Odsherred Insights

4th Edition

Nature, Heritage, and Mobility in Odsherred

11 May – 19 May 2024

GHENT UNIVERSITY

DEPARTMENT OF GEOGRAPHY

UNIVERSITY OF COPENHAGEN

Roskilde Universitet

Introduction

Every year, students in the Master of Science in Geography and Geomatics of Ghent University (Belgium) undertake a research trip abroad. Since 2021, the destination of this project work has been Odsherred, Denmark, in collaboration with Roskilde University and the University of Copenhagen. This fourth edition took place from the 11th to the 19th of May 2024 in Udsigten.

Apart from excursions in Odsherred and the surrounding areas, the research trip has included an intensive geographic fieldwork project where students actively investigate the local spatial dynamics in the more rural area of Odsherred. The overall aim of this project work is to enhance students' scientific and intellectual competencies in geography through critical literature reviews, research design, fieldwork (e.g., surveys and interviews with locals), data collection, scientific analysis, and oral and written presentations. The topics investigated are all self-defined research projects, applying skills from other courses in a context abroad. The project work emphasises an interdisciplinary approach, covering different aspects (physical geography, landscape research, social and economic geography, as well as geomatics).

The students were assisted by teachers and researchers from Ghent University, the University of Copenhagen, and Roskilde University, as well as people from Geopark Odsherred, the Municipality of Odsherred, and local organisations and inhabitants. Below you can find an overview of the different research projects that were undertaken.

1. Landscape Character Assessment

- Ruben Lemmens, Timon Neels, and Thomas Van Liefferinge -

Discovering Odsherred, a travel through its distinctive landscapes: A landscape characterisation of Odsherred, Denmark.

2. Rewetting landscapes

- Bo Van Wetter, Bran De Schuytter, Marijke Van Cappellen, Glenn Desplentere, and Ellen Timmermans -

Rewetting landscapes in Odsherred, Denmark: Restoring nature's carbon sinks.

3. High nature value

- Jeanne Annendyck, Marie Dhondt, Lennert Van de Vyver, and Emma Vanhaverbeke -

A tale of two landscapes: Evaluating the high nature value of agricultural and rewilded areas.

4. Fishing activity

- Gitta Galle, Matthias Bourgeois, Maxime Willaert, and Yolan Bosteels -

From sea to shore: Exploring changes in Sjæland's fishing activity.

5. Migration patterns

- Febe Cromphout, Yarno De Baetzelier, Myrte De Koster, Kato Selis, and Luna Vanden Eede -

Odsherred on the move? Analising internal migration trends and future aspirations.

6. Inclusive mobility

- Frauke Van Kerckhove, Helena Van Parys, Bas Ponnet, and Tom Verheyden -

All aboard? A journey to inclusivity in Odsherred's public transport: Examining the accessibility of the public transport system in Odsherred, Denmark.

7. Burial mounds

- Wannes Vandenhaute, Dries Keppens, Nikolas Dobbelaere, Floris Vanden Broucke, and Olivier Vermeulen -

Digging out the spatial distribution and characteristics of burial mounds in Odsherred, Denmark.

The 4th Edition of the Odsherred Insights was made possible by the collaboration of many people from several organisations.

Organisers:

Veerle Van Eetvelde (Ghent University)
Lars De Sloover (Ghent University)
Maite Dewinter (Ghent University)
Seppe De Wit (Ghent University)
Kiara Haegeman (Ghent University)
Sofie De Winter (Ghent University)

With collaboration of:

Andreas Aagaard Christensen (Roskilde University)
Henrik Vejre (University of Copenhagen)

Stakeholders that were involved:

The Municipality of Odsherred
Geopark Odsherred
All interviewed locals
Local organisations

Special thanks to:

Per & Katia from Udsigten

FACULTEIT WETENSCHAPPEN

MASTER OF SCIENCE IN GEOGRAPHY AND GEOMATICS

DISCOVERING ODSHERRED, A TRAVEL THROUGH ITS DISTINCTIVE LANDSCAPES

A LANDSCAPE CHARACTERISATION OF ODSHERRED

Word count: 11,236

Ruben Lemmens, Timon Neels and Thomas Van Liefferinge
Student number: 02004235, 02003457, 02000127

Responsible lecturer: Prof. dr. Veerle Van Eetvelde, department Geography and Geomatics
Assistants: Lars De Sloover, Maite Dewinter, Seppe De Wit en Kiara Haegeman, department Geography and Geomatics

Course: Integrated international project

Academic year: 2023 - 2024

UNIVERSITEIT GENT

TABLE OF CONTENTS

1 INTRODUCTION

The European Landscape Convention defines landscape as “an area, as perceived by people, whose character is the result of the action and interaction of natural and / or human factors” (“Council of Europe Landscape Convention”, 2000). The landscape character may be defined as a distinct and recognisable pattern of elements, or characteristics, in the landscape that make one landscape different from another, rather than better or worse (Tudor, 2014). Basically, landscape character is what makes different landscapes distinct from each other. All landscapes have evolved over time and will continue to do so. Therefore, managing these changes is important to ensure that sustainable outcomes can be achieved in an environmental, social and economic sense. To manage these changes in the landscape, it is crucial to understand the different landscape areas and their character in detail. There are many ways to do research on landscape character. One of them is the methodology developed in Flanders, Belgium by Van Eetvelde et al. (2024). The report of this methodology says that it can be applied in any Flemish area. As this methodology is based on mostly physical aspects of the area, it could be interesting to research whether this Flemish methodology can be applied in other places too and what problems can come to appearance. This is the methodology that will be used to perform the research on landscape character.

The study area of this research is the municipality of Odsherred in Denmark. This is a peninsula in the northwest of the island Zealand. It is an interesting study area for this research because of its diversity in landscape types, as well as the fact that there already exists a landscape character assessment (LCA) of the municipality. However, this LCA was done with a completely different methodology and was done in 2012. Therefore, it will also be interesting to compare our results achieved with the Flemish method in 2024, and this already existing one.

2 RESEARCH QUESTIONS

This research will try to provide an answer to the following research questions.

1. What landscape character areas can be distinct in Odsherred?
2. How do biophysical qualities distinguish the different character areas?
3. What are the take home messages for the Flemish methodology?

3 THEORETICAL FRAMEWORK

Landscape character is defined as the distinct, recognisable and consistent pattern of elements in the landscape. These patterns give each location its "sense of place". This is what makes landscapes different from one another. Landscape character can be a way of thinking about and looking at a landscape more holistically and objectively, instead of focusing on subjectivity and scenic beauty. Landscape has been influenced by both natural processes and cultural processes. Natural processes can define the physical structure, like the topography, soils, landform and geology. These are the fundamental basic patterns of the landscape. Cultural processes reflect what humans do and have done to the landscape, which include characteristics like plot boundaries, settlement and land cover. These are more fluid and reflect social changes over time. They're layered on top of the physical elements. People's appreciation of and relation to the landscape and how they make use of it, is layered on top of these cultural elements (*Landscape Character Assessment | Worcestershire County Council*, n.d.).

So, this research will focus on landscape character, but it has to be emphasised that there is a difference between landscape character and landscape type. These landscape types are defined as "generic, typically homogenous types of landscape that may occur in different parts of the country. They have similar geology, topography, drainage patterns, vegetation, land use, patterns of settlement and aesthetic character." (Landscape Character Area, 2022). They are a broader term than landscape character. One landscape type can consist of multiple

landscape characters, but a landscape character can't consist of multiple landscape types. A great example of this will be shown in section 7.1 with the summerhouses in Odsherred.

The Worcestershire County Council (n.d.) considers landscape character an important factor to consider in the assessment of planning applications. In an application for residential development, the landscape type (and its most important characteristics) of the intended location should be considered in the proposed change to the site. An employee from the spatial planning department at the Odsherred municipality also mentioned that a landscape characterisation map can be useful for spatial planning. It can be helpful to determine suitable locations for solar panels and/or wind turbines. It can also be a good tool to consider when it comes to the architecture of new buildings. This research might help determine which architecture is related to certain areas. She also mentioned that they didn't use a research or document that can really link the physical environment with spatial planning (E. Cadee, personal communication, May 14, 2024). This research might be used for that.

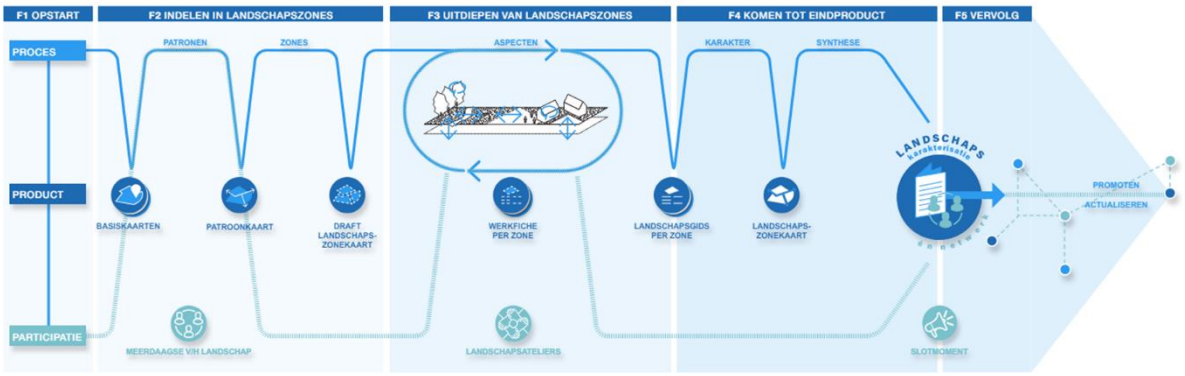
Like mentioned in the introduction, there already exists a landscape characterisation of Odsherred from 2012. This will be discussed into more detail near the end of this paper. However, it is worth mentioning here that this research has been used by the municipality of Odsherred. In a legal case, the municipal plan of 2021 is mentioned. The case is about permits for a certain property that is designated as particularly valuable agricultural area and area with geological conservation values according to this municipal plan. The section of this type of area refers to the landscape characterisation of 2012. It mentions certain elements in the landscape that are rich in experiences. They contain special visual experience opportunities and they must be secured as landmarks for the future. This makes it clear that the already existing characterisation has had an influence on the municipal plan and therefore the law of the municipality. It is also noticeable that this LCA approaches the landscape from a more social and cultural side and that it highly values the human experience in the landscape (Afgørelse I Klagesag Om Odsherred Kommunes Afgørelse Om, at Fremstilling Og Salg Af Smykker, Ikke Kræver Landzonetilladelse, Samt Om Landzonetilladelse Til P-plads, På [A1], Hørve, 2022). This research will focus more on the physical aspect of the landscape, which will be discussed below in the next section, the method.

4 METHOD

This research uses the Flemish landscape characterisation methodology made by Van Eetvelde et al. (2024) to perform a landscape characterisation in the Danish municipality of Odsherred. The method in this research will follow the Flemish methodology as closely as possible, but due to limitations of time, location and data, some steps of the Flemish methodology will be given less emphasis. The impact of these limitations will also be critically discussed. A schematic overview of the Flemish methodology is given in Figure 1

Figure 1

Methodology Landscape Characterisation for Landscapes in Flanders



Note. Adapted from *Methodologie voor landschapskarakterisatie in Vlaanderen* (p. 8), by Van Eetvelde, V., Foré, P., Boussaert, J., Herpels, J., Terryn, E., & Dabaut, N, (2024), Commissioned by Departement Omgeving, Vlaamse Landmaatschappij, Agentschap Onroerend Erfgoed, Agentschap Natuur en Bos and Team Vlaams Bouwmeester.

4.1 Starting points

As it is the purpose of this study to perform research in the municipality of Odsherred, this will be the study area. Yet, it has to be considered that administrative borders are highly artificial, so it is likely that the landscape characters that will be described will be stretching further than the study area. By also looking beyond the study area, neighbouring municipalities can make connections if they were to carry out a landscape characterisation too. Thus, a global picture of the landscape across borders can be formed. Still, it is very useful to use the boundaries of the municipality, because powers such as spatial planning, environmental policy or tourism

are often used demarcated at municipal level. So, if certain agencies want to use the characterisation, it is easy if this is delineated at the municipal level.
In addition, consideration should be given to the scale of the study area and the maps, because at different scales, different patterns may be discovered. For the landscape characterisation Van Eetvelde et al. (2024) recommend a scale of approximately 1:50 000 and a study area between 200 km² and 600 km². The area of Odsherred is 355 km² (Odsherred Kommune, n.d.).
Next, the Flemish methodology also requires to determine stakeholders of the area that can participate in the research. In this research the participation of stakeholders will play less of a role, as this is time consuming and the time that can be spend in Denmark is limited. However, stakeholders can provide valuable and unique information that can be used in a landscape characterisation. Therefore, meetings will be held with a spatial planner from Odsherred and a staff member of the Geopark Odsherred.

A last starting point is that a landscape characterisation requires a lot of terrain visits. These terrain visits will be held from the 12th of May 2024 till the 15th of May 2024. This is only a short period of time, so differences through time or seasons will not be observable. Possible differences through time should be kept in mind. These visits will be done by car. On certain points in the area the car will be parked, and the visit will continue on foot.

4.2 Base maps

Next, base maps of the area have to be developed. In the Flemish methodology there are seven base maps that have to be made. These base maps are elevation, water, soil, building and built-up area, open space, image and historical maps. These themes are the layers that make up the biophysical system and the cultural landscape according to Van Eetvelde et al. (2024). The data that has been used to make the maps will be discussed in the paragraph *Data.* Due to lack of data, it has been decided not to make the image map. This map tries to depict the elements that influence your view when you are standing in the landscape. It is important that the base maps are visualized in an identical way, because otherwise it could be possible that there are different patterns that will be discovered. Next to that, it is also important that the scale of the maps is the same.

The purpose of the base maps is to analyse their patterns. The base maps have to be analysed by placing a tracing paper on top of it. On that tracing paper the general structures that are remarkable are drawn with markers and pencils. It is important to think carefully about how a structure is referred to and that the patterns of the map are intuitively drawn, only based on the patterns that you can see. This way the patterns are showing truly what is visible on the map and are not the result of reasoning on what could be behind the visible patterns. When drawing the patterns it is also important to not think about the patterns you've already drawn on other base maps. For each map a different tracing paper has to be used. This analysis will not be done on historical maps because these are not detailed enough about the landscape to discern patterns. Historical maps of the region will just be used to have some extra time-depth information about the landscapes in the past.

4.3 Pattern map

Subsequently, another tracing paper has to be used to combine all the patterns of the five different base maps. This tracing paper has to be placed on top of each other tracing paper separately in a certain order. First the patterns of the elevation and water map have to be marked on the tracing paper, after that the soil map, and finally the buildings and built-up area map and the open space map. During this process, some patterns will also be lost, as only the most general and distinctive patterns are taken to the next tracing paper. In this way, a map is created that gives an overview of the general patterns of the phyiscal system of the landscape. This map is called the pattern map and is shown in Figure 2.

Figure 2

Pattern map of Odsherred

4.4 Landscape character areas

Based on this map landscape character areas can be drawn for a first time. Areas have to be drawn in such a way that there is a combination of characteristics and patterns that are standing out for each area. There has to be considered that borders of areas are often not quite clear. One time, an area can change in a different area in a very smooth way with sometimes a transition area in between. The other time, the border of the areas is very clear. It is also possible that an area can be split up in separate sub areas. The most important is that there is a clear argumentation why a certain area is part of one area and not of the other and why the border is where it is. Therefore, it is important to create a description of each area that tells what characteristics make it stand out from another. Additionally, there has to be tried to give a name to each region. Preferably this name is used in local communities to refer to the region. If there is no information about local names, it is sufficient to give the region a name that tells as much as possible about its character. Next to that, there also has to be considered that the character of an area often does not stop at the border of the study area and that the area beyond the study area also has to be considered to have a good overview of the area. This is only a first characterisation and has to be verified on the terrain later. The

different areas and their borders still can change a lot in comparison to this first characterisation.

4.5 Terrain visits and experts interviews

Landscape can be perceived different as expected. Additionally, new elements that are not noticed on the maps can now be noticed or elements that were noticed beforehand may be evaluated differently. All of this make terrain visits very important to verify the analysis that has already been done. These terrain visits are essential because landscape is observed in the field and not from behind the desk. Desk studies only serve to get an initial view on the landscape and to orient into the landscape and the information behind it. Next to that, terrain visits can provide extra information that can't be found without going into the field.

The terrain visits will be done by car. This mode of transport allows to visit the entire study area in a few days and also allows to observe certain places in more detail. By driving through the landscape, a first impression can already be formed on the different landscape character areas in the region. Yet, by car the landscape changes very quick as you pass through it, so certain elements you will not be able to see. Additionally, the landscape is only observed from the road, so this gives an observation only from a specific point of view. Therefore, on certain places stops will be made to continue the observation on foot. This way the landscape can be observed at a slower pace and more in detail.

To decide which places have to be visited on the terrain, the landscape character area map is used. Two types of places have to be visited. The first types of places are those where the border between the areas is not clear or where it is not sure the border is exactly on the place where it is drawn on the map. There, the border has to be determined on the terrain more exactly. Transition areas have to be visited to verify if this transition is also clear in the landscape and whether or not there still can be drawn a clear border inside or at the borders of the transition area. A second type of places that have to be visited is landscape character areas that certainly have a distinct character to verify its character and to refine it. Visiting these two types of places across the entire municipality will provide a good overview of the different landscape characters in Odsherred.

During the process of landscape characterisation, it is important to have feedback from stakeholders that are active in or have knowledge of the study area, because they know their terrain the best and can give valuable information. Therefore, the Flemish method requires that you consult those stakeholders in every step of the process. Unfortunately, this is very difficult to do remotely, because you have to consult stakeholders with physical maps and terrain visits to get the best results. To still have at least some local input, two expert interviews will be held. One with Ella Cadee, a spatial planner of the municipality of Odsherred and another with Jakob Walløe Hansen, a geologist and nature guide of the Geopark Odsherred. Both will be asked whether they recognise the areas that you see on the landscape area map and if they would change something with their background knowledge. Specific questions about how they would characterise certain areas will also be asked. Finally, there will be probed whether they think this landscape characterisation is useful and what they think it would be useful for.

