, chemical runoff, or visual intrusion

are highly dynamic (Rayfield et al. 2008). Therefore, while the distance thresholds used in this analysis provide a baseline for quantifying structural intactness across the Swedish land base, they serve as a spatial proxy for remoteness rather than a direct measurement of ecological disturbance limits.

4.4 Methodological Reflections and Limitations

4.4.1 The Limitations of Binary Analysis

The primary methodological limitation in the analysis is treating the influence as a binary spatial metric. The analysis treats the landscape strictly as either influenced (within) or remote (outside). This approach assumes a uniform decay of disturbance on species, including humans, that does not account for the physical reality of how noise, light, pollution, vibrations and visual impacts travels through different terrains and affects different organisms, life cycle stages, traits and seasons, etc.

In reality, the zone of influence is highly variable. This model cannot distinguish between a major European highway carrying thousands of vehicles per day and a low-traffic gravel forestry track both generate the same buffer. This is a known problem with distance-based approaches and likely leads to an overestimate of fragmentation in southern Sweden, where minor roads are ubiquitous, and possibly an underestimate of effective disturbance around large industrial sites in the north (Trombulak & Frissell 2000; Kati et al. 2020).

A related issue is shape. As noted in the literature regarding intact forest landscapes the ecological value of a remote area is heavily dependent on its contiguous size and how much core area it actually contains (Williams et al. 2020; Potapov et al. 2013). The analysis calculates total FAL area but does not assess patch geometry. A long, narrow strip of land between two parallel roads technically qualifies as FAL under the distance rule, but functionally it provides none of the interior habitat conditions that species require. In the northern mountains, where FAL patches are genuinely large and contiguous, this is less of a concern. In the south, where the residual FAL area is small, many of the mapped patches are likely these narrow strips rather than ecologically meaningful cores. Future work using Morphological Spatial Pattern Analysis (MSPA) or similar approaches could filter out these geometrically marginal areas and can give a sharper picture of functionally intact land (Kurt Riitters et al. 2015; Sandström et al. 2016; Svensson et al. 2020).

4.4.2 Data Temporality and the Pace of Industrial Expansion

The analysis is based on the National Land Cover (NMD) Base Map from 2018. While this dataset offers high classification accuracy (94–95% for broad classes), it does not represent the most recent situation.

This time gap is especially important regarding the recent expansion of renewable energy. Since 2018, Sweden has rapidly expanded its wind power capacity, building major new projects across the northern counties (Marin 2025). During the data preparation for this study, a preliminary check showed that simply adding the physical footprint of the wind turbine polygons to the analysis barely changed the total remote area (a difference of only 0.0018%). However, the real threat comes from the new roads and wind turbine foundations built to reach these turbines. Because these new road networks are missing from the 2018 base map (Swedish Energy Agency 2025), and given that wind farms are often placed on high-elevation sites identified here as remote areas, it is highly likely that the true extent of FALs in counties like Norrbotten and Jämtland is smaller today than these results show.

4.4.3 The Definition and Granularity of Infrastructure

In this study, human infrastructure was mapped using the NMD Artificial Surfaces classes (51: Buildings, 52: Non-building/road surfaces, and 53: Roads/railways). While this provides a strong national baseline, however, it lacks the details needed to separate major, high-impact infrastructure from smaller, low-impact features (SEPA 2018).

Because of this, the analysis cannot assign different buffer sizes based on the actual size or use of the infrastructure. A major highway and a small gravel forestry track are treated exactly the same. By treating all artificial surfaces equally, the method may exaggerates the loss of remoteness in southern Sweden (where small roads are everywhere) while potentially underestimating the true zone of influence around massive industrial complexes in the north. For future work weighted buffer approach with more detailed national road dataset would be better.

Furthermore, the 10-meter resolution of the NMD, while high for a national map, can miss narrow, hidden features like older tractor tracks or winter forest roads. If these tracks are covered by tree canopy, the map classifies them as Forest rather than Artificial Surface. As a result, some areas identified here as remote might actually be accessible to off-road vehicles, meaning the total roadless area is likely slightly overestimated as a result.