Next, based on the terrain visits and expert interview the landscape character area map will be adjusted to a final version. This map provides an overview of the different landscape character areas in the municipality of Odsherred. Each character area has a description of what makes the area characteristic and different from the other areas. Both the borders between the areas as the core of the areas have to be described to get a good overview of the landscape characters and to provide answers to the research questions.

At last, the Flemish methodology for landscape characterisation will be compared to the Danish method. This Danish landscape characterisation was on purpose not used in the previous steps of the method to not have any pre-judgements on the landscape characters of the region. Still, it is important to compare the two methods to get more insight on the different methodologies on landscape characterisation. By comparing the two methods the strengths and weaknesses can be discovered and the take home messages for the Flemish method can be determined. Yet, it should be kept in mind that the Danish landscape characterisation has been done already more than ten years ago.

5 DATA

In this section, the data that has been used for each base map will be discussed. As a methodology that is made for Flemish areas is used, some data is difficult to find. So, for some data there had to be found an alternative. The data is discussed per map. To delineate the study area, the borders of Odsherred were retrieved from OpenStreetMap (2015).

5.1 Elevation

A digital elevation model is used to show the elevation of the municipality. This model is specifically SRTM data with a grain of 25 m from the year 2000. This means that we have a resolution of 25 by 25 meters. The model also dates from 2000 because no more recent and better ones could be found. If a better model had been found, it would have been used, but this was not the case. A better resolution could also have worked better for conducting analyses.

5.2 Water

The water map of Odsherred lacks a lot of information compared to what is needed for the Flemish methodology. Probably the most important data it lacks is the flood vulnerability of the areas.. We do have access to the areas that would flood depending on the sea level rise (data is available per 10 cm in sea level rise until 6 m). After careful consideration, it was decided that this data wouldn't get used for this map however. The map does portray all the waterways, bodies of water and drainage areas of Odsherred. A digital elevation model was used as a background. The waterways were not divided into natural and man-made ones because of a lack of data. All of the data on this map was received through the QGIS plugin "DMP Data Catalogue". This data comes from the Danish Miljøportal.

5.3 Soil

The soil map that is used comes from the Geological Survey of Denmark and Greenland (GEUS). There are two main ways the soils are divided on this map: soil type (like sand, gravel,

clay etc.) and the origin of the water in the soil (meltwater, freshwater, saltwater). The origin of the water is something that is usually not taken into account in the Belgian soil maps. As you can see on the map, “meltwater gravel” and “meltwater sand” are shown twice in the legend, but with different letter codes. In the original data, a distinction was made between the soils of postglacial origin and those of glacial origin. The two types whose letter code starts with a “T” are of glacial origin. However, they are not shown differently from the soils of postglacial origin because this distinction was deemed unnecessary for the goal of our research. The presence of these two glacial soil types in Odsherred was also very small, almost negligible.

5.4 Historical maps

The historical maps that will be used in this research come from the website *https://historiskekort.dk/* where there has been searched on the keywords Odsherred, Asnæs, Nykøbing, Vig and Odde to find the most usable maps.

5.5 Buildings and built-up area map and open space map

The data that has been used for the buildings and built-up area map and open space map are almost the same.The same data is used because these two maps are each other’s negatives. As a background layer, a Digital Elevation Model is used. This model is SRTM data with a grain of 25 m from the year 2000. On top of this background layer there is a land use and land cover layer developed by the university of Aarhus (Levin, 2024). This layer is a raster layer with a grain of 10 m and from the year 2021. Every few years, the layer gets updated. The version used in this research is *Basemap04,* as this is the most recent version. The layer has originally more than a thousand land cover and land use classes, but there is also a version that aggregates the different classes to some thirty classes. This version is used in this research, as this is more convenient to have a clear and general overview of the land use classes.

6 RESULTS

6.1 Study area

The study area of this research is the municipality of Odsherred in Denmark. The delineation of the study area is shown in Figure 3. It is located in the northwest of the island of Sjælland, the biggest island of Denmark. The landscape has mainly been formed under the influence of the last ice ages. During the last ice age, glaciers and their melting had a huge impact on the formation of the landscape in Odsherred. Next to that, water and wind also played a big role in the formation later. Finally, in the last centuries humans also had an impact on the landscape. All these factors made up the landscape the way it is today (UNESCO Global Geopark Odsherred, n.d.b; J. W. Hansen, personal communication, May 16, 2024).

Figure 3

Delineation of study area Odsherred

6.2 Base maps

6.2.1 Elevation, water and soil maps

The first three maps created show the elevation, water and soil of Odsherred. They are discussed together because they can influence each other in some areas. Figure 4 shows the elevation map. On this map, the relief of the municipality is clearly depicted. The colours used to clearly visualize the relief are green that turns into yellowish colours, and eventually turn into red. These respectively go from low-lying places (sometimes even below sea level) to higher places. The choice to use these colours is primarily related to visualization. First, other colours were tried, for example a black and white image, but it was concluded that this did not provide a good representation of the municipality. Based on the used colours, it can also be determined at which locations there is a fast or slow change in height. This can give us an idea of whether we are talking about steep or flat slopes. This can be observed, for example, in the southeastern part of the municipality. The highest place is also located there. In this part there is a rapid change in altitude. Coloured in red from that highest point, it quickly becomes a green colour south and east, with some locations even located below sea level. This change may lead us to conclude that a steep slope will be located there. However, this is not much present in the municipality. In other places, red colours are no longer visible, but yellow ones are visible, which indicate a hillier landscape.

The water map is shown in Figure 5. This map shows all waterways and water bodies. This may include rivers, canals, streams, ponds, lakes, etc. If we take a look at this map, there is water all over the area. In some locations there are several canals that run through the landscape and empty into the sea. In other places we find large bodies of water or a large number of watercourses close together. In addition to the water, the elevation model is also included on this map. As already mentioned, the maps are discussed together because they have a certain influence on each other. That is clearly visible on this map. In the higher places (the dark areas) there are few or no waterways or bodies to be found. The more you go to the lower areas, the more water you will find.

The soil map is shown in Figure 6. A variety of colours can be observed on this map. This is due to the wide variety of soil types in the municipality that are visible in the legend. In addition

to these common types, there are types that contain neither of the distinctions. These are aeolian sand, clayey till and sandy till. The most common type is also clayey till. In addition, saltwater sand is also relatively common, all other soil types occur to a lesser extent. Also, as with the water map, the municipality's elevation model has a connection with the soil that can be found there. A DEM is not visible on the soil map, but comparisons can be made. It is striking that higher areas have clayey till as soil. In the lower areas the saltwater sand soil is the dominant one. Both in the higher and lower parts there is also a wide variety of other types that are less common.

Figure 4

Elevation map of Odsherred

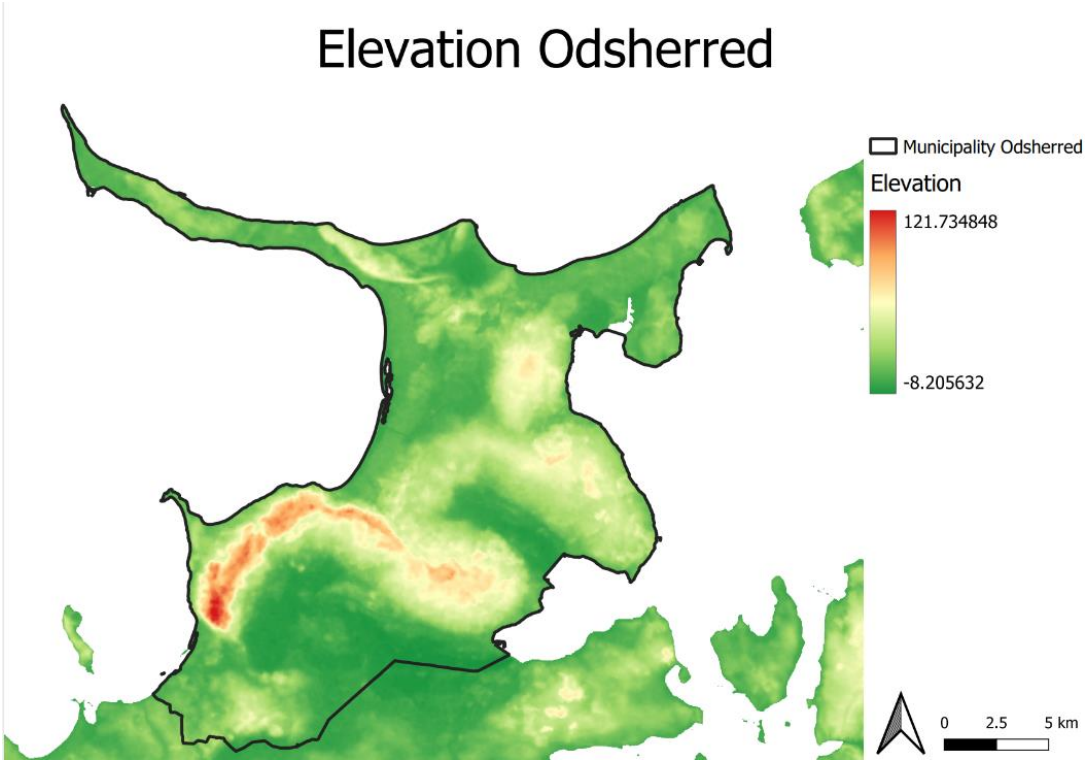


Figure 5

Water map of Odsherred

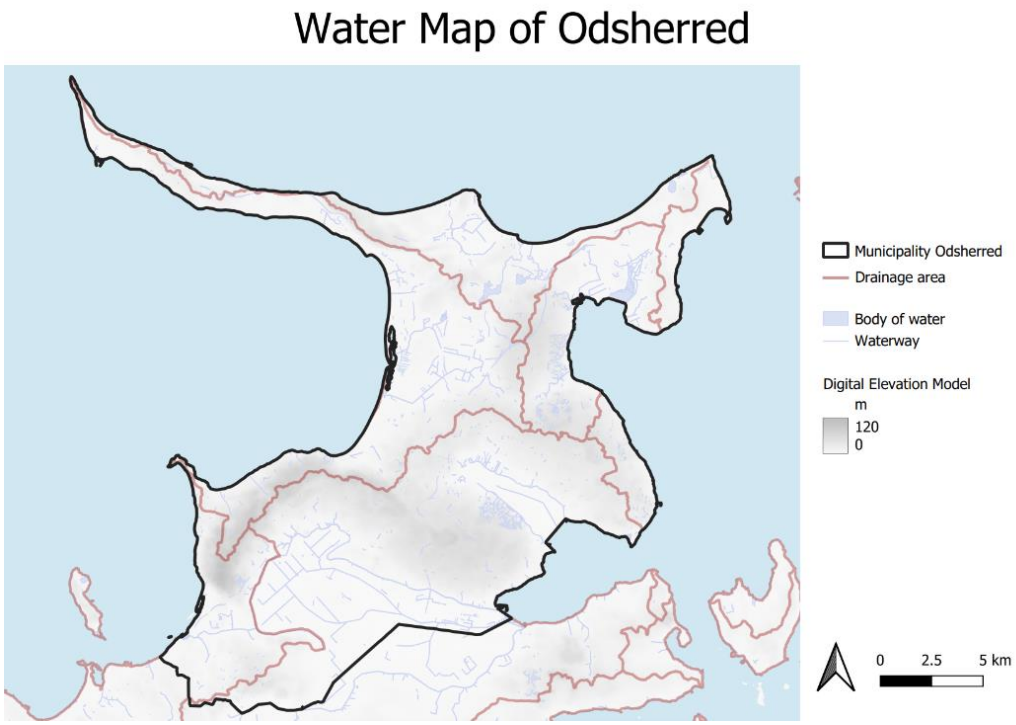
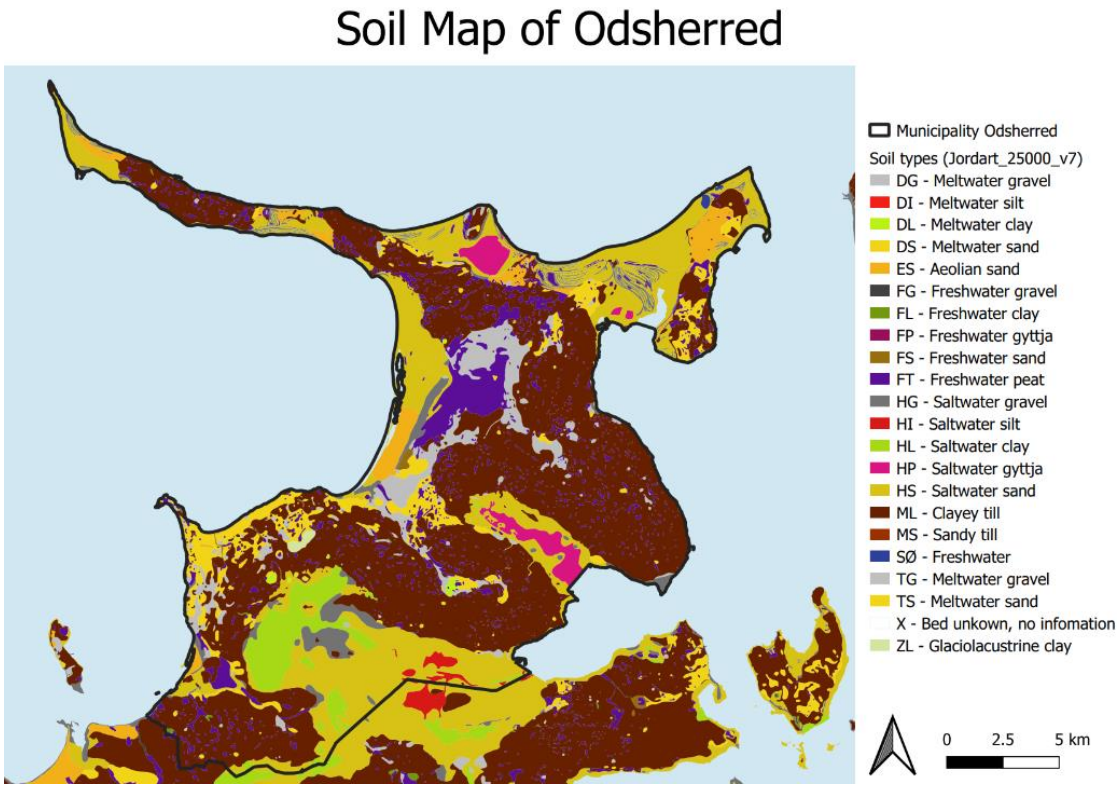


Figure 6

Soil map of Odsherred



6.2.2 Buildings and Built-up Area and Open Space

The map of the buildings and built-up area is shown in Figure 7. The open space map is shown in Figure 8. The difference between the buildings and built-up area map and open space map is the classes that are shown on the map. The buildings map only shows the man-made infrastructure such as railways and roads, the buildings such as high-rise and low-rise buildings and the built-up area such as recreation, business and residential. The other classes are made transparent and are not shown. Therefore, the map gives a good overview of the regions where man-made structures dominate the landscape. This way the characteristics of these structures are also highlighted. On the open space map the classes that are displayed on the buildings and built-up area map are made transparent and the other classes are shown. These classes are nature, forest, intensive agriculture and extensive agriculture among others. This way the land use of the open space stands out. Both maps display the waterbodies and waterways.

The choice of the colours that has been used for the maps is also an important detail. Because the way a map is coloured, can influence the impression of a map a lot. Colours that are quite similar are not standing out, so it is important that colours that look the same are used for classes that are relatable. Colours that cause a contrast have to be used for classes that are not similar. Specifically, the built-up area and buildings are sorted in a different class. Yet, the buildings that correspond to the related built-up area class are depicted in more or less the same colour. The exact same colour is not used, so the two classes are still distinguishable. On the other hand, classes such as residential, commercial and business get contrasting colours in order to stand out. On the open space map the classes that are similar such as intensive and extensive agriculture get both a yellowish colour, while forest gets a contrasting green colour to stand out more.

On the buildings and built-up area map the patterns that were standing out the most were the cities and villages and the perpendicular street patterns in some regions among others. The patterns that were standing out the most on the open space map were the forest, regions with more nature and regions with more extensive agriculture than their surrounding regions. Intensive agriculture dominates in most of the regions.

Figure 7

Buildings and Built-Up Area Map of Odsherred

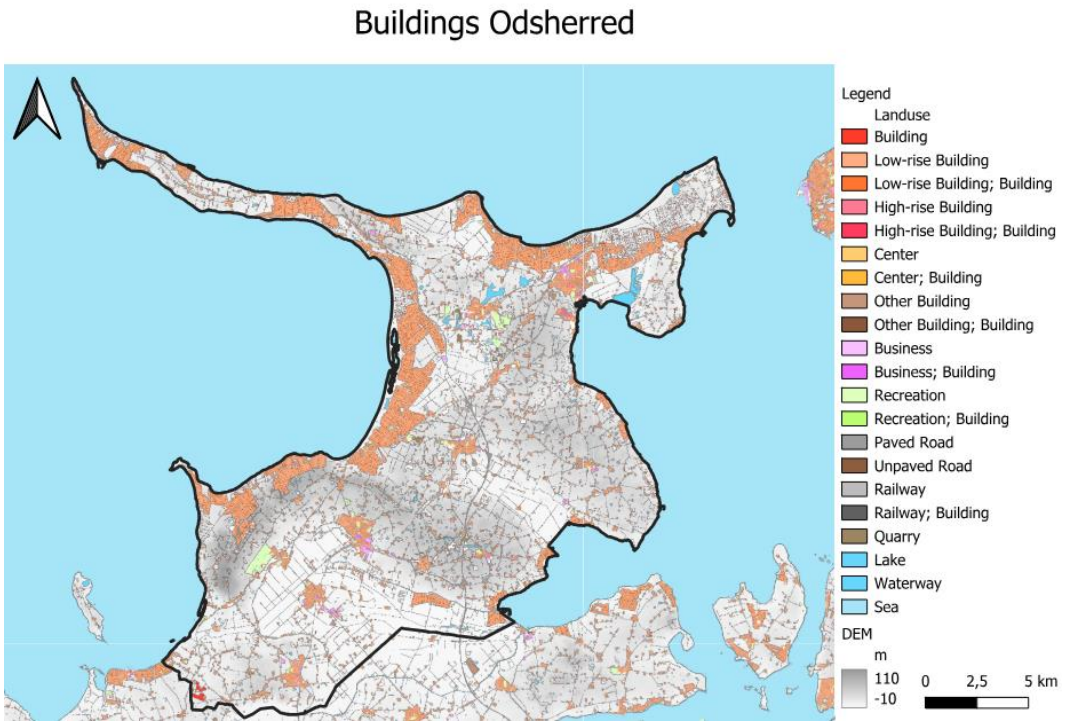
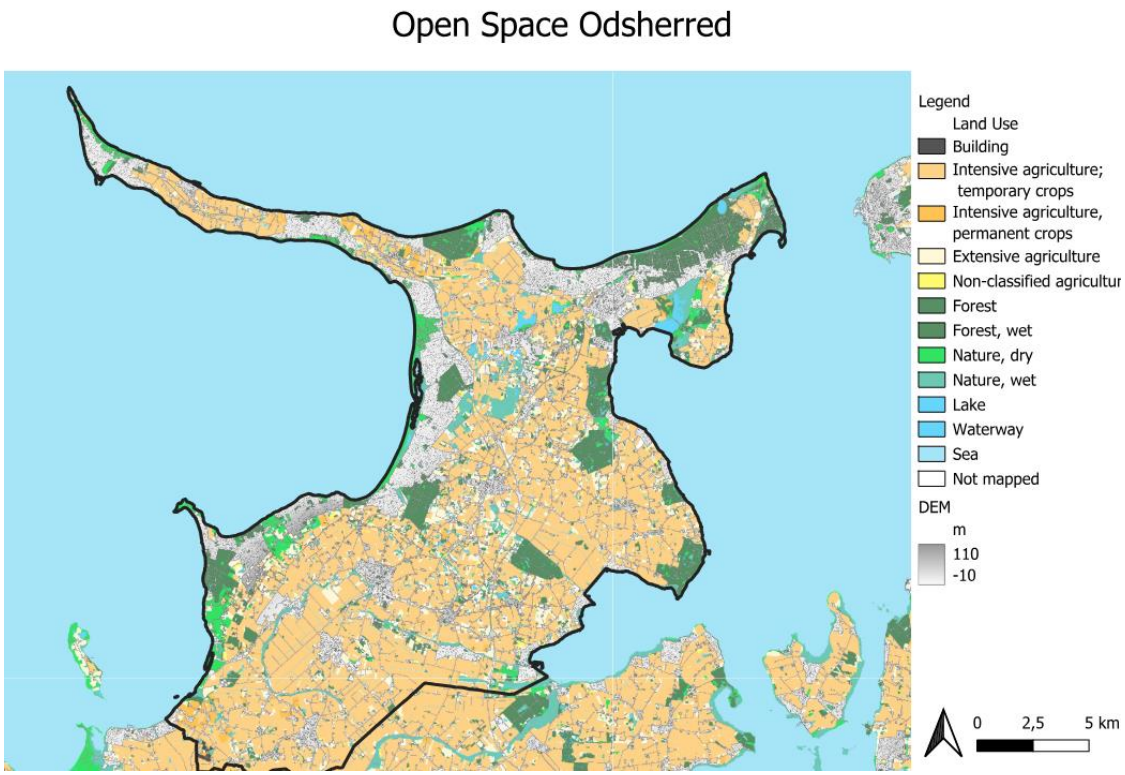


Figure 8

Open Space Map of Odsherred



6.2.3 Historical maps

As previously said, the historical maps will only be used as a source of background information, as the available maps are not detailed enough to perform a pattern analysis. On the other hand, there are detailed maps of certain regions with plot boundaries, such as Figure 10, but still there are not a lot of landscape structures that are visible on those maps. The scale is also often limited to one city or village which causes that not all of the study area is covered with such maps. Yet, there are maps that cover the entire region of Odsherred, such as Figure 9, but still, these are not detailed enough to do a pattern analysis. The advantage of those maps is that there is some extra time-depth information. On Figure 9 the Lammefjord and the Sidinge fjord is not reclaimed yet. On Figure 10 there can be noticed that the Annebjerg forest was already a forest the moment the map was made.

Figure 9 and 10

Odsherred and Annebjerggård Hgd., Nr. Asmindrup

Note. [Figure 9] Adapted from *Historiske Kort,* (1785), Consulted via https://historiskekort.dk/Kort?fritekstsoegning=odsherred&limit=50&offset=0&sort=titel&direction=asc
[Figure 10] Adapted from *Historiske Kort,* By N. R. Lyngbye (1808), Consulted via https://historiskekort.dk/Kort?fritekstsoegning=Nyk%C3%B8bing&limit=50&offset=0&sort=titel&direction=asc

6.2.4 Landscape area map

Figure 11 shows the final landscape character map of Odsherred, based on everything that has been discussed so far. It consists of 36 landscape areas, along with four transition zones and two subzones. The key here is that each landscape area has a distinctive character that makes it different from the other landscape areas. Each of the landscape areas is internally fairly homogenous. Two of the landscape areas in the south of Odsherred, Vallekilde Region and Lammefjord, don't have a fully defined border, as these landscapes continue further south of the municipality's border. Defining the border of this landscape area outside Odsherred fell outside the scope of this research. It was a conscious choice to let the landscape areas span further outside Odsherred. This way, if similar research is ever done in the Holbæk municipality or the Kalundborg municipality, it should be possible to put the maps of these analyses together.

The borders of the landscape areas are the way they are because of a number of possible reasons. Some are very clear, both on certain maps and when you're standing in the landscape itself. Examples of these are the borders of the forests and summerhouses. These have clear physical borders. There are also some landscape areas that are distinct from each other internally, but where it is very hard to determine where exactly this change in character happens. For this reason, transition zones were made. These exist between each of the following areas: the region of "Vejrhøj", the "Southern Vig Rig", the "Northern Vig Rig", the "Agriculture around Stårup" and the "Agriculture around Stenstrup". All of these landscape areas are predominantly agricultural with small villages. They are all relatively hilly areas too. What makes them distinct from each other is that some are hillier than others. This couldn't always be seen on the elevation map, but it was clear during the terrain visits. It is, however, impossible to draw a border where it goes from "less hilly" to "hillier" or vice versa. There are also two subzones. These are both forests located right next to summerhouses. These summerhouses are also built in forests, which it was decided that these forests are not entirely distinct from the summerhouses, making them a subzone of these areas.

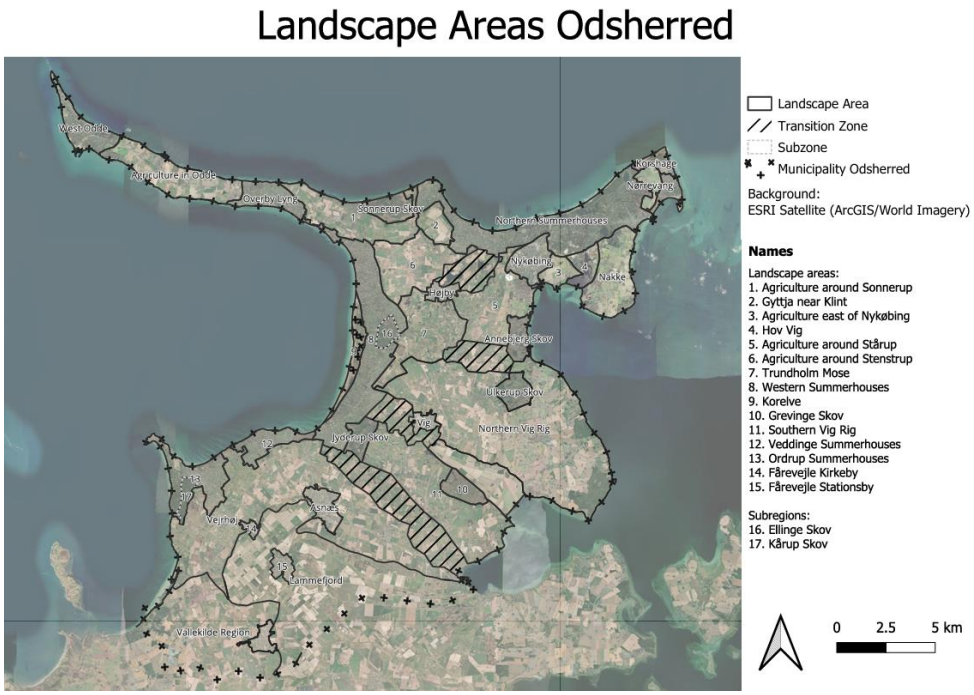
It is also worth mentioning that the borders of the landscape areas align with the coast, with the exception of the Korelve region, which will be discussed in greater detail further down this paper. An argument could be made to include parts of the sea into the landscape areas at the

coast that can be seen from land. However, it would be impossible to determine the borders of these areas on the sea, as some parts are visible from multiple different landscape areas. Another reason that the sea wasn't included inside the borders of these landscape areas, is that the sea itself has a very distinct character from any of the determined landscape areas on land. This means that if the used methodology is followed, the sea itself would have to be divided into multiple landscape areas depending on different factors like the species that live in it, the depth of the sea floor, history, etc. This, of course, is completely outside the scope of our research. It would also be less useful for one of the major possible uses of this research, which is spatial planning.

For the names of the landscape areas, already existing names for the regions were used as much as possible. However, these don't always exist. Especially for certain agricultural areas, the areas are often named after the largest settlement inside it. For some areas, wind directions were also used. In the following section, each landscape area will be discussed in more detail. Some are discussed together because of different reasons, like having the same landscape type (like the summer houses), origin (like the fjords) or simply being located next to each other (like northeastern Odsherred).

Figure 11

Landscape Character Map of Odsherred



6.3 Detailed observation of specific landscape areas

6.3.1 Summerhouses

A first landscape type in the study area are the summerhouses. There are six summerhouse areas in the region: Northern Summerhouses, Western Summerhouses, Veddinge Summerhouses, Ordrup Summerhouses and two summerhouse areas in the Odde. All of the summerhouses have the same typology of landscape. First, the soil is sandy and poor. The area has also a low elevation. Most of the areas have a relative average age in comparison to the rest of the area. They are younger than the moraine hills, but older than the reclaimed fjords. The sandy soils are deposits from the sea during the quaternary period (J. W. Hansen, personal communication, May 16, 2024). They are also considered as large residential areas on land use maps.

The summerhouse areas are big residential areas that appear as a forest at first sight. Yet, they consist of relatively large and open plots with summerhouses on it, which are mostly the second residence of many Danes to go on holiday to (Figure 12). The border of each plot consists mostly of large tree rows. This way the border with other landscape areas is also clear. The summerhouses areas start where the tree rows are. On one side of the area the border is the sea, except for the Western Summerhouses where there is a lagune between the sea and the summerhouses that is considered as a different landscape area.

Figure 12

Summerhouse in the Northern Summerhouse area

The summerhouse areas have the same typology, but there are still differences between the areas. These differences make up their unique character. For example, the plots of the Western Summerhouses are relatively smaller than the plots of the Northern Summerhouses. The summerhouses in the north are also wealthier than the ones in the west (E. Cadee, personal communication, May 14, 2024). Further in-depth research of each area could give more insight in the difference of the characteristics of each summerhouse area. The Western Summerhouse area is also called Lyng (J. W. Hansen, personal communication, May 16, 2024).

Some summerhouse areas also have some subzones inside of their area. These subzones are areas that are not considered as an entirely different area. They share some characteristics but have still some own characteristics. For example, in the Western Summerhouse area there is Ellinge Skov that is a forest almost entirely surrounded by the summerhouses. In the forest there are no summerhouses. This is because in the past people thought the area was not fertile and they planted a forest on that piece of land. It is still part of the summerhouse area, because they both have a woody view, and the forest is almost entirely surrounded by the summerhouses. However, there are no plots and houses in the area and the area has a significant size. That's why it is considered as a subzone.

A last remarkable border that needs some more explanation is the border between the Western Summerhouses and the Veddinge Summerhouses. There, a small forest separates the two summerhouse areas. There is no connection by road between them, so there is less interaction between those two summerhouse areas than there is internally in the summerhouse areas. Yet the forest is not big enough to consider it as a different region.

6.3.2 Odde

Odsherred received its name thanks to the Odde, the peninsula in the northwest of the municipality (J. W. Hansen, personal communication, May 16, 2024). Outside Odsherred, it is more commonly known as Sjællands Odde. On the elevation map can be seen that the centre of the Odde is located higher than the rest of the Odde. This area used to be an island, but via sand deposits it got later connected to Sjælland. The Odde also got extended in the west through these deposits. These areas are therefore lower. There is almost a perfect correlation

between the elevation, soil and land use in the Odde, so the borders of the defined landscape areas are very clear and each area has a very distinct character. These landscape areas in the Odde are West Odde, Agriculture in Odde, Overby Lyng and Agriculture around Sonnerop. This last area is not fully part of the Odde, if at all, as it extends more inland, but nevertheless it will be discussed in this section.

West Odde mainly includes the Yderby Summerhouses, which are located on sandy soil. It also includes a small military domain at the tip, which is used by the navy as the "Center for Weapons" (Gniben og Sjællands rev, n.d.). This is too small and has too little impact on the landscape for it to be its own landscape area. The area called "Agriculture in Odde" is located on the former island. Its soil is more suited for agriculture and it has a higher elevation. There are some small towns located in this area. Overby Lyng is also an area of summerhouses. These summerhouses are also located in a foresty area. It is surrounded by beaches in the north and south. The last landscape area that will be discussed here is the "Agriculture around Sonnerop". It is, like the name suggests, an agricultural area with a lot of smaller towns scattered around the region. Sonnerop is the biggest "urban" area in it, so that's why it's included in the name. The area is hilly, as can be seen on the elevation map. It has a sort of small ridge that starts at the northern coast of the area and spans across its whole southern border. Looking at the open space map, it also has a noticeably higher amount of intensive agriculture with permanent crops compared to most of the other agricultural regions in Odsherred. In Figure 13, the Odde and its elevation differences can clearly be seen in the background.

Figure 13

The Odde can be seen in the background

6.3.3 Northeast Odsherred

Northeast Odsherred is a region with a lot of different characteristics. The northeast consists of several areas that are located next to each other, but whose characteristics differ greatly from each other. There are a total of six different areas in the northeast, not including the summerhouses. These areas are: Nykøbing, East-Nykøbing, Hov Vig, Nakke, Nørrevang and Korshage. With these last two located on the northeastern tip and the other four located a bit more to the south.

The area most westerly in the northeast is the town of Nykøbing. There are different types of buildings such as low-rise buildings, high-rise buildings and business buildings. Nykøbing is therefore a town and, like the other major towns in the municipality, is a separate area. It is the largest settlement of Odsherred.

Located to the east of Nykøbing we have the area called “Agriculture east of Nykøbing”. This partly has the same name as the city, but there are no buildings here, and is therefore seen as a separate area. In this area we only find intensive agriculture. The soil here is saltwater sand with small pieces of saltwater gyttja which is also different from what lies beneath the city itself.

More to the east is the area called Hov Vig. In this area, and hence the name given to it, is the Hov vig nature reserve. It is shown in Figure 14. This nature reserve consists of a large lake surrounded by forests. These forests cover the entire area. Because this is the case, it can also be seen as a separate forest area, just as Nykøbing is seen as a separate town. However, for us it is not considered a forest because it is not the same size and is not as dense as the other forest areas. The same soil as in the agriculture east of Nykøbing is located here.

Nakke is located even more to the east. It is characterised by the presence of various elements in terms of open space. There are forests, buildings and agriculture in this area. There is a mix of both intensive and extensive agriculture. The buildings are only low-rise buildings. There is also a lot of variation in soil type. There is a mix of four types here, namely clayey till, saltwater

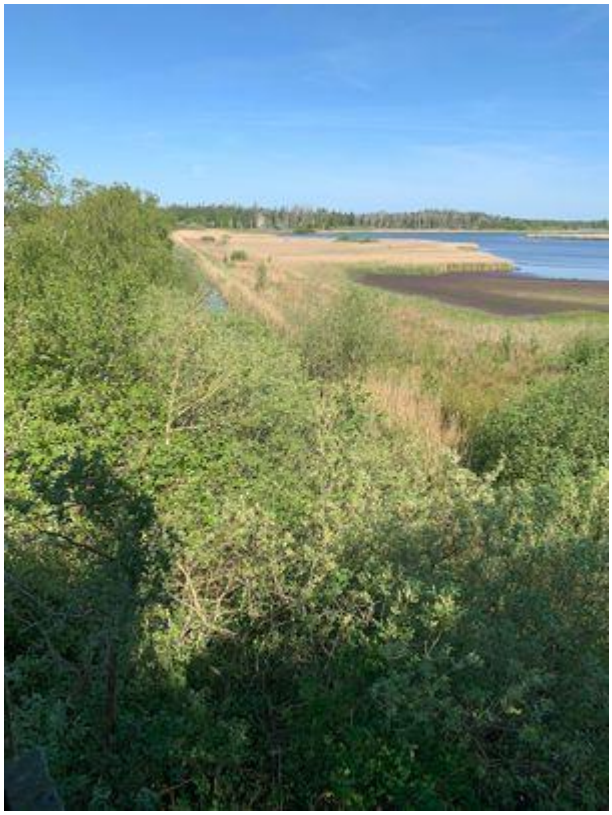
sand, meltwater sand and freshwater peat. This differs from the previous areas that only had one or two types. The town of Nakke is located in this area, hence its name.

North of the four areas already discussed are the areas of Nørrevang and Korshage. These have a different character, because there is a difference in the open space. In Nørrevang there is mainly nature, both dry and wet. There is also a small forest, as well as a small body of water. In Korshage, on the other hand, we find no nature or forest. Here the entire area is agricultural, both extensive and intensive. There are buildings in both areas, more specifically only low-rise buildings. The soils are also about the same. There is aeolian sand, meltwater sand, saltwater sand and clayey till.

For all areas together, not many differences can be observed for the water map and height map. There is water in every area, although in one area it may be a lake and in another it may be rivers. The whole area is relatively hilly, with the exception of the agriculture east of Nykøbing.

Figure 14

Hov Vig Nature reserve



6.3.4 Central ridges

This is the area that extends from the southwestern tip of Vejrhøj to the agricultural area around Stenstrup. In addition to these two areas, Agriculture around Starup, Northern Vig Rig and Southern Vig Rig are also a part of it. There are also transition zones in-between each of these areas. These zones mean that there is a border, but it is not known where exactly it is located. In Figure 15, the view from the highest point in this area is shown.