4.5 Implications for Conservation and Green Infrastructure

The findings of this study provide a clear spatial baseline for national and European Green Infrastructure planning (EC 2020; Svensson et al. 2020). Remote landscapes are now a highly scarce resource. Future conservation requires informed decision-making regarding strict land-use trade-offs.

1. The concentration of FALs in the northern mountains confirms the critical importance of the Scandinavian Mountains Green Belt (Svensson et al. 2020). As these are the only remaining reservoirs of large-scale remoteness, their protection is essential for maintaining resilience against climate change and supporting range shifts for biodiversity.
2. Because remoteness is functionally extinct in the south and shrinking in the north, managing the remaining FALs requires strict land-use planning. Theoretical frameworks like land sparing (setting aside intact areas) and land sharing (integrating conservation into land use) can help guide choices on the continued exploitation of FALs (Fischer et al. 2014).
3. Industrial expansion, particularly wind power, frequently targets remote landscapes to avoid social disturbance. While building in FALs offers the path of least social resistance, it directly threatens undisturbed landscapes, disrupts indigenous Sámi reindeer husbandry, and risks permanently fragmenting the last intact boreal networks (Marin 2025). Decision-makers must openly weigh the trade-off between low immediate social impact and the irreversible loss of ecological integrity.
4. To effectively secure ecological continuity across regions, spatial conservation policies must be adopted to prevent further fragmentation. A highly efficient approach is the implementation of a national or European Roadless Rule to legally protect remaining landscapes from new industrial expansion and infrastructure development (Kati et al. 2020). The FAL-approach taken here further develops this mapping opportunity.
5. The value of remoteness ultimately relies on how species, including humans, respond to the multiple aspects and qualities associated with remoteness. The FAL-approach offers a first-step in mapping, to be further specified by target-specific adjustment to focal species or other matters of concern in sustainable landscape planning.

5. Conclusions

This thesis examined the distribution and land cover composition of Far Away Landscapes (FALs) in Sweden to establish a quantitative baseline of landscape remoteness. Using multi-scale geospatial distance analyses of National Land Cover (NMD) data at nested thresholds ($\geq 500\text{m}$, $\geq 1000\text{m}$, and $\geq 2000\text{m}$) from Artificial Surfaces, the study isolated and quantified the remaining remote terrain. The results reveal severe structural fragmentation, Sweden's remote areas are highly scattered and strongly influenced by human infrastructure. Specifically, the results shows a sharp decline where the proportion of remote terrestrial land changes from 26.8% at $\geq 500\text{m}$ to just 6.8% at $\geq 2000\text{m}$. Furthermore, the analysis found that structural remoteness has practically vanished in southern and central Sweden, leaving the northwestern interior to host over 97% of the nation's remaining remoteness. In terms of land cover, the dense network of forestry roads has bisected the boreal forest, causing remote forest area to drop by 77% across the distance gradient and effectively shifting Sweden's last isolated places out of the productive woods and into the high-altitude alpine tundra. This thesis recommends treating spatial distance from infrastructure as a finite, measurable resource, and calls for spatial models that assess the functional connectivity of remaining FAL patches. These steps can offer a clear spatial baseline to improve green infrastructure planning and secure the ecological continuity of Sweden's remaining intact environments.

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Popular Science Summary

Human population is growing at a alarming rate of 0.9% per year and it is projected to reach 10 billion by the year 2050. With increasing population, the pressure on the natural resources increases day by day and the concept of conservation have to be reconsidered.

When I look out over the Swedish landscape, it is easy to be misled by the endless sea of green and assume we are surrounded by an infinite wilderness. However, my research into what I call "Far Away Landscapes" (FALs) has shown me that the remote areas are actually a fragile, disappearing resource. I wanted to see how much of our land is truly distant from the "artificial surfaces" of roads, buildings, and railways that signal a human footprint and what we define "natural landscape", is it really natural or not.

By layering nested buffers of 500m, 1000m, and 2000m across high-resolution national maps, I discovered a pattern, while about 27% of Sweden is at least a five-minute walk from a road, that number collapses to a tiny 6.8% when you look for a spot just two kilometers away from people. This revealed a country deeply divided and in the industrialized south and along the coasts, remoteness has almost entirely vanished, leaving the rugged northern interior as the last reservoir for 97% of Sweden's remaining large-scale remote region.