The differences or changes mainly lie in the open space and the elevation. The Vejrhøj area mainly contains intensive agriculture, but once through the transition zone to Southern Vig Rig, there is more extensive agriculture than before. Once in Northern Vig Rig, there is again more intensive agriculture, but also more afforestation that is not considered a separate area in the characterisation. Further towards Starup there is again more extensive agriculture and less forest area. Then, Stenstrup is reached, where there is no forest and again more intensive agriculture. For the elevation there is also a difference in the area. In the south the area is much higher than further north, but there is no continuous change between high and lower parts after each transition. With each transition zone that gets crossed, the landscape becomes either more or less hilly. This couldn't always be seen on the maps, but was obvious when driving through the landscape.

For the other themes, there is little to no difference after each transition zone. The buildings and soil are similar in every part of the area. The buildings are mainly low-rise buildings and the soil is clayey till throughout the area, containing freshwater peat in various spots. There is still a small difference visible in the water map. For example, there are waterways in the north of the area, but this does not change zone by zone.

Figure 15

View from the highest point on the central ridges

6.3.5 Fjords

The two fjords in Odsherred are the Lammefjord and Sidinge Fjord. They are by far the youngest regions in the municipality. These areas are located where the glaciers used to be in the last ice age. Both polders were reclaimed from the sea between 1870 and the Second World War. Both areas are dominated by agriculture, a low and an extremely flat topography. The Lammefjord even has the lowest point in all of Denmark, at seven meters below sea level (Misachi, 2018). It also extends further into the municipality of Holbæk. It mainly consists of intensive agriculture with some extensive agriculture and a of couple villages. The northern and western border mostly consists of the Nordkanal, which also include wetlands around them. A part of the western border, however, consists of the railway near Hørve. It is noticeable that the landscape is hillier at the other side of these borders. The main soil type in the area is sand, as it is recently reclaimed land. In much of the area, a rectangular pattern exists among the agricultural parcels.

Figure 16

Lammefjord

The Sidinge Fjord is the smaller and flatter of the two polders. It consists almost entirely of intensive agriculture. There is no real settlement in the area. There is a small forest and there are some houses spread throughout the area however. Something noticeable about these houses was that many of them were completely surrounded by trees, whereas the rest of the regions didn't have a substantial amount of trees. Just like in the Lammefjord, the borders of the Sidinge Fjord are very distinct. It is completely surrounded by higher laying areas and the sea.

Figure 17

The Sidinge Fjord

6.3.6 Cities and villages

The cities and villages are one of the areas that are the most standing out of the region, especially on the buildings and built-up area map. It is clear they are very influenced by human activity. These areas are densely populated and have a lot more buildings and infrastructure than their surroundings (Figure 18). The borders of the areas are also clear as these are where the built-up area stops, and the agricultural land begins. This is often a very clear border.

The difficulty to define the borders of these types of landscapes is to decide which villages and cities are an area on their own and which are part of a larger area together with their agricultural surroundings. This has been decided based on the interviews with the experts. Asnæs, Nykøbing, Højby, Vig, Hørve, Fårevejle Stationsby and Fårevejle Kirkeby are considered as areas on their own as they have some internal dynamics that are less related to the surrounding areas. Other villages and settlements are considered as part of a bigger area, because they are too small to consider them as an area with an own character.

The different regions still differ in their functions which characterises them. Nykøbing for example has more commercial and business influence than the other regions and Højby is important for the administrative functions it has.

Figure 18

Nykøbing

6.3.7 Forests

The forests in the region are especially standing out on the open space map. As with the cities, villages and settlements the boundaries are clear for these types of landscape. They start where the trees start. However, this is the same description as the summerhouses have for their borders. The difference then is that forests are densely forested, while there are still buildings in summerhouse areas.

The difficulty with the forest is as with the cities, villages and settlements, it is hard to define which forests form an area on their own and which are part of a bigger area. Here there has been decided to consider forests that are big enough and do not have a lot of relations with their surroundings as an area on their own. These criteria make Annebjerg Skov, Ulkerup Skov, Jyderup Skov, Sonnerup Skov and Grevinge Skov as landscape character areas that are standing out. These areas are big enough to stand out among their surrounding areas and are less in relation with their surrounding areas like for example the forest west of Egebjerg is as a remaining of the clearing of agricultural land around the village. A more in-depth study of each forest could bring more insight about the internal differences and characteristics of the forests.

Figure 19

Border between Annebjerg Skov (left) and agricultural area near Stårup (right)

6.3.8 Vallekilde region

The Vallekilde Region is located in the southwest of Odsherred and is named after its largest settlement, Vallekilde. Just like the Lammefjord, this landscape area continues across the municipal border, into Kalundborg and Holbæk. This area is dominated by agriculture, with many buildings scattered throughout the whole area and Vallekilde is the only true settlement. Most of the agriculture is, just like in all of Odsherred, extensive, although there is a noticeable amount of intensive agriculture too. Throughout the region, you will also find a number of small forests. Wetlands are also present in the area, mainly around the waterways. Another element about the area is that it is relatively hilly, although with some flat areas too. It is much hillier than the flat Lammefjord, but it is definitely not as hilly as the Vejrhøj region. The eastern border of the Vallekilde Region consists of the settlement of Hørve, the railway and the Nordkanal. The northern border is made up by parts of two roads, the Kalundborgvej and the Dragsmøllevej. When driving on these roads, it was noticeable that the area north of it was much hillier than the southern Vallekilde Region.

Figure 20

The hilly terrain of the Vallekilde Region

6.3.9 Korelve

Korelve is the name of the lagoon in the west of Odsherred at the Sejerø bay. This area stands out as it is a vast region where no trees, buildings or other structures are blocking the view. The western sand ridge is still actively forming. This is due to the waves in the bay that are at

a certain point not able anymore to transport the sand. Consequently, they put sand deposit on the sand bank. The sand bank moves gradually to the coast and comes to the surface at a certain point where it forms a sand ridge. The water behind the sand ridge forms a lagoon (UNESCO Global Geopark Odsherred, n.d.a). The area is very sandy with low-nutrient vegetation. The area can be used for recreation or for cattle or sheep to graze.

The borders of the region in the west are the trees of the summerhouse area as seen on Figure 21. In the east, the sea forms a clear border. In the north and the south, the area changes in a thin beach that is not that vast anymore and where the lagoon disappeared. There the beach is part of the summerhouse area again.

Figure 21

Korelve with view on southwestern border

6.3.10 Gyttja near Klint

This area is located in the north of the municipality and approximately in the middle next to Sonnerup Skov and the northern summerhouses. The name given to this area is gyttja near Klint. Klint is the small village located to the north of the area, but it is the word gyttja that is the main reason for characterising it as a separate area. The bottom there is saltwater gyttja with saltwater sand at the ends. However, this type of soil is not found in neighbouring areas. There are also other factors that characterise the area as different from the rest. The elevation is also different. The area is lower than the areas around it, as it is largely below sea level. A difference can also be seen in the open space. The area only consists of intensive agriculture. This is not the case in the surrounding areas. To the south there is more intensive and extensive agriculture together. To the northeast there are buildings due to the summer houses that are located there and to the northwest there is a forest area. There is also a difference on the building map. There are very few buildings in the area, which are only located next to the roads. This is more present in the surrounding areas, especially, as mentioned, near the summer houses. There are also more buildings in the others and of different types. All these factors provided a reason to characterise this as a separate area.

6.3.11 Trundholm Mose

The defined landscape area Trundholm Mose is larger than the swampy region that is generally known under this name. The landscape area includes the entire flat region that contains a lot of wetlands, waterways and small bodies of water, as well as a mix of extensive and intensive agriculture. Since this area includes a lot of wetlands, not many roads are going through it and the few that do, didn't offer the best visibility to accurately determine the exact borders. Therefore, the borders were defined almost exclusively via the base maps. Looking at the elevation map, this area is noticeable lower and flatter than the areas around it, with the exception of the summerhouses in the west. On the open space map, the presence of wetlands can be seen. The soil of the area mainly consists of peat and gravel, which has also caused the presence of a gravel mine. The lack of settlements in the area should also be mentioned. This makes sense considering the wetness of the soil in the area. The ground water levels have been rising noticeably in the last years (H. Veje, personal communication, May 13,

2024). And lastly, the theme park Sommerland Sjælland is also located in this area. It is too small and has too little of an impact on the landscape for it to be considered its own landscape area with its own character. Based on the elevation and soil maps, it belongs to this area.

Figure 22

Trundholm Mose

6.4 Comparing landscape character with existing characterisations

6.4.1 Comparing the method

The Flemish method for landscape characterisation has already been discussed in the method section. This part also briefly looks at the method used by Denmark, but mainly the similarities and differences that are identified here. The existing landscape characterisation of the municipality of Odsherred was made in 2012. Its method was based on the Danish Ministry of Environment's "Guidance on the landscape in municipal planning", which was made in 2007.

In general, both methods are similar in arriving at the final product. First and foremost, both objectives are of course to characterise the area. More specifically, it concerns dividing the municipality into different areas in which common characteristics are present. Preliminary information is also sought and the local community is involved for the characterisation and evaluation of the landscape. In addition, and most importantly to complete the characterisation, thematic maps are created to divide the municipality. However, this is also the most important difference. In both methods, base maps are created, but the themes

between the two are different. Both methods also discuss each area separately. In addition to the difference in thematic maps, it may also be important to emphasize the following. In Flanders, the method for making a characterisation is the official method given by the government. However, this is not the case with the Danish method. This is a specific method that was used to characterise the municipality and is not an official method imposed by the Danish government. It is just based, as mentioned, on method from the Danish Ministry of Environment.

The number of thematic maps created is the same. There are seven in total. For the Flemish method these are: elevation, buildings, open space, water, soil, images and historical maps. As mentioned in the method, images and historical maps were not used due to the lack of data that Denmark does not have. In the Danish method, the following thematic maps are created: character strength, condition, special visual experience, vulnerability, strategic goals, coastal foreland, coastal landscape. Here it is clearly visible that the themes differ from each other. This leads to a different characterisation of the municipality. The focus of the two methods is therefore clearly different. The Flemish method focuses on the development of landscapes and also the physical aspects. With the Danish method the focus is mainly on the social and cultural aspects of the landscapes.

6.4.2 Comparing the result

The Danish result is shown in Figure 23. The result using the Flemish method is shown in Figure 11 of which this was already shown and discussed in the results section. The comparison of both results shows that there is clearly a different division of the areas in the municipality. The Flemish method involves more division than the Danish method. The Danish method has divided the municipality into thirteen areas, while in the Flemish method there 36, excluding the transition zones and subzones. Some demarcated areas in the Danish methods are similar to those of the Flemish, but are no longer divided. This is the case for the areas numbered one, two and four. For example number one is Odden. In the Danish version, this area, as you might call it, includes the tail of the municipality. In the Flemish version, however, this place is more divided. This is also the case with numbers two and four. The summer houses are located in these areas, but there are also other areas that are characterised as separate in the

Flemish version. Number two is divided into seven areas in the Flemish characterisation and number four into two.

Other areas are very different from each other. This is the case for the area referred to in the Flemish characterisation as the central ridges, in which the transition zones are located. These zones are also not discussed in the Danish characterisation. In the Danish characterisation, the area is divided in a different way that does not resemble the areas in the Flemish characterisation if you were to see the transition zones as an effective border. In addition, the forests and towns are not seen as a separate area. They are not demarcated and belong to a larger area in the Danish version compared to the Flemish version. This is also a reason why fewer areas exist on the Danish map, compared to the one with the Flemish method.

In addition, there are also areas that are very similar in both characterisations. These areas were also given the same name in both characterisations. It concerns the Lammefjord and the Sidinge fjord, which are demarcated in approximately the same places in both methods. Only in the Lammefjord the town of Fårevejle Stationsby has been demarcated as a separate area in the Flemish characterisation since, as mentioned in this method, the major towns were seen as separate areas. This also applies to the southwestern part of the municipality. This area was given the name Vallekilde region in the Flemish characterisation, which is also very similar to the region that was demarcated in the Danish characterisation. There, however, it is slightly more divided into more areas, just as in the Flemish characterisation, the town of Hørve is indicated separately. When viewed together, they both look about the same.

Figure 23

Landscape character map: Danish method

Note. [Figure 23] Adapted from Yumpu.com. (z.d.). Landskabsanalyse 2013 - Odsherred Kommune. yumpu.com. https://www.yumpu.com/da/document/read/18416805/landskabsanalyse-2013-odsherred-kommune#google_vignette

7 DISCUSSION

There was a chance that the characterisation map could have looked different if certain executions had gone differently. The time that could be used to visit the area was limited. As a result, certain areas were not further explored and better mapped. This could have led to other areas in the characterisation.

Other areas could also be characterised if we could have met earlier with experts from the region itself. In this way, relevant information can also be provided that can be useful for creating the maps. In addition, this can also be of extra use because it often has more value than just looking up information online. The same also applies to meeting stakeholders. These people may not be experts, but if they are from the region and they know more information than can be found online, this can also provide added value. This can be done both on site and online. If it were possible online, it could be done much earlier. The additional information obtained can therefore be processed earlier in the characterisation.

There are also other factors that could have led to a different characterisation of the municipality. It is about how the municipality was explored. Most of it was done by car and in some places also on foot. The car was mainly used due to, as already mentioned, the limited time available so that the entire area could be visited and characterised. With most of the area covered by car, photographs were quickly taken and an attempt was made to characterise what could be seen in this way. The places that were visited on foot were often mapped in more detail. It is easier to photograph and map everything better on foot. Another way would have been by bicycle, for example. By bike, just like on foot, you can take photos and characterise the area more easily. However, this was ruled out as an option due to the lack of time to do everything.

Another factor that is also partly linked to the use of the car for exploration is that in some places there are not many streets and there are also hilly places. This means that certain areas are inaccessible and not visible. In some places there were paths, so it could still be done on foot. However, in some places this was not the case and these were impossible to visit. Therefore, these places were mainly characterised based on the base maps.

The question that is also often asked is: "What can we learn from LCA and what is it useful for?". Firstly, a landscape characterisation can offer us many insights. It helps identify and describe the characteristic features and elements of a landscape, including natural, cultural and perceptual aspects. It provides insight into the historical development of landscapes and the cultural practices that have shaped them and also highlights areas of ecological

importance and helps understand habitats and species distribution. In addition, it monitors changes in the landscape over time, identifying trends and possible future changes.
For these reasons, landscape characterisation can also be applied in different ways. For example, it helps in the development of policy that protects and improves the landscape character and guides sustainable development. It can also be used in environmental impact assessments to evaluate the effects of proposed developments on the landscape character. A characterisation supports the development of sustainable tourism by identifying and promoting landscapes of high aesthetic or cultural value. It also helps plan recreational activities and facilities that are consistent with and enhance the landscape character. And like mentioned before, it can be of great use to spatial planners. There are many other things for which characterisation can be useful. So in general it is an important concept for many purposes. It is therefore important to make a good landscape characterisation.

8 CONCLUSION

In the Danish municipality of Odsherred, 36 landscape character areas can be distinguished, along with four transition zones and two subzones whose character is not distinct enough from the area they belong too, despite being noticeably different. Each landscape area has a distinct character that makes it unique and different from all the other landscape areas. These are internally homogenous. This study has shown that Odsherred is a diverse region, with a lot of different landscape types including summerhouses, cities, forests, a lagoon, wetlands, a nature reserve and different kinds of agricultural landscapes like the flat reclaimed land and the hillier areas on the ridges. But locations with the same landscape type can still have a different character. Some of the borders of the landscape character areas can be very clearly defined, like with a complete change in land use, sudden major elevation changes and waterways. With some areas, the borders are vaguer, which is the reason transition zones were added to the final map. There, it is clear that there is a difference between both areas, but there is no hard border that can be drawn between them.

To make this landscape characterisation, the Flemish methodology was used. This was specifically designed for Flanders, so as became clear during the research, this method could

not be applied perfectly to the Danish municipality. Part of the reason for that is a lack of certain data. The base maps are the pillars of this method and define the whole research and thus the result. However, the importance of each these maps can differ depending on the study area. The water map was not used much compared to the other maps as it wasn't found to be very useful during much of the research. This is perhaps due to the lack of major waterways in Odsherred compared to Flanders. The historical maps also didn't influence the final result, mostly due to a lack of a detailed historical map like the map of Ferraris in Flanders. It can be concluded that the Flemish method can be used in other places, as long as the researchers are well aware of the major elements that define the landscape in their study area and that this has an influence on the method.

9 REFERENCES

Afgørelse i klagesag om Odsherred Kommunes afgørelse om, at fremstilling og salg af smykker, ikke kræver landzonetilladelse, samt om landzonetilladelse til p-plads, på [A1], Hørve. (2022, April 19). Naevnenes Hus. https://pkn.naevneneshus.dk/afgoerelse/de5d4047-5740-4271-b8b0-57563c3933f3

Council of Europe Landscape Convention. (2000). In Council of Europe. Council of Europe. https://rm.coe.int/16807b6bc7

Gniben og Sjællands rev. (n.d.). UNESCO Global Geopark Odsherred. Retrieved June 15, 2024, from https://geoparkodsherred.dk/odsherred/gniben-og-sjaellands-rev/

Landscape character area. (2022). Designing Buildings. https://www.designingbuildings.co.uk/wiki/Landscape_character_area

Levin, G. (2024). *Basemap.* Aarhus University. Departement of Environmental Science. Consulted via https://envs.au.dk/en/research-areas/society-environment-and-resources/land-use-and-gis/basemap

Misachi, J. (2018, May 10). The most extreme points of Denmark. WorldAtlas. https://www.worldatlas.com/articles/the-most-extreme-points-of-denmark.html

Odsherred Kommune. (n.d.) *Nøgletal: Se nøgletal og fakta om Odsherred Kommune.* Consulted on the 12th of June 2024 via https://www.odsherred.dk/da/foelge-politik-og-udvikling/okonomi-og-resultater/noegletal/

OpenStreetMap contributors. (2015) Planet dump [Data file from 2024 of database Geofabrik]. Retrieved from https://planet.openstreetmap.org.

Tudor, C. & Natural England. (2014). An approach to landscape character assessment. https://assets.publishing.service.gov.uk/media/5aabd31340f0b64ab4b7576e/landscape-character-assessment.pdf

UNESCO Global Geopark Odsherred. (n.d.a) *Korelve.* Consulted on the 16th of June via https://geoparkodsherred.dk/odsherred/korelve/

UNESCO Global Geopark Odsherred. (n.d.b) *Landskab.* Consulted on the 16th of June via https://geoparkodsherred.dk/odsherred/landskab-1/

Van Eetvelde, V., Foré, P., Boussaert, J., Herpels, J., Terryn, E., & Dabaut, N. (2024). *Methodologie voor landschapskarakterisatie in Vlaanderen*. Commisioned by Departement Omgeving, Vlaamse Landmaatschappij, Agentschap Onroerend Erfgoed, Agentschap Natuur en Bos and Team Vlaams Bouwmeester.

FACULTEIT WETENSCHAPPEN

OPLEIDING: Master of Science in de geografie en geomatica

REWETTING LANDSCAPES IN ODSHERRED: RESTORING NATURE'S CARBON SINKS

Aantal woorden: 7636

Bo Van Wetter, Bran De Schuytter, Marijke Van Cappellen, Glenn Desplentere & Ellen Timmermans

Stamnummers: 02200435, 0200384, 02300791, 02003634 & 02106022

Verantwoordelijke lesgever: Prof. dr. Veerle Van Eetvelde, vakgroep geografie

Opleidingsonderdeel: Geïntegreerd internationaal projectwerk

Academiejaar: 2023 - 2024

UNIVERSITEIT GENT

INHOUD

1 INTRODUCTION

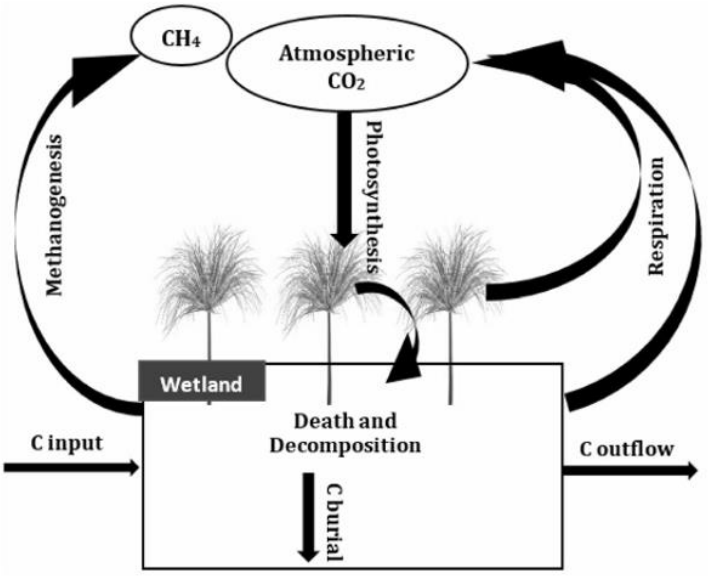
Peatlands, occupying a mere 6% of the Earth's terrestrial surface, exert a major influence on the global carbon cycle. These ecosystems play an important role in carbon sequestration, with natural peatlands acting as significant carbon dioxide (CO_2) sinks, capturing an average of 25 grams of carbon per square meter annually (Schrier-Uijl *et al*, 2014). However, anthropogenic activities, particularly agricultural practices, and drainage, have drastically altered the carbon dynamics of peatlands, transforming them from carbon sinks to sources of greenhouse gases (GHGs).

Carbon sequestration in wetlands refers to the process by which atmospheric CO_2 is captured and stored in wetland ecosystems, preventing it from re-entering the atmosphere and contributing to the greenhouse effect. Wetlands, characterised by waterlogged conditions, play a vital role in this process through a series of biogeochemical mechanisms. Primarily, wetland vegetation, including emergent, and submerged plants, facilitates carbon sequestration through photosynthesis. During photosynthesis, these plants absorb atmospheric CO_2 and convert it into organic carbon compounds, which are then incorporated into their tissues. As organic matter accumulates in wetland soils, it undergoes partial decomposition under anaerobic conditions, leading to the production of methane (CH_4) and CO_2. However, due to the waterlogged and anoxic nature of wetland soils, much of the organic matter remains undecomposed and is eventually buried, effectively sequestering carbon for extended periods. Additionally, wetlands act as sinks for organic carbon inputs from adjacent terrestrial and aquatic sources, further enhancing their capacity for carbon storage (Were *et al*, 2019). Figure 1 displays a simplified visualisation of the GHG exchange between wetlands and the atmosphere.

Drainage leads to oxidation of peat and subsequent release of stored carbon into the atmosphere. Moreover, the intensification of agricultural activities exacerbates GHG emissions, particularly CH_4 and nitrous oxide (N_2O), through the application of chemical fertilisers and manure (Schrier-Uijl *et al*, 2014).

Figure 1

Schematic Visualisation of Carbon Exchange in Wetlands



Note. Adapted from *Earth Systems and Environment* (p.329), by Were, D., Kansiime, F., Fetahi, T., Cooper, A. & Jjuuko, C., (2019), Springer (https://doi.org/10.1007/s41748-019-00094-0)

In the context of Denmark's National Inventory Report (2020), efforts to mitigate GHG emissions from agricultural peatlands have gained prominence, with rewetting emerging as a promising strategy. By restoring wetland ecosystems, Denmark aims to reduce carbon loss and nutrient discharge (Nielsen *et al.*, 2020).

Multiple variables have been identified as influencing factors in the exchange of GHG in peatlands. Tiemeyer *et al.* (2016) emphasises the significance of the mean annual ground water table, highlighting its role in regulating GHG emissions. This finding underscores the potential efficacy of rewetting strategies, which involve raising the water table to the surface level, as a mitigation measure. However, findings from a study conducted in Denmark by Elsgaard *et al.* (2012) offer a contrasting perspective. Their research suggests that temperature serves as a more robust indicator of GHG exchange dynamics. Particularly because temperature emerged as a primary driver of ecosystem respiration in their study, overshadowing the influence of water table depth. Notably, their study focused exclusively on drained grounds with a low groundwater table (GWT), suggesting that the observed temperature dependence does not necessarily contradict the potential reduction in CO_2 flux associated with rewetting efforts. Schrier-Uijl *et al.* (2014) found a strong decrease in CO_2 for rewetted sites in the Netherlands compared to similar sites in agricultural use. However, it is important to

note that an increase in CH_4 was also found. This effect is expected to be reduced over time when the rewetted ecosystem stabilises. This stabilisation would reduce both the CO_2 uptake and CH_4 emission.

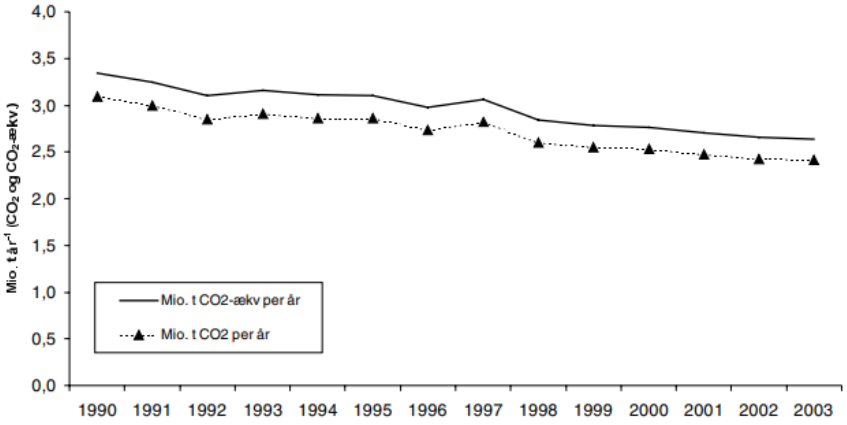
To further explore the potential benefits of rewetting in peatlands, this research aims to identify the most suitable areas for wetland restoration in the municipality of Odsherred, Denmark. This study is guided by the following main research question: Which areas in Odsherred are the most suitable for rewetting? And two sub-research questions: Which factors affect the storage and release of greenhouse gases in the suitable areas? And what is the impact of raising the groundwater table on greenhouse gas storage and release in the suitable areas? By addressing these questions, the study seeks to provide a comprehensive understanding of how rewetting can optimise carbon storage and thus mitigate adverse environmental impacts. The findings will inform local and national strategies for sustainable land management and climate change mitigation in Danish peatland ecosystems.

2 SITUATION IN DENMARK

Gyldenkærne *et al.* (2005) calculated the total net CO_2 emission based on land use and land use change (LULUCF) for Denmark. The calculations included factors such as the restoration of wetlands and changes in groundwater levels in certain agricultural areas. In 1990, a total net emission of 3.3 million tons of CO_2 was estimated. By 2003, the emission had been reduced to 2.6 million tons. The decrease was attributed to a reduction in total agricultural area, but the restoration of wetlands since 1998 also contributed to the decline. In total, the restoration of wetlands would have caused a reduction of 0.06 million tons by 2003. This decline is expected to continue in the future due to an increase in the number of restored wetlands. The decrease is attributed to the implementation of wetlands and 'Miljøvenlige Jordbrugsforanstaltninger' (MVJ) schemes. The MVJ schemes, or the Environmentally Friendly Agricultural Practices, provide subsidies for reducing nitrogen consumption, maintaining grasslands, and increasing water levels to create wetlands and so on. A rise in the water level is usually implemented by clogging drainage pipes and damming ditches. The MVJ schemes provide subsidies for raising the water level for 20 years. After the 20-year period, it is assumed that the areas will be so moist that they will no longer be used for agricultural purposes. In 2003, agreements were made to establish 38 wetlands, covering a total area of 4792 hectares.

Figure 2

Total emission of CO_2 by LULUCF from 1990 to 2003



Note. Adapted from *Opgørelse af CO2-emissioner fra arealanvendelse og ændringer i arealanvendelse* (p.72), by Gyldenkaerne, S., Münier, B., Olesen Jorgen, E., Olesen Svend Elsnab, & Christensen Bent T., (2005), Danmarks Miljøundersøgelser, p72 (http://www2.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/rapporter/AR213.pdf)

According to Gyldenkærne S. *et al.* (2005)., 3279 hectares of the total 4792 hectares of wetlands are used as agricultural land, resulting in a total percentage of 68%. These data are from several years ago and may have changed since then. Nevertheless, the figures indicate that a large portion of the wetlands in Denmark is being drained. As indicated, draining wetlands has a significant impact on emission output. To meet the requirements of the Paris Agreement, Denmark has already re-wetted several areas using the MVJ schemes.

Farmers in Denmark already receive a one-time compensation when they change land use through rewetting. There is also a financial scheme to explore the possibilities of rewetting specific peatland areas and to provide support for the actual rewetting process. Additionally, Denmark is the only country where plans are already underway to implement an eco-scheme. This means that farmers would be compensated for planting grass on drained peatlands, with the grass being harvested to remove nutrients. This allows the land to be flooded with reduced emissions of nitrogen and methane. While the program is currently based on annual commitments, it would be better if it obligated farmers to long-term extensification and required the eventual rewetting of the area. Without these enduring commitments, the efforts to restore and protect peatlands are at risk of being half-hearted (BirdLife Europe and the European Environmental Bureau, 2022).

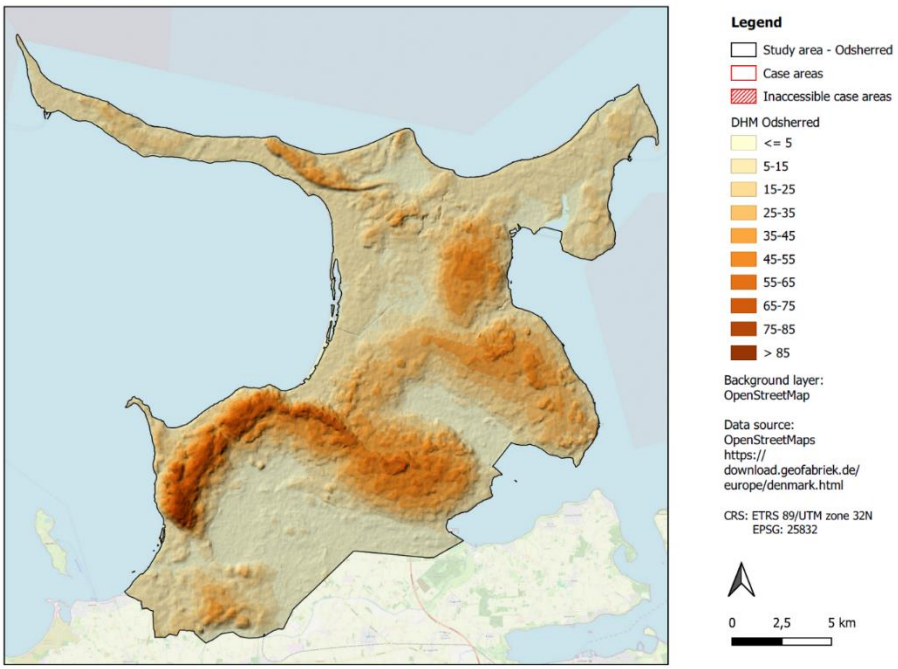
3 MATERIALS AND METHODS

3.1 Study area

The study area consists of the municipality of Odsherred, located on the northwestern side of the Zealand Island of Denmark. The municipality was established in 2007 through the amalgamation of Dragsholm, Trundholm, and Nykøbing-Rørvig. The economy is heavily reliant on tourism, with approximately 24 000 second homes, making it a prominent destination for seasonal residents. These holiday houses are mostly located along the extensive coastline, which is 157 km long. Besides tourism, the economy is also driven by the relatively substantial agricultural sector, though local production remains limited (Werther, 2022).

Figure 3

Study area – municipality of Odsherred



The landscape is strongly marked by the geological origin of the area, shaped during the Weichselian glaciation period. The landscape's geomorphology was influenced by the formation and movement of glaciers, resulting in the creation of terminal moraines. These moraines were formed by advancing glaciers that displaced sediment and rocks, forming ridge-shaped hills ahead of their movement. Adjacent to the glaciers, meltwater sediments accumulated in outwash plains. During the late-glacial phase of the Weichselian period, as glaciers began to retreat, they left behind these moraines, which now form prominent features within the landscape (Odsherred Commune & NIRAS, 2012). The glacial melting caused a glacio-isostatic rebound across

the region, and a rapid rise in sea levels from the discharge of meltwater. Initially, the isostatic rebound outpaced the sea-level rise, resulting in elevated terrain. However, during the final stages of the melting phase of the Laurentide ice sheet (8.5-8.3 ka BP), sea levels surged rapidly (Stattegger & Leszczyńska, 2023). The escalating sea levels inundated portions of the outwash plains and lower-lying areas, submerging them beneath the Littorina Sea, which deposited marine sediments. Concurrently, the continuing isostatic rebound initiated a coastline recession to its present-day configuration. Remnants of the glacial era, including moraines, fjords, and erratic boulders, among other features, persist as relicts within the contemporary landscape.

History of peat extraction and drainage (Denmark)

Pollen analyses have shown that the exploitation of peatlands began in the Iron Age (1000-800 BCE). This likely occurred because forests quickly disappeared due to wood cutting for fuel and the expansion of agricultural land. Peat was dried and served as an alternative fuel to charcoal. Research has shown that peat yields a more efficient return in iron smelting, explaining why peat extraction became increasingly common in the Iron Age (Moesgaard Museum, w.d.). During that time, peatlands were not only used for peat extraction but also served as sacred places. Over time, they lost this significance and were further degraded, either through drainage or extensive peat extraction. In the mid-19th century, underground drainage began in Denmark (Mortensen, 1986). It is estimated that about 80% of the total land area has been affected by drainage, with only four percent of the land still covered by bogs and wet meadows. Many lakes and waterways disappeared due to drainage (Gyldenkaerne *et al.,* 2005). Today, the remaining peatlands in Denmark are valued and protected as unique habitats between land and water (Moesgaard Museum, w.d.).

The Lammefjord is a polder in Denmark at the base of the Odsherred peninsula. Previously a deeply branched arm of the sea leading west from the Isefjord, the fjord was dammed starting in 1873, and continuing in stages until 1943. The staged development of the area created a large open landscape with large plots of intensively cultivated fields. The soil differs based on how deep the area lays beneath the sea level. In the zone between 0 and –3 m sand, clay, and stones were deposited. The zone between -2 and -5 m consists of fertile dune soils (Odsherred Commune & NIRAS, 2012).

3.2 Methodology

Our methodology is structured into two main phases: desktop work and fieldwork. The desktop work involves a multi-criteria analysis (MCA) using QGIS 3.32, to identify potential locations for wetland restoration. Suitable locations should have the greatest potential for carbon capturing. The fieldwork then focuses on gathering additional data and validating our findings from the MCA. An overview of the data used over the entire project can be found in Table 3.

3.2.1 Desktop Analysis

The MCA integrates various variables to produce a single outcome in the form of a suitability map. First all the variables were selected that were useful for the research, based on a literature study and the available data. An overview of these variables or factors is given in Table 1. As there is no qualitative dataset available on the groundwater table, it could not be included in the initial MCA. Ideally, the groundwater table should be included in the analysis. The variables land use and wetness index both include a constraint. Build areas and areas with a wetness less than 8.12 are excluded from the analyse. The 8.12 threshold was based on the minimum average value of the wetness index in today existing wetlands in Odsherred.

Table 1

Factors and their weights

Factors	Weight
Land use	0,21
Wetness index	0,21
Carbon	0,16
Nitrogen	0,13
Waterway proximity	0,13
Wetland proximity	0,08
Phosphorus sorption capacity	0,08

In the next step, all factors were standardised to a value of 0 to 1. The closer the value is to 1, the higher the suitability for rewetting. For example, a high nitrogen value will have a value closer to 0 because it lowers the suitability for rewetting. Both nitrogen, waterway proximity, wetland proximity, and phosphorus sorption capacity were inversely linearly standardised. This means high values were standardised towards 0 and low values towards 1. For proximity, a buffer of 100 meters was created around the wetlands and waterways, as rewetting often involves blocking ditches and drainage pipes nearby.