What truly surprised me was what I now think of as the forestry paradox, the fact that being a forest-rich nation does not mean to actually have remote forests. Because our modern industrial model relies on a dense pattern of gravel roads used to harvest timber, our deep forests have been bisected into smaller and smaller fragments, losing 77% of their remote core area in the process. This has pushed the heart of Sweden's wild out of the trees and up into the rocky alpine tundra where roads simply cannot be build. This isn't just a loss of quiet for hikers, it is directly effecting the Sámi people too, whose reindeer rely on these connected, silent paths for their ancestral migrations. As we rush to build wind farms in these last quiet corners to power our "green transition," my work shows that we are consuming a finite, non-renewable resource that we can never truly replace.

I hope my findings help us realize that if we want to save the integrity of our natural world, this is bigger than Sweden and we need to start valuing the distance between us and start with the better ways to estimate the remoteness and conservation. With my work I contributed a tiny part to this big endeavor.

Appendix.

Table A1: Value, Class Name and Definition for NMD Base Map (SEPA 2018).

| Value | Class | Definition |
|--------------|--|---|
| 123 | Mixed coniferous on wetland | Tree-covered areas on wetlands with a total crown cover of >10% where >70% of consists of pine or spruce, but none of these species are >70%. Trees are higher than 5 meters. |
| 124 | Mixed forest on wetland | Tree-covered areas on wetlands with a total crown cover of >10% where neither coniferous nor deciduous crown cover reaches >70%. Trees are higher than 5 meters. |
| 125 | Deciduous forest on wetland | Tree-covered areas on wetlands with a total crown cover of >10% where >70% of the crown cover consists of deciduous trees (primarily birch, alder and/or aspen). Trees are higher than 5 meters. |
| 126 | Deciduous hardwood forest on wetland | Tree-covered areas on wetlands with a total crown cover of >10 where >70% of the crown cover consists of deciduous trees, of which >50% is broad-leaved deciduous forest (mainly oak, beech, ash, elm, linden, maple, cherry and hornbeam). Trees are higher than 5 meters. |
| 127 | Deciduous forest with deciduous hardwood forest on wetland | Tree-covered areas on wetlands with a total crown cover of >10 where >70% of the crown cover consists of deciduous trees, of which 20 - 50% is broad-leaved deciduous forest (mainly oak, beech, ash, elm, linden, maple, cherry and hornbeam). Trees are higher than 5 meters. |
| 128 | Temporarily non-forest on wetland | Open and re-growing clear-felled, storm-felled or burnt areas on wetlands. Trees are less than 5 meters. |
| 2 | Open wetland | Open land where the water for a large part of the year is close by, in or just above the ground surface. |
| 3 | Arable land | Agricultural land used for plant cultivation or kept in such a condition that it can be used for plant cultivation. The land should be able to be used without any special preparatory action other than the use of conventional farming methods and agricultural machinery. The soil can be used for plant cultivation every year. Exceptions can be made for an individual year if special circumstances exist. |
| 41 | Non-vegetated other open land | Other open land that is not wetland, arable land or exploited vegetation-free surfaces and has less than 10% vegetation coverage during the current vegetation period. The ground can be covered by moss and lichen. |
| 42 | Vegetated other open land | Other open land that is not wetland, arable land or exploited vegetation-free surfaces and has more than 10% vegetation coverage during the current vegetation period. |
| 51 | Artificial surfaces, building | A durable construction consisting of roofs or roofs and walls and which is permanently placed on the ground or partly or wholly below ground or is permanently placed in a certain place in water and is intended to be designed so that people can stay in it. |
| 52 | Artificial surfaces, not building or road/railway | Artificial open and vegetation-free surfaces that are not building or road/railway. |
| 53 | Artificial surfaces, road/railway | Road or railway. |
| 61 | Inland water | Lakes or water-courses. |
| 62 | Marine water | Sea, ocean, estuaries or coastal lagoons. |
| 0 | Outside mapping area | Outside the borders of Sweden and the Exclusive Economic (EEZ) Zone |