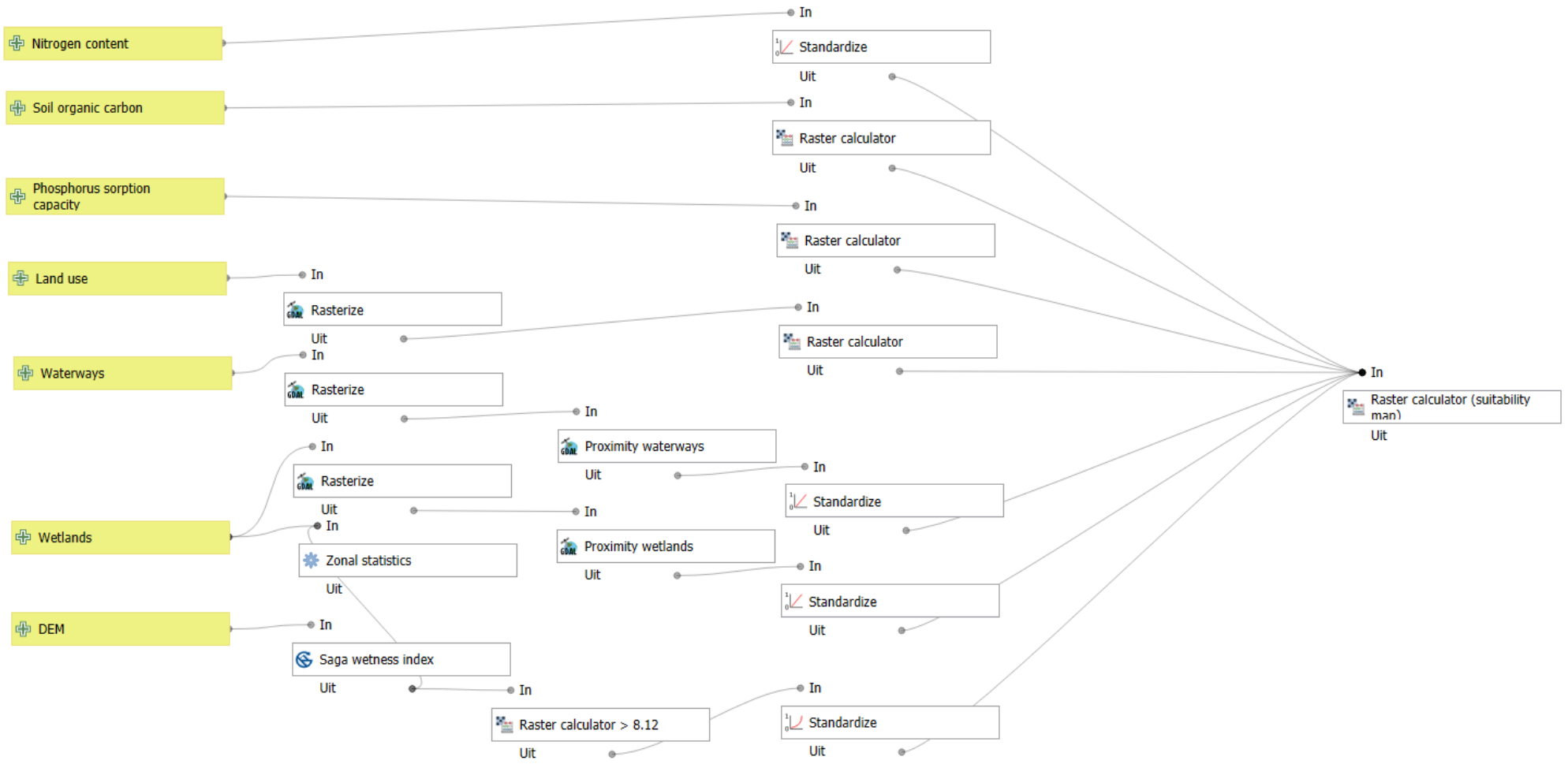
The wetness index was logarithmically standardised because only at higher value does the suitability for rewetting significantly increase. The carbon content is standardised manually. The carbon content was subdivided into >6% carbon and >12% carbon, which were standardised to 0.5 and 1, respectively. Values lower than 6% got value 0. According to Danish guidelines for rewetting, at least 75% of the area must contain at least 6% carbon (Rosendahl *et al.*, 2021), but this was challenging to verify in the suitability analysis. For land use, forest, pasture, grassland, and nature reserves were assigned a value of 1 because these land uses have less disturbed soil, increasing suitability for rewetting. Other land uses, such as arable land and orchards, were assigned a value of 0.5. The built-up areas are used as a constraint. Figure 4 provides a clear overview of the various steps undertaken in the MCA. Soil organic carbon, phosphorus sorption capacity, and land use were standardised using the raster calculator because these were WMS layers or were standardised per category.

In the next step, weights were assigned to the factors because some factors are more important for rewetting than others. The weights were determined using an Analytical Hierarchy Process, with the relative importance established based on a literature review. The weights for each factor are shown in Table 1.
Formula 1 shows the algorithm entered into the raster calculator. First, the sum of all factors multiplied by their corresponding weights was calculated. This sum was then multiplied by the constraints of built-up areas and a wetness index <8.12. Since these areas received a value of 0 from the raster, they are eliminated from the suitability for rewetting. In this calculation, 7 factors and 2 constraints were used, resulting in n=7 and m=2.

$$S = \sum_{i=1}^{n} w_i f_i \prod_{j=1}^{m} c_j \quad (1)$$

Figure 4

Cartographic model of the MCA



3.2.2 Fieldwork

The fieldwork consists of a series of measurements and observations to gather additional data and validate the findings from our desktop analysis. This involves assessing the selected areas identified as suitable for wetland restoration based on the results of the MCA. During fieldwork, various methods are employed to collect on-site data, including measuring bulk density and estimating the groundwater table. Bulk density measurements are conducted by taking soil cores of a known volume and weighing the soil matter after drying it in an oven. The soil samples are taken with cylinders having an average height of 51 mm and average diameter of 50 mm, which brings the average volume of the coring cylinders to 100.138 cm^3. The difference in volume between these cylinders is negligible. The dry weight of the soil is then divided by the original volume to find the bulk density. Additionally, the height of the groundwater table is identified by observing signs of oxidoreductase, such as orange/red spots in the soil matrix, during soil coring. This can be used to estimate the CO_2 capturing potential using the formula (2) below, from Liu *et al.* (2020). Coring also allows for an estimation of the thickness of the organic or peaty layer. The employed sampling method for selecting coring locations within the case study areas, is strategic sampling, more specifically stratified random sampling. This allows for maximal information gathering with minimal resources, because not every point in a grid needs to be targeted, as well as some flexibility, which can be useful to avoid trespassing on private property.

$$Net\ annual\ CO_2\ fluxes\ =\ 752\ \times\ MWL\ -\ 4750 \quad (2)$$

The height of the oxidoreductase could be used as a proxy for the groundwater table, allowing it to be implemented in the MCA. This analysis can, of course, only be conducted in the two case study areas. Since a new factor was added to the MCA, the weights of the factors had to be adjusted (Table 2). By re-running formula 1, where there are now 8 factors, a new suitability map for the two areas was obtained.

Table 2

Factors and their adjusted weights

Factors	Weight
Land use	0,19
Groundwater table	0,19
Carbon	0,14
Wetness index	0,11
Nitrogen	0,11
Waterway proximity	0,11
Wetland proximity	0,07
Phosphorus sorption capacity	0,07

3.2.3 Data

Table 3

Parameters

Parameter	Resolution	Type	Source
Soil Organic Carbon	30 m	Discrete	Miljoegis
Phosphorous binding capacity (> 25cm)	30 m	Discrete	Miljoegis
Land use	0.1 m	Nominal	Openstreetmap
Ground Water Table			Data.geus.dk
Nitrogen	400 m	Continuous	Miljoeportal
DEM	25 m	Continuous	UGent
Saga Wetness Index	25 m	Continuous	Calculated from DEM (SAGA Wetness Index)
Wetlands	0.1 m		Datafordeler Denmark
Waterways	0.1 m		Openstreetmap (waterways)/ Datafoldeler Denmark (ditches)
CO_2 (via GWT)			Calculated from GWT
Thickness Organic Layer			Terrain
Bulk density			Terrain
Estimated GWT			Terrain

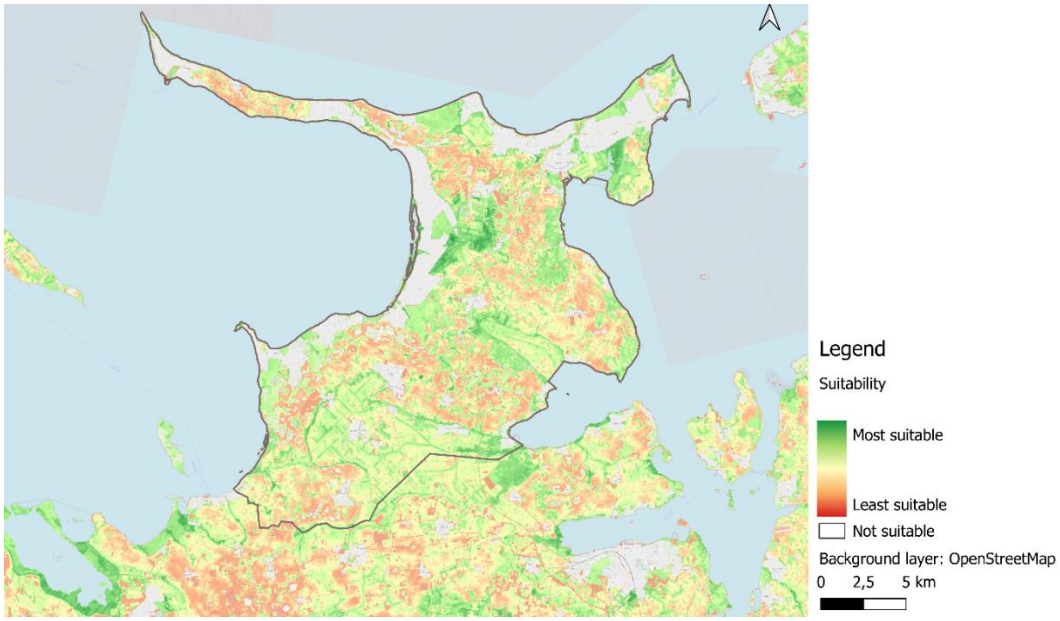
4 RESULTS

4.1 Suitability map

Figure 5 shows the degree of suitability for rewetting in colour gradations from red (least suitable) to green (most suitable), with completely unsuitable areas marked in grey. The northwestern horn (north) of Odsherred shows mainly red and grey areas, with some scattered green areas. More central to the northern coastline, there is a green zone to the southeast and southwest of Klint. More green areas are present in the northeastern horn, mainly along the coastline but also more inland. For instance, west of Nakke there are green and yellow areas. Centrally inland, the area of Trundholm Mose is very suitable (dark green). Another large contiguous suitable area (green and yellow) is located along the Lammefjord floodplain and extends almost to the far west of the municipality. Furthermore, the western and northern edges of Lammefjord show mixed suitability with both green and red areas with predominantly unsuitable areas. At the large bay, the Sejerø Bugt, on the west coast of Odsherred, the coastline shows only a few green areas. Notable, the west coast and further inland is not suitable for rewetting (grey zone). Areas north and south of the bay are also mainly unsuitable. The green zones are mainly present in low-lying areas and along coastlines. If we compare this suitability map with the altitude map (Figure 14), the red zones are mainly located in higher-lying areas. Figure 8 shows that all existing wetlands have relatively high suitability scores.

Figure 5

Suitability map for rewetting in Odsherred and surroundings



The map in Figure 6 provides a visual representation of the suitability for rewetting in Klinte Sø. According to the analysis before fieldwork, the northern and eastern parts of Klinte Sø have the highest suitability for rewetting. This corresponds to the highest potential for CO_2 storage as shown in Figure 12. The western and southern parts of Klinte Sø are higher in elevation and are marked as less suitable and therefore have a lower potential for CO_2 capture. Furthermore, the central area shows a mixed suitability with mainly green and yellow areas. Areas that are intensively used for agriculture can show clear lines where land use changes. These areas are often less suitable for rewetting because of the disturbances caused by agricultural activities. The green lines and patterns on the map may also correspond to the presence of existing waterways. Areas closer to waterways are more suitable for rewetting, as proximity to water increases rewetting potential. However, drainage systems can also cause red lines by making areas drier. Compared to the map 'after fieldwork', when the groundwater table was implemented, some red and orange areas, mainly in the south, have become more green and yellow. The red and orange zones have disappeared. This suggests that fieldwork data have shown that these areas are more suitable for rewetting than originally thought. The furthest north is less suitable than expected, as is the central area. Furthermore, the suitability zones are clearly defined. Thus, there is a stronger contrast between the yellow and green areas.

Figure 6

Suitability for rewetting in Klinte Sø

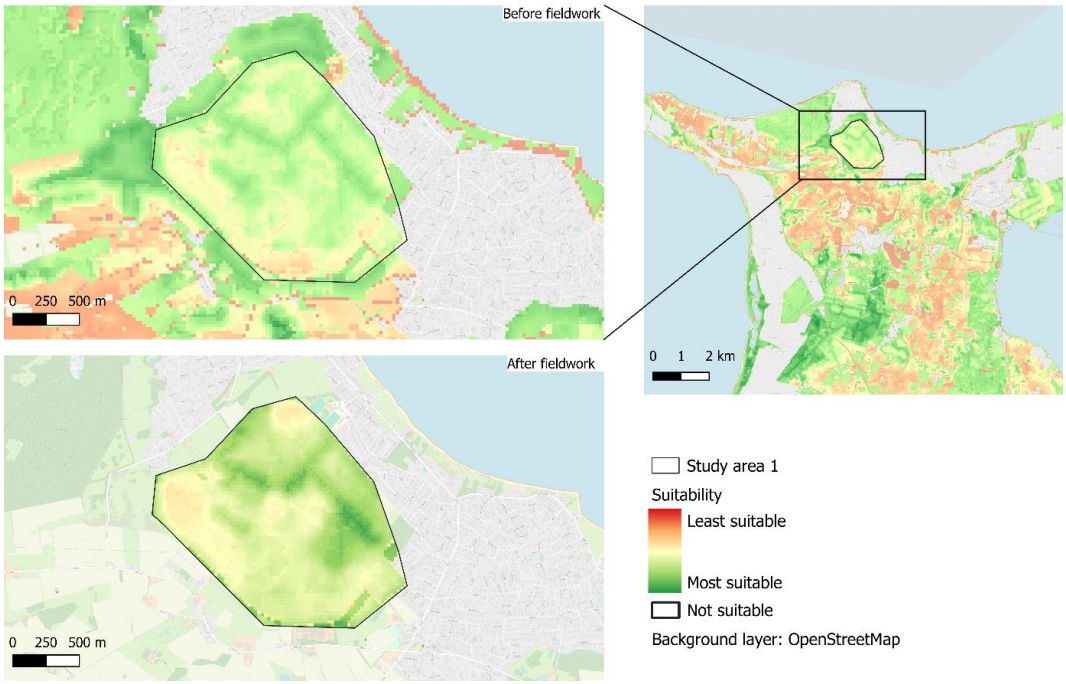


Figure 7 shows the suitability for rewetting in Trundholm Mose. This map reflects the impact of historical and current land use on the area. The northwestern part of Trundholm Mose, where active rewetting has already taken place, shows higher suitability. The central areas also show high suitability. Historically, this area was intensively used for agriculture, but activities have declined over the years. This has led to the development of grasslands and natural wetlands, which has improved suitability for rewetting, although the old drainage systems still have some influence. The central and northwestern areas have thicker organic layers, as shown in Figure 11. Figure 13 shows that Trundholm Mose has areas with high potential for CO_2 storage. The highest values for CO_2 storage are found just northwest of the centre, corresponding to the green areas on the suitability map. In contrast, the southern parts of Trundholm Mose show lower suitability for rewetting. These areas have a history of intensive agriculture, which has led to soil degradation and lower water retention capacity.

The 'after fieldwork' map generally shows more lighter green and yellow areas. At the southern edge of the area, there is a remarkably larger area of yellow and orange zones. This suggests that the fieldwork data has shown that some areas are less suitable for rewetting than originally thought.

Figure 7

Suitability for rewetting in Trundholm Mose

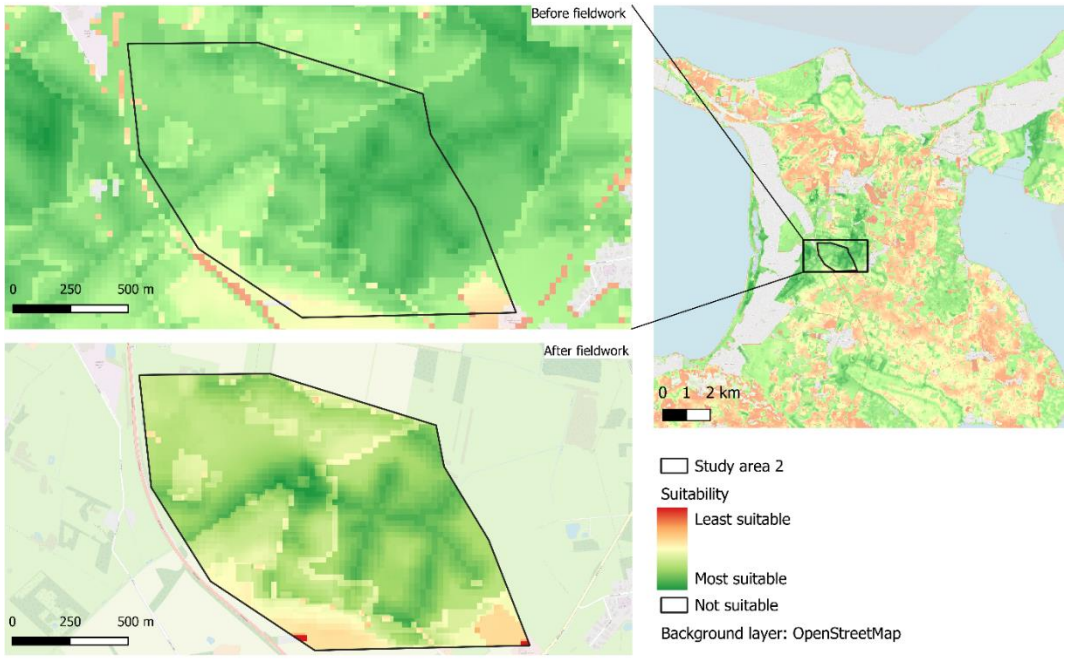
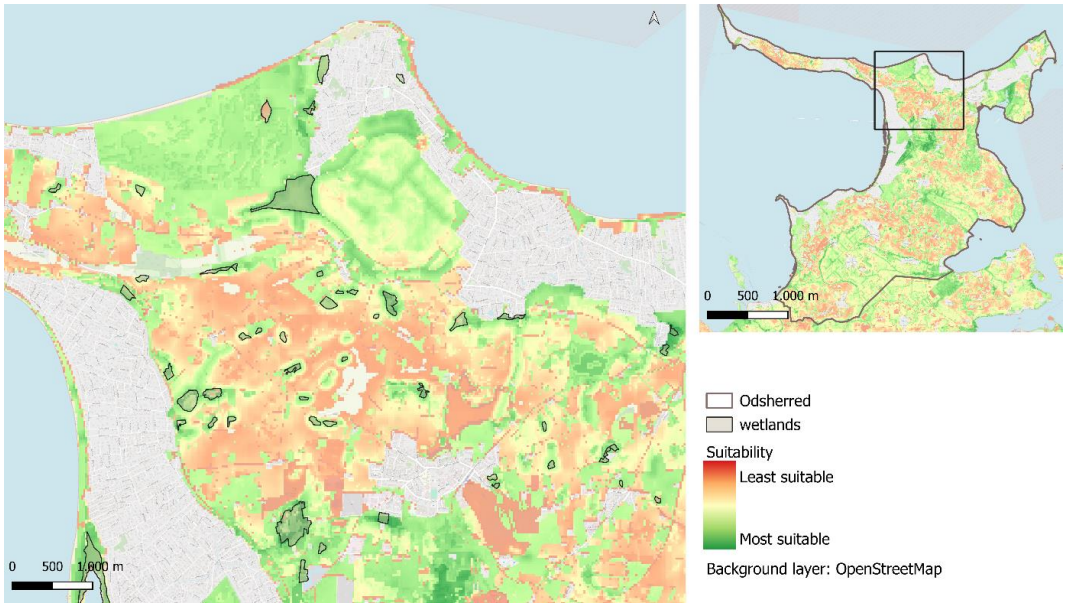


Figure 8

Existing wetlands in Odsherred



4.2 Auger borings

As described in the methodology, auger borings were conducted at various points in the landscape to provide further information on the soil profile, water table and local thickness of the organic layer. These measurements also provide information about the genesis of the landscape, which affects the properties of the soil. The drilling locations are shown in Figures 9 and 10. After the various variables were recorded at different drilling locations, they could be interpolated across the entire study area using QGIS 3.32. Figure 9 depicts the locations of the auger borings at Klinte Sø, while Figure 10 illustrates the locations at Trundholm Mose. The areas have a total of nineteen and sixteen samples, respectively. At Trundholm Mose, a concentration of five samples can be observed in the northwestern part of the area. This is due to the stratified random sampling method employed during the fieldwork. The small area of Trundholm Mose that has been rewetted differs in soil characteristics from the rest of the region. The remaining fourteen sampling points cover the rest of the region well geographically. At Klinte Sø, fewer measurements were taken than at Trundholm Mose, and the samples are also less well distributed over the area, resulting in large gaps in the geographic distribution of the samples.

Figure 9

Bore locations Klinte Sø

Figure 10

Bore locations Trundholm Mose

4.3 Thickness of the organic layer

In Figure 11, the thickness of the organic layer in Trundholm Mose is presented after interpolating the organic thickness at the different drilling locations. The thickness of the organic layer varies from 12 to 90 cm. The organic layer is thickest in the central area where farming activities have largely stopped and in the southwestern area where farming is still active. This does not apply to the entire area, only to certain places.

In the central area, the organic layer is thickest towards the southwestern area and vice versa. In the rest of the central and southwestern areas, the organic layer is quite thin. In the northwestern area of Trundholm Mose, which is actively rewetted (Figure 18a) the organic layer thickness ranges from 12 to 50 cm. Notably, in the western part of this area, the organic layer is thinner than in the eastern part of the area.

Figure 11

Thickness organic layer

4.4 Potential for CO_2 capturing

As explained in the methodology, the potential for CO_2 capturing was estimated using formula (2), as described by Liu *et al.* (2020), to find the emissions with the current groundwater table and with a groundwater table up to the surface. The emissions with a hypothetical groundwater table of zero were then subtracted from the current emissions to find how much could be gained from carbon sequestration. Places that currently have a low groundwater table will thus have more potential for rewetting. The potential CO_2 in kg ha^{-1} yr^{-1} that could be captured by rewetting, is visualised for Trundholm Mose and Klinte Sø in Figures 12 and 13, respectively. Overall Trundholm Mose has more extreme values for CO_2 capturing potential, ranging from only 7.520 kg ha^{-1} yr^{-1} to 75.200 kg ha^{-1} yr^{-1}. The highest values are found just off centre in the northwestern direction. The lowest values are found in the whole eastern part of Trundholm Mose. Spatially there is more variation in Klinte Sø, but in a more confined range, from 15. 040 kg ha^{-1} yr^{-1} to 48. 880 kg ha^{-1} yr^{-1}. The whole northwestern part of Klinte So has a relatively low potential. Higher values can be found in the western and the northern parts of the area, with the exception of the most northern part, which again has very low potential. The southern part of Klinte So has intermediate potential for CO_2 capturing by raising the groundwater table.

Figure 12

Potential amount of CO_2 that can be captured by rewetting in Klinte Sø

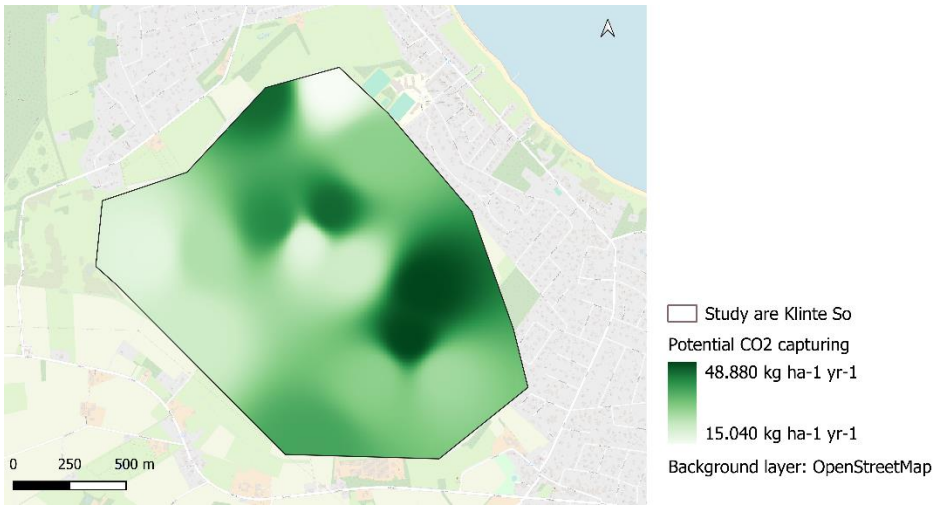
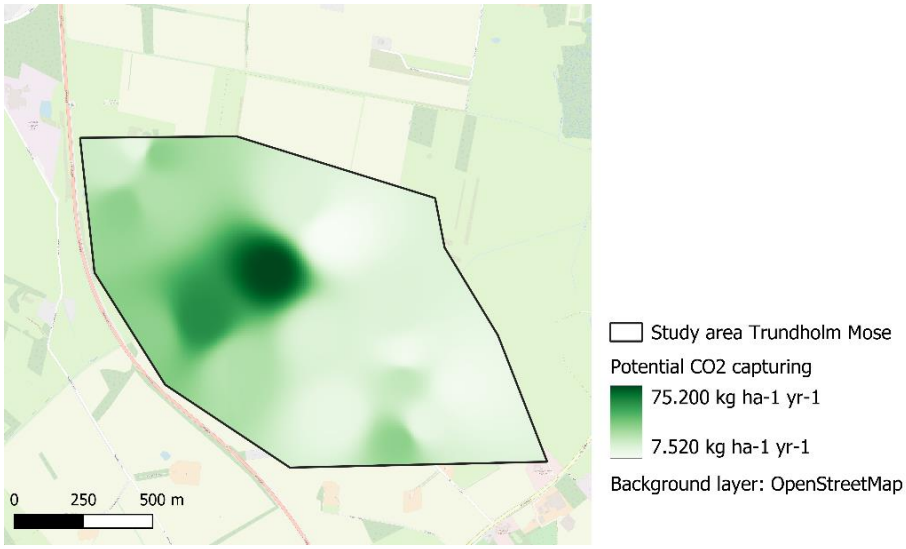


Figure 13

Potential amount of CO_2 that can be captured by rewetting in Trundholm Mose



4.5 Soil profiles

The soil profiles resulting from the on-site coring are divided into three areas. The Trundholm Mose area that was rewetted, the Trundholm Mose that is not rewetted, and Klinte Sø. For each area, an average soil profile was constructed. For the rewetted area of Trundholm Mose, the initial 30 cm of the profile consist of black organic material, beneath which lies a deep layer of coarse sand. The sand is characterised by high moisture content and a yellow-ochre colour. For the area of Trundholm Mose that was not rewetted, the layer of organic

material is on average slightly less deep, being only 25 cm. A layer of coarse sand, measuring between 25 cm and 1 m in depth, lies beneath the layer of organic material. The layer is slightly less wet and contains a greater quantity of organic matter, resulting in a light brown colour. A layer of very thick grey clay was observed to lie beneath a depth of 1 m.

In the case of Klinte Sø, the initial layer, which is approximately 50 cm deep, is composed of a loam and clay complex with the presence of small aquatic shells. The layer is characterised by a dry and light brown colour. The second layer, which is between 50 and 70 cm deep, is composed of a fine sand, loam, and clay complex with small aquatic shells. The complex exhibited slight moisture content and exhibited an orange hue. The third layer is characterised by the presence of wet coarse grey sand, which exhibits a higher degree of organic matter.

4.6 Bulk density

The bulk density, in conjunction with other soil properties and the groundwater table, provides an indicator of the amount of soil organic carbon present in the soil. As shown in Table 4, the total of sixteen field measurements were taken, divided into two areas. The study sites were Trundholm Mose and Klinte Sø. The Trundholm Mose area was further divided into two sub-areas: the rewetted area and the area that is currently not rewetted. This subdivision enables the effect of rewetting on the bulk density of the soil to be compared, thereby providing indirect information about the amount of organic carbon in the soil. Upon comparison of the three areas, certain aspects become evident. A comparison of the weight differences between the rewetted and non-rewetted areas of Trundholm Mose reveals an average weight of approximately 50 g for both. The rewetted area exhibits a weight of 50.975 g, while the non-rewetted area displays a weight of 49.243 g. The average for the Klinte Sø area is 30.373 g, which represents a considerable discrepancy when compared to the Trundholm Mose area. This difference is also evident in the disparity in bulk density, with the mean value for Klinte Sø being considerably lower than that of Trundholm Mose. The greater variation observed in the Trundholm Mose area can be attributed to the higher water content of these soils in comparison to those in the Klinte Sø area. The difference in bulk density for the Klinte Sø measurements is also very noticeable. In Trundholm Mose the range of the values is 0.160 g/cm^3 and 0.145 g/cm^3 for the rewetted and not rewetted area respectively. In contrast the range in Klinte Sø is 0.365 g/cm^3.

Table 4

Bulk density of soil measurements for Trundholm Mose and Klinte Sø

Location	Name point	Weight wet soil (g)	Weight dry soil (g)	Difference in weight (g)	Bulk density wet soil (g/cm^3)	Bulk density dry soil (g/cm^3)	Difference in bulk density (g/cm^3)
Trundholm Mose Rewetted	T1	128.380	81.930	46.450	1.282	0.818	0.464
	T2	114.320	54.570	59.750	1.142	0.545	0.597
	T3	147.660	102.170	45.490	1.475	1.020	0.454
	T4	161.820	116.540	45.280	1.616	1.164	0.452
Trundholm Mose Not Rewetted	B1	103.700	43.970	59.730	1.036	0.439	0.596
	B2	139.120	90.260	48.860	1.389	0.901	0.488
	B3	111.190	67.450	43.740	1.110	0.674	0.437
	B4	148.440	96.870	51.570	1.482	0.967	0.515
Klinte Sø Not rewetted	N1	138.340	121.480	16.860	1.381	1.213	0.168
	N2	170.290	142.000	28.290	1.701	1.418	0.283
	N3	160.340	114.540	45.800	1.601	1.144	0.457
	N4	146.630	108.010	38.620	1.464	1.079	0.386
	N5	133.980	93.540	40.440	1.338	0.934	0.404
	N6	148.630	119.890	28.740	1.484	1.197	0.287
	N7	132.100	97.150	34.950	1.319	0.970	0.349
	N8	153.400	144.120	9.280	1.532	1.439	0.093

5 DISCUSSION

5.1 Geographical variance of suitability

The suitability map for rewetting (Figure 5) reveals distinct spatial patterns of suitability across the municipality of Odsherred. Areas marked in green, indicating high suitability, are predominantly found in low-lying regions, old fjords and former lake beds. In contrast, areas marked in red, indicating low suitability, are primarily located in higher-lying regions. This section discusses the factors contributing to these patterns and the reasons behind the high suitability of old fjords and disappeared lakes.

The co-occurrence of multiple positive factors in these regions plays a significant role in their high suitability scores. Former lakes and fjords often contain higher amounts of peat and organic material due to their historical waterlogged conditions. Additionally, these areas are typically low-lying and close to existing water bodies, enhancing their potential for rewetting. The good agreement between the suitability map and existing wetlands further underscores this observation. While it could be argued that the factor 'proximity to existing wetlands might solely account for the high suitability scores, this factor was assigned a relatively low weight

in the MCA. Therefore, it cannot be the decisive factor. Existing wetlands are also often situated in low-lying areas with higher organic carbon content in the soil, contributing to their high suitability.

The fieldwork findings revealed that some areas, such as Trundholm Mose, had lower suitability scores than initially anticipated. This discrepancy is primarily due to the high groundwater table observed during field measurements, which reduces the potential for additional carbon capture. The absence of a qualitative dataset on groundwater table heights meant that this variable could only be incorporated into the MCA after fieldwork data had been collected. Consequently, areas with high groundwater tables demonstrated lower suitability for rewetting in the second MCA, as their capacity for increased carbon sequestration is limited.

5.2 Geographical variance of the thickness of the organic layer

The thickness of the organic layer can vary considerably depending on the environmental conditions under which it is formed. Beucher *et al.* (2020) identified four major groups that affect the thickness of the organic layer: topography, climate, soil, and vegetation. The topography group is primarily comprised of variations in elevation and slope, but also includes distances to rivers, seas, and ditches. The climate group is comprised of meteorological variables. The soil group encompasses variations in land cover, geology, and soil. The vegetation group comprises the various types of vegetation present in the study area. However, it is important to note that the formation of peat is highly variable and may vary significantly depending on small-scale localised differences.

Given the limited geographic extent of the Trundholm Mose study area, it is likely that the primary driver of peat formation is topographic variation, such as elevation. The central and southwestern parts of Trundholm Mose exhibit the thickest organic layer, which correlates with the lowest elevations on the digital elevation model (DEM). The northwestern part of the area is situated at a slightly higher elevation within the landscape, yet it exhibits a comparatively thin organic layer. Despite this, the area has been subjected to active rewetting since 2021. The eastern portion of the study area exhibits a slight upward slope, which is accompanied by a corresponding decrease in the thickness of the organic layer. The thickness of the organic layer is thus determined by the topography of the area, while the land use has a more limited effect.

5.3 Geographical variance of potential for CO_2 capturing

The potential for CO_2 capturing is only determined by the mean water level and two constants. Consequently, the potential is determined by the topographic influences that lower or raise the water table. The most significant impact of human activity on the water table is the creation of ditches to facilitate the drainage of groundwater to nearby rivers, lakes, or the sea. The construction of dams across ditches and the subsequent prevention of groundwater drainage allows for the creation of artificial wetlands. By utilising a theoretical groundwater table of 0 m, and subsequently comparing this to the actual water table in order to determine the potential, it can be observed that areas with a lower water table will have a higher potential to capture CO_2. It can be reasonably assumed that these areas will be situated in close proximity to the aforementioned drainage ditches.

5.4 Evaluation of bulk density and soil profiles

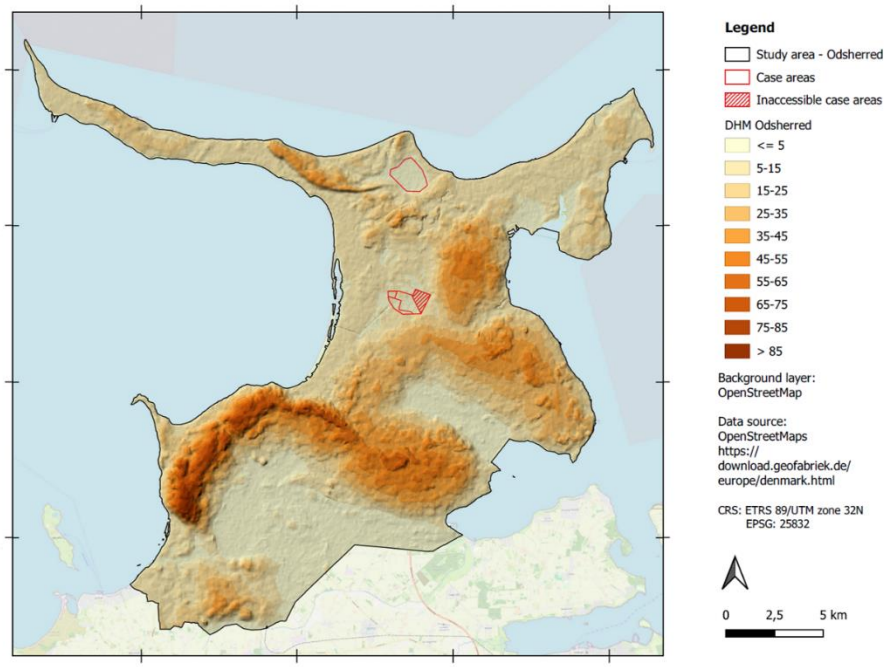
The bulk density and soil profiles of the three areas (Klinte Sø, Trundholm Mose rewetted, and Trundholm Mose non-rewetted) were aggregated to enable comparison between them. While the comparison provides interesting data about the areas, such as the small difference in bulk density between the rewetted and non-rewetted areas of Trundholm Mose, it also highlighted the need for larger and temporally more varied datasets to enable the use of statistical analysis. These limited datasets are a consequence of the constraints of the research project. Consequently, the research would be enhanced by the acquisition of larger and temporally more diverse datasets, which would permit the utilisation of statistical analyses to provide a more comprehensive representation of the relationships within the landscape.