Table A2: Far Away Landscape area $\geq 500m$ distance from artificial surface, hectare

| Id | County | Open land | Forest land | Open wetland | Inland water | Farm land | Total land cover |
|------------------|-------------------|------------------|--------------------|---------------------|---------------------|------------------|-------------------------|
| 1 | Norrboten west | 2,770,526 | 1,614,481 | 854,143 | 450,922 | 1 | 5,690,072 |
| 2 | Norrboten east | 42,791 | 726,336 | 284,801 | 60,217 | 77 | 1,114,222 |
| 3 | Västerbotten west | 665,186 | 706,519 | 243,257 | 144,894 | 2 | 1,759,857 |
| 4 | Västerbotten east | 11,406 | 364,596 | 116,360 | 48,719 | 240 | 541,322 |
| 5 | Jämtland | 816,492 | 849,033 | 367,859 | 227,812 | 23 | 2,261,218 |
| 6 | Västernorrland | 6,635 | 241,791 | 26,310 | 33,189 | 39 | 307,965 |
| 7 | Gävleborg | 1,914 | 109,771 | 14,738 | 45,196 | 44 | 171,663 |
| 8 | Dalarna | 124,103 | 377,613 | 119,567 | 51,908 | 36 | 673,227 |
| 9 | Värmland | 3,995 | 179,924 | 26,926 | 57,331 | 749 | 268,926 |
| 10 | Uppsala | 770 | 20,658 | 4,357 | 6,873 | 2,321 | 34,979 |
| 11 | Stockholm | 866 | 15,783 | 743 | 6,927 | 723 | 25,042 |
| 12 | Västmanland | 559 | 25,274 | 5,395 | 10,035 | 1,431 | 42,693 |
| 13 | Örebro | 617 | 31,172 | 7,643 | 22,811 | 1,020 | 63,264 |
| 14 | Södermanland | 412 | 9,304 | 1,174 | 17,408 | 807 | 29,106 |
| 15 | Västra Götaland | 3,135 | 66,614 | 17,676 | 55,539 | 3,257 | 146,220 |
| 16 | Östergötland | 956 | 15,627 | 2,678 | 35,229 | 2,101 | 56,592 |
| 17 | Jönköping | 288 | 11,125 | 14,526 | 15,680 | 163 | 41,782 |
| 18 | Kalmar | 17,636 | 11,728 | 3,627 | 7,420 | 1,979 | 42,391 |
| 19 | Gotland | 4,135 | 18,832 | 1,599 | 2,016 | 2,599 | 29,181 |
| 20 | Halland | 504 | 4,189 | 1,252 | 5,226 | 357 | 11,527 |
| 21 | Kronoberg | 214 | 6,819 | 4,499 | 33,677 | 145 | 45,353 |
| 22 | Bleking | 69 | 705 | 80 | 194 | 245 | 1,294 |
| 23 | Skåne | 1,027 | 2,320 | 2,999 | 11,157 | 1,836 | 19,339 |
| Total land cover | | 4,474,238 | 5,410,213 | 2,122,211 | 1,350,380 | 20,195 | 13,377,237 |

Note: The value 0 (zero) shows presence < 0.5 ha. No value shows no presence

Table A3: Far Away Landscape area $\geq 1000m$ distance from artificial surface, hectare

| Id | County | Open land | Forest land | Open wetland | Inland water | Farmland | Total land cover |
|------------------|------------------|------------------|--------------------|---------------------|---------------------|-----------------|-------------------------|
| 1 | Norrboten west | 2,635,507 | 1,139,058 | 659,117 | 348,906 | | 4,782,589 |
| 2 | Norrboten east | 13,788 | 178,451 | 102,255 | 10,918 | | 305,413 |
| 3 | Västerboten west | 621,432 | 392,622 | 151,530 | 73,872 | | 1,239,456 |
| 4 | Västerboten east | 1,582 | 30,167 | 18,232 | 5,735 | | 55,716 |
| 5 | Jämtland | 722,056 | 340,963 | 225,866 | 107,653 | 0 | 1,396,539 |
| 6 | Västernorrland | 780 | 11,931 | 2,843 | 2,976 | 0 | 18,531 |
| 7 | Gävleborg | 76 | 2,107 | 829 | 10,590 | | 13,602 |
| 8 | Dalarna | 95,342 | 93,857 | 50,103 | 11,221 | | 250,523 |
| 9 | Värmland | 359 | 11,122 | 2,954 | 11,882 | 0 | 26,318 |
| 10 | Uppsala | 15 | 949 | 463 | 737 | 10 | 2,175 |
| 11 | Stockholm | 79 | 410 | 14 | 910 | | 1,412 |
| 12 | Västmanland | 22 | 967 | 438 | 3,053 | 3 | 4,484 |
| 13 | Örebro | 9 | 411 | 420 | 4,688 | | 5,529 |
| 14 | Södermanland | 2 | 34 | 27 | 2,362 | | 2,425 |
| 15 | Västra Götaland | 147 | 5,128 | 2,051 | 16,044 | | 23,371 |
| 16 | Östergötland | 21 | 191 | 380 | 12,265 | 12 | 12,869 |
| 17 | Jönköping | 12 | 679 | 3,410 | 2,508 | 0 | 6,610 |
| 18 | Kalmar | 9,837 | 447 | 1,390 | 166 | 87 | 11,927 |
| 19 | Gotland | 292 | 1,618 | 175 | 207 | 3 | 2,294 |
| 20 | Halland | 39 | 209 | 33 | 912 | | 1,192 |
| 21 | Kronoberg | 21 | 355 | 93 | 9,401 | | 9,870 |
| 22 | Bleking | | | | | | |
| 23 | Skåne | 8 | 63 | 288 | 3,195 | | 3,554 |
| Total land cover | | 4,101,427 | 2,211,740 | 1,222,912 | 640,201 | 117 | 8,176,397 |

Note: The value 0 (zero) shows presence < 0.5 ha. No value shows no presence

Table A4: Far Away Landscape area $\geq 2000m$ distance from artificial surface, hectare

| Id | County | Open land | Forest land | Open wetland | Inland water | Farm land | Total land cover |
|-------------------------|------------------|------------------|--------------------|---------------------|---------------------|------------------|-------------------------|
| 1 | Norrbottn west | 2,302,725 | 673,684 | 447,430 | 231,516 | | 3,655,353 |
| 2 | Norrbottn east | 1,807 | 17,839 | 11,719 | 394 | | 31,759 |
| 3 | Västerbottn west | 498,785 | 175,839 | 77,410 | 32,170 | | 784,205 |
| 4 | Västerbottn east | 120 | 373 | 360 | 13 | | 865 |
| 5 | Jämtland | 509,422 | 129,785 | 113,228 | 50,984 | 0 | 803,420 |
| 6 | Västernorrland | 5 | 104 | 7 | 7 | | 123 |
| 7 | Gävleborg | 0 | 22 | 27 | 1,211 | | 1,261 |
| 8 | Dalarna | 53,131 | 19,440 | 18,259 | 1,702 | | 92,531 |
| 9 | Värmland | 3 | 56 | 2 | 666 | | 726 |
| 10 | Uppsala | | | | 12 | | 12 |
| 11 | Stockholm | | | | | | |
| 12 | Västmanland | 0 | 0 | 0 | 294 | | 294 |
| 13 | Örebro | 0 | 1 | 0 | 542 | | 543 |
| 14 | Södermanland | | | | | | |
| 15 | Västra Götaland | 3 | 379 | 21 | 4,992 | | 5,395 |
| 16 | Östergötland | 0 | | 31 | 2,273 | | 2,304 |
| 17 | Jönköping | 1 | 9 | 153 | | | 162 |
| 18 | Kalmar | 2,767 | 19 | 329 | | | 3,114 |
| 19 | Gotland | | | | | | |
| 20 | Halland | | | | | | |
| 21 | Kronoberg | 0 | 9 | 2 | 801 | | 812 |
| 22 | Bleking | | | | | | |
| 23 | Skåne | | | | 53 | | 53 |
| Total land cover | | 3,368,769 | 1,017,556 | 668,977 | 327,629 | 0 | 5,382,932 |

Note: The value 0 (zero) shows presence <0.5 ha. No value shows no presence

Table A5: Far Away Landscape (FAL) area for Open Land, Forest Land, and Open Wetland at distance from artificial surface, in hectare.

| County | Open Land | | | Forest land | | | Open Wetlands | | |
|-------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|----------------|
| | ≥500m FAL | ≥1000m FAL | ≥2000m FAL | ≥500m FAL | ≥1000m FAL | ≥2000m FAL | ≥500m FAL | ≥1000m FAL | ≥2000m FAL |
| Norrbottn west | 2,770,526 | 2,635,507 | 2,302,725 | 1,614,481 | 1,139,058 | 673,684 | 854,143 | 659,117 | 447,430 |
| Norrbottn east | 42,791 | 13,788 | 1,807 | 726,336 | 178,451 | 17,839 | 284,801 | 102,255 | 11,719 |
| Västerbottn west | 665,186 | 621,432 | 498,785 | 706,519 | 392,622 | 175,839 | 243,257 | 151,530 | 77,410 |
| Västerbottn east | 11,406 | 1,582 | 120 | 364,596 | 30,167 | 373 | 116,360 | 18,232 | 360 |
| Jämtland | 816,492 | 722,056 | 509,422 | 849,033 | 340,963 | 129,785 | 367,859 | 225,866 | 113,228 |
| Västernorrland | 6,635 | 780 | 5 | 241,791 | 11,931 | 104 | 26,310 | 2,843 | 7 |
| Gävleborg | 1,914 | 76 | 0 | 109,771 | 2,107 | 22 | 14,738 | 829 | 27 |
| Dalarna | 124,103 | 95,342 | 53,131 | 377,613 | 93,857 | 19,440 | 119,567 | 50,103 | 18,259 |
| Värmland | 3,995 | 359 | 3 | 179,924 | 11,122 | 56 | 26,926 | 2,954 | 2 |
| Uppsala | 770 | 15 | | 20,658 | 949 | | 4,357 | 463 | |
| Stockholm | 866 | 79 | | 15,783 | 410 | | 743 | 14 | |
| Västmanland | 559 | 22 | 0 | 25,274 | 967 | 0 | 5,395 | 438 | 0 |
| Örebro | 617 | 9 | 0 | 31,172 | 411 | 1 | 7,643 | 420 | 0 |
| Södermanland | 412 | 2 | | 9,304 | 34 | | 1,174 | 27 | |
| Västra götaland | 3,135 | 147 | 3 | 66,614 | 5,128 | 379 | 17,676 | 2,051 | 21 |
| Östergötland | 956 | 21 | 0 | 15,627 | 191 | | 2,678 | 380 | 31 |
| Jönköping | 288 | 12 | 1 | 11,125 | 679 | 9 | 14,526 | 3,410 | 153 |
| Kalmar | 17,636 | 9,837 | 2,767 | 11,728 | 447 | 19 | 3,627 | 1,390 | 329 |
| Gotland | 4,135 | 292 | | 18,832 | 1,618 | | 1,599 | 175 | |
| Halland | 504 | 39 | | 4,189 | 209 | | 1,252 | 33 | |
| Kronoberg | 214 | 21 | 0 | 6,819 | 355 | 9 | 4,499 | 93 | 2 |
| Bleking | 69 | | | 705 | | | 80 | | |
| Skåne | 1,027 | 8 | | 2,320 | 63 | | 2,999 | 288 | |
| Total Land Cover | 4,474,238 | 4,101,427 | 3,368,769 | 5,410,213 | 2,211,740 | 1,017,556 | 2,122,211 | 1,222,912 | 668,977 |

Note: The value 0 (zero) shows presence <0.5 ha. No value shows no presence

Table A6: Comparative percentage of land cover composition for Norrbotten East and West counties across FAL distance thresholds (%)

| Norbotten East | NMD Map | 500m distance | 1000m distance | 2000m distance |
|-----------------------|----------------|----------------------|-----------------------|-----------------------|
| Open land | 4.4 | 1.2 | 0.4 | 0 |
| Forest land | 70.6 | 21.5 | 5.2 | 0.5 |
| Open wetland | 16.4 | 8.4 | 3 | 0.3 |
| Inland water | 5.5 | 1.7 | 0.3 | 0 |
| Farm land | 1 | 0 | | |
| Total land cover | 98.1 | 33 | 9 | 0.9 |
| Norbotten West | NMD Map | 500m distance | 1000m distance | 2000m distance |
| Open land | 41.4 | 38.8 | 36.9 | 32.3 |
| Forest land | 34.6 | 22.6 | 15.9 | 9.4 |
| Open wetland | 15.2 | 11.9 | 9.2 | 6.2 |
| Inland water | 8 | 6.3 | 36.9 | 3.2 |
| Farm land | 0 | | | |
| Total land cover | 99.3 | 79.8 | 99.1 | 51.2 |

Note: The value 0 (zero) shows presence <0.1%. No value shows no presence

Table A7: Distribution of Far Away Landscapes in Kalmar County (ha)

| Buffer Distance | 500m distance | 1000m distance | 2000m distance |
|------------------------|----------------------|-----------------------|-----------------------|
| Open Land | 17,636 | 9,837 | 2,767 |
| Forest | 11,728 | 447 | 19 |
| Open Wetland | 3,627 | 1,390 | 329 |
| Inland Water | 7,420 | 166 | — |
| Farmland | 1,979 | 87 | — |
| Total | 42,391 | 11,927 | 3,114 |

Note: Values of "—" indicate no recorded presence at that threshold.

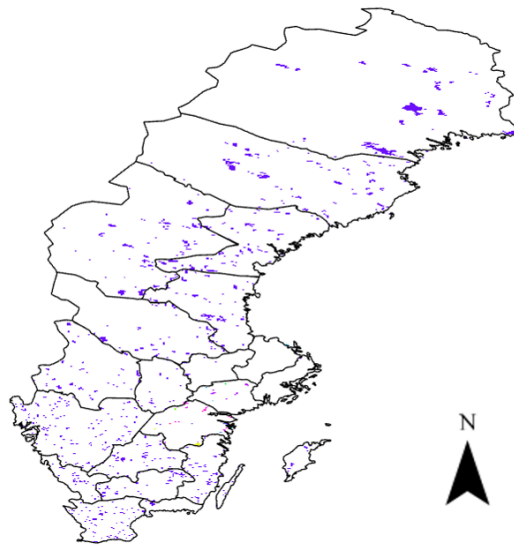


Figure A1: Distribution of Wind Power Infrastructure across Sweden, based on data acquired from the Wind Farm map service (Swedish Energy Agency 2025).

During the preparatory phase, additional datasets regarding renewable energy infrastructure were reviewed to ensure the completeness of the Artificial Surfaces proxy. While the initial research design considered a separate overlay analysis for wind and solar power impacts, a preliminary spatial review determined that these features were already captured within the primary NMD dataset.

Wind Power Data Review: Data on wind power installations, including onshore and offshore turbines, were acquired for validation from the Wind Farm map service (Swedish Energy Agency 2025). The spatial extent of these wind power polygons, as extracted on April 20, 2025, totaled 621,456 ha (approximately 6,214,560,436 m²), representing 1.42% of Sweden's total land area. However, a geometric intersection analysis revealed that these wind power polygons were already present in the NMD Artificial Surfaces layer. Since the primary methodology defines FALs as areas outside the buffer of Artificial Surfaces, these wind energy zones were already effectively excluded from the FAL territory. That's why a separate wind power impact overlay was deemed redundant and was not included in the final analytical workflow.

Solar Power Data Review: A similar approach was used for solar energy infrastructure (Swedish Energy Agency 2025). The reviewed solar panel polygons covered approximately 0.8% of the land area, mainly located in southern Sweden. As with the wind power data, spatial checks confirmed that these were also already mapped within the NMD Artificial Surfaces boundaries. Therefore, no separate solar impact assessment was required to delineate the FALs.

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