5.5 Case study analysis: Trundholm Mose and Klinte Sø

In the study area, we have two major case areas, the northern area 'Klinte Sø' and 'Trundholm Mose'. Trundholm Mose can be divided into another four areas. The north-western area that has been actively rewetted since 2021, the southwestern area that consists mainly of farmland, the central area where farming activities have largely stopped, resulting in drainage pipes that are no longer well maintained, and the inaccessible area in the north-west.

Figure 14

Case areas – Klinte Sø and Trundholm Mose

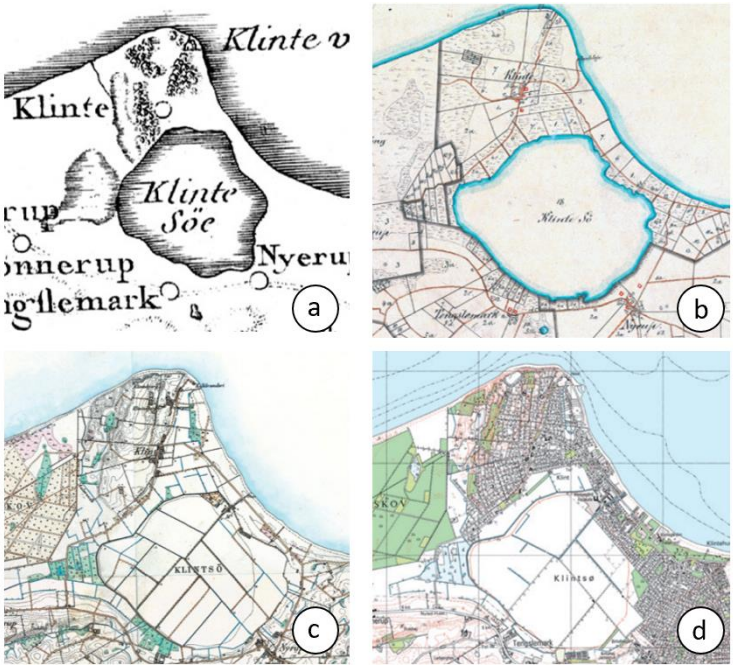


5.5.1 Klinte Sø

Klinte Sø was a lagoon lake (Figure 15a) of approximately 255 hectares in size. In 1856, it was sold at an auction in the town hall of Nykøbing. It was purchased by a speculator from Copenhagen named Jürgensen. In the same year, the lake was drained. The area is still drained today through the use of pumps. This is because the lowest areas are 2.8 meters below sea level (Hansen, 2019). The area divided into large parcels, and along the boundaries of these parcels, there are often rows of deciduous trees. Klinte Sø is intensively used for agriculture, with crops such as potatoes, carrots, rapeseed, silage grass, etc. (Figure 16). This is primarily rainfed arable cultivation. Given the intensive cultivation in this area, human influence is significant. Human influences include ploughing, raised beds, surface compaction, artificial drainage etc. The main landform within this case area is level land, more specifically a level depression. The bulk density in Klinte Sø in lower than that in Trundholm Mose. The difference in bulk density can be attributed, in part, to the origin of Klinte Sø, which is sediment deposition in lakes. Such depositions can vary significantly. Moreover, the measurements are distributed more widely, and the topography is more diverse, with some measurements taken on the slight slopes on the edge of the area.

Figure 15

Maps Klinte Sø – (a) 1771; (b) 1890; (c) 1897; (d) 1993



Note. Adapted from *Klintsø blev tørlagt af pengemand uden landboviden* (p.1), by Hansen K., (2019), Det tabte land (https://www.dettabteland.dk/sjaelland/klintsoe.pdf).

Figure 16

Land use Klinte Sø – Rapeseed, grass, carrots, etc.

5.5.2 Trundholm Mose

The origin of Trundholm Mose can be summarised as follows: During the Nordic Stone Age, the sea level reached its highest point in Trundholm Mose. Following this, 5000 years of climate change, storms, and sea floods led to the erosion of the Sejerø Bay. Large deposits of sand and gravel formed seawalls, isolating the inner part of the bay from the open sea. This resulted in the formation of a freshwater lake that later

transformed into a marsh due to the accumulation of plant material. These conditions favoured the formation of a carbon-rich, organogenic soil in an anoxic environment (Rosendahl *et al.,* 2021).

The marsh was drained in 1799 for arable farming and grazing (Odsherred Geopark, 2021). Throughout the 20th and 21st centuries, the intensive use of the land gradually decreased, leading to the development of grasslands and natural marshes. During these periods, smaller parcels were merged into larger ones, indicating a decrease in the number of landowners in the area (Rosendahl *et al*, 2021). This phenomenon is clearly observable in the central area of Trundholm Mose (Figure 18b and c). Here, large parcels of grassland with patches of deciduous shrubs, and these lands are often very wet. In the southwestern area, there is some farming, specifically rainfed arable cultivation. This area is most influenced by human activities. Human influences include ploughing, artificial drainage, soil compaction, etc. The difference in bulk density is only slightly different in the sub-areas of Trundholm Mose. The rewetted area of Trundholm Mose has a higher average bulk density of 1.7 g/cm^3 than the non-rewetted area, while the difference with Klinte Sø is approximately 20 g/cm^3. The difference in bulk density is mostly determined by the geographic evolution of the area.

Figure 17

Map Trundholm Mose 1862-1899

Note. Adapted from *Høje målebordsblade*, by Christensen, A. F. (w.d.), Dataforsyningen (https://dataforsyningen.dk/map/3577?fbclid=IwZXh0bgNhZWOCMTAAAR3bFgh0nvcPVuNW-eKc56qi-Xty8HZ39LFF1WGP5ao2V0aq6SRkBjYP-0_aem_AZDW_ir1Ire1EGzz8jd2YJ43b3Foy6LzrG452T39HIG1I_vWyw2Q3V61PtElHXLTBxoSyKGncjV9UjbTHDH7hfRc).

Figure 18

Trundholm Mose - (a) The northwestern area that has been actively rewetted; (b) and (c) The central area where farming activities have largely stopped

5.6 Evaluation of research methodology and constraints

In this study, we investigated which areas are the most suitable locations for rewetting in Odsherred, without focusing on planned rewetting projects. This allowed us to focus on smaller, more feasible areas for rewetting and conduct an analysis of the entire area. The feasibility was evaluated using a Multi-Criteria Analysis (MCA). The advantage of an MCA is that it considers several criteria or factors simultaneously.

The locations of the auger borings were determined by means of stratified random sampling. In contrast to the systematic approach employed by standard sampling methods, which collect soil data at fixed intervals, stratified random sampling takes contextual knowledge into account in order to identify the most optimal locations for measuring the soil, thereby ensuring the greatest possible representation (Brown, 2006). The method increases the representativeness of the samples by dividing the study area into different sub-areas based on characteristics that are of interest to the research. This method reduces the potential for sampling bias and improves the overall accuracy of the results (Howell *et al.*, 2020). The use of contextual data in stratified random sampling introduces a subjective element, thereby introducing bias to the analysis. However, if the variables and attributes are shared transparently, it can be made consistent with other research (Brown, 2006). This sampling technique is highly time-efficient and requires a smaller number of

samples to provide a higher degree of precision in heterogeneous regions than the standard sampling methods (Brown, 2006; Howell *et al.*, 2020).

The fieldwork was limited by several temporal and physical limitations. The fieldwork was severely constrained by time, with only three and a half days available for fieldwork. This limited timeframe was further constrained by travel time to and from the accommodation. Because of this limitation, no seasonal effects, on for example the ground water table, could be taken into account. When measuring the bulk density, temporal constraints meant that the soil samples could only be dried for 12 hours. However, all soil samples were dried for the same amount of time. Therefore, these findings in bulk density might not be comparable with measurements in other studies but the samples can be compared with each other. Additionally, some physical constraints limited the extent of the fieldwork. Firstly, some parts, such as the south-western part of Klinte Sø, were large fields that were being worked during the fieldwork and were therefore inaccessible. Furthermore, the terrain was traversed by extensive ditches, rendering certain areas inaccessible. Additionally, the south-eastern portion of Trundholm Mose is comprised of hunting grounds that were actively utilised during the fieldwork period. Other areas were partially flooded, making drilling impractical.

Another large limitation lies in the exclusion of certain important parameters in this analysis. Due to budget constraints as well as other practicalities, no direct measurements could be taken of the greenhouse gas emissions. These would have to be taken over a prolonged period of time, due to the strong temporal variability. Estimation of the emissions could also have been improved by monitoring the height of the groundwater table over the extend of multiple months, since formula 2 is actually based on the average annual groundwater table. If more time were available, this estimation of the emissions could be compared to a second estimation of emissions, based on the soil temperature, as ecosystem respiration is strongly dependent on temperature according to Elsgaard *et al.* (2012). This comparison would allow for the identification of possible biases associated with the estimation method. Another interesting variable that could have been included in this research, is the current amount of organic carbon present in the soil. The dataset that was used, is actually based on measurements that were done around ten years ago. Subtracting the current and previous amounts of soil organic carbon, could give an idea of how much carbon was emitted, as CO_2 or CH_4, over a ten-year period. However, the most important consideration that was left out of the evaluation, is the social economic aspect. Social factors, such as the involvement and needs of local communities, may influence proposed solutions. Furthermore, an analysis of economic aspects can help to assess the financial resources needed for long-term implementation. A rough approximation of the costs was

included, in the shape of the land use factor in the MCA. However, the social and economic consequences of rewetting should be researched more thoroughly.

Due to the aforementioned restrictions, only a limited number of observations could be made, which may have resulted in a reduction in the accuracy of the results. This may also be visible in the figures which visualise the thickness of the organic layer and the potential amount of CO_2 that can be captured by rewetting these areas. This is due to the presence of large hotspots for a specific value, caused by a limited number of samples with significantly higher or lower values. However, when considering a larger timeframe or the implementation of large-scale projects, such as those aimed at enriching digital soil maps, where a sufficient number of samples can be taken, random sampling is generally a suitable choice. This is due to the ease of implementation, the low cost of the method, the absence of assumptions to quantify standard errors, and the relatively precise estimate (Brus & Kempen, 2011).

6 CONCLUSION

This study aimed to identify the most suitable areas for wetland restoration in the municipality of Odsherred, Denmark, to optimise carbon storage and mitigate adverse environmental impacts. The analysis revealed that the most suitable locations for rewetting are primarily situated in the centre of the commune, around Trundholm Mose. Additional suitable areas were identified in old fjords and former lakes, such as the Lammefjord and Klintø Sø. These are areas characterised by specific conditions, such as the presence of soil organic carbon and a lower topography, that enhance their potential for carbon sequestration when rewetted.

Two critical factors influencing the suitability of these areas for rewetting were identified. First, the height of the groundwater table plays a significant role; areas with a lower groundwater table present more potential for additional CO_2 capture. This is due to the higher potential for carbon sequestration when the water table is raised, reducing the aerobic decomposition of organic matter. Second, the organic carbon content in the soil is crucial, as areas with high organic carbon content that remain drained, will continue to emit greenhouse gases. Rewetting these areas can mitigate these emissions and enhance carbon storage.

Raising the groundwater table in suitable areas is expected to result in both lower greenhouse gas emissions and increased carbon sequestration. This dual benefit underscores the importance of targeted rewetting strategies for mitigating climate change impacts.

7 REFERENCES

Beucher, A., Koganti, T., Iversen, B. V., & Greve, M. H. (2020). Mapping of Peat Thickness Using a Multi-Receiver Electromagnetic Induction Instrument. *Remote Sensing*, 12(15), 2458. https://doi.org/10.3390/rs12152458

BirdLife Europe and the European Environmental Bureau. (2022). *Peatlands and wetlands in the new CAP: too little action to protect and restore*. Retrieved on 5 may 2024, from https://eeb.org/wp-content/uploads/2022/04/Briefing-Peatlands-and-Wetlands-No-Branding.pdf.

Brown, A. (2006). Strategic sampling. In Springer eBooks (pp. 43–54). https://doi.org/10.1007/1-4020-3757-0_5

Brus, D., & Kempen, B. (2011). Sampling for validation of digital soil maps. European Journal Of Soil Science, 62(3), 394–407. https://doi.org/10.1111/j.1365-2389.2011.01364.x

Christensen, A. F. (z.d.). *Dataforsyningens Let adgang til data*. Dataforsyningen. https://dataforsyningen.dk/map/3577?fbclid=IwZXh0bgNhZWOCMTAAAR3bFghOnvcPVuNW-eKc56qi-dXty8HZ39LFF1WGP5ao2V0aq6SRkBjYP-0_aem_AZDW_ir1Ire1EGzz8jd2YJ43b3Foy6LzrG452T39HIG1I_vWyw2Q3V61PtElHXLTBxoSyKGncjV9UjbTHDH7hfRc

Elsgaard, L., Görres, C. M., Hoffmann, C. C., Blicher-Mathiesen, G., Schelde, K., & Petersen, S. O. (2012). Net ecosystem exchange of CO2 and carbon balance for eight temperate organic soils under agricultural management. Agriculture, Ecosystems and Environment, 162, 52–67. https://doi.org/10.1016/j.agee.2012.09.001

Gyldenkaerne, S., Münier, B., Olesen Jorgen E., Olesen Svend Elsnab, & Christensen Bent T. (2005). Opgørelse af CO2-emissioner fra arealanvendelse og ændringer i arealanvendelse. http://www2.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/rapporter/AR213.pdf.

Hansen, K. (2019). Klintsø blev tørlagt af pengemand uden landboviden. In *Klintsø Blev Tørlagt Af Pengemand Uden Landboviden* (pp. 1–10). https://www.dettabteland.dk/sjaelland/klintsoe.pdf.

Howell, C. R., Su, W., Nassel, A. F., Agne, A. A., & Cherrington, A. L. (2020). Area based stratified random sampling using geospatial technology in a community-based survey. BMC Public Health, 20(1). https://doi.org/10.1186/s12889-020-09793-0

Liu, W., Grootjans, A. P., Everts, H., Fritz, C., & de Vries, N. (2020). Estimation of greenhouse gas emission reductions based on vegetation changes after rewetting in drentsche aa brook valley. Mires and Peat, 26. https://doi.org/10.19189/MaP.2019.OMB.StA.1767

Moesgaard Museum. (w.d.). Peat cutting and bog finds. Retrieved on 4 may 2024, from https://www.moesgaardmuseum.dk/en/exhibitions/permanent-exhibitions/grauballe-man/the-bog/peat-cutting-and-bog-finds/?fbclid=IwZXhOBgNhZWOCMTAAAR37LPfg6YzlsIa8SvDhL-vPSWkUBBuJhzBGtrLdEn9l8XSnzwm5jC1f_zA_aem_Af6sZYyVlWi1lMtRqqTefTiNpCmExbBeWXq2mG66NNMfdTy5kP3_CS-2rgouN8cq_658DfhLRlvs6cZZZN5Mg6ZB.

Mortensen, J. R. (1986, November). Drainage in Denmark Developments and prospects for the future. In *Proceedings of the Symposium of the 25th International Course on Land Drainage: Twenty-Five Years of Drainage Experience, Wageningen, The Netherlands* (pp. 24-28).

Nielsen, O.-K., Pejdrup, M. S., Winther, M., Glydenkaerne, S., Mikkelsen, M. H., Alberktsen, R., Thomsen, M., Hjelgaard, K., Fauser, P., Bruun, H. G., Johannsen, V. K., Vesterdal, L., Callesen, I., Caspersen, O. H., Scott-Bentsen, N., Rasmussen, E., Petersen, S. B., Olsen, T. M., & Hansen, M. G. (2020). DENMARK'S NATIONAL INVENTORY REPORT 2020: Emission Inventories 1990-2018 – Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. http://dce2.au.dk/pub/SR372.pdf

Odsherred commune & NIRAS. (2012). Landskabskarakteranalyse Odsherred. Retrieved 01-05-2024 from Karakteranalyse van het landschap (e-pages.dk).

Odsherred Geopark. (2021). *Trundholm Mose*. https://geoparkodsherred.dk/odsherred/trundholm-mose/.

Rosendahl, E., Rust, J., Heines, M., Leperq, S., & Vandervelden, T. (2021). A Path to Climate Mitigation: Factors Hindering and Facilitating the Rewetting of Trundholm Mose.

Schrier-Uijl, A. P., Kroon, P. S., Hendriks, D. M. D., Hensen, A., van Huissteden, J., Berendse, F., & Veenendaal, E. M. (2014). Agricultural peatlands: Towards a greenhouse gas sink - A synthesis of a Dutch landscape study. Biogeosciences, 11(16), 4559–4576. https://doi.org/10.5194/bg-11-4559-2014

Stattegger, K., & Leszczyńska, K. (2023). Rapid sea-level rise during the first phase of the Littorina transgression in the western Baltic Sea. Oceanologia, 65(1), 202–210. https://doi.org/10.1016/j.oceano.2022.05.001

Tiemeyer, B., Albiac Borraz, E., Augustin, J., Bechtold, M., Beetz, S., Beyer, C., Drösler, M., Ebli, M., Eickenscheidt, T., Fiedler, S., Förster, C., Freibauer, A., Giebels, M., Glatzel, S., Heinichen, J., Hoffmann, M., Höper, H., Jurasinski, G., Leiber-Sauheitl, K., … Zeitz, J. (2016). High emissions of greenhouse gases from grasslands on peat and other organic soils. Global Change Biology, 22(12), 4134–4149. https://doi.org/10.1111/gcb.13303

Tiemeyer, B., Freibauer, A., Borraz, E. A., Augustin, J., Bechtold, M., Beetz, S., Beyer, C., Ebli, M., Eickenscheidt, T., Fiedler, S., Förster, C., Gensior, A., Giebels, M., Glatzel, S., Heinichen, J., Hoffmann, M., Höper, H., Jurasinski, G., Laggner, A., … Drösler, M. (2020). A new methodology for organic soils in national greenhouse gas inventories: Data synthesis, derivation and application. Ecological Indicators, 109. https://doi.org/10.1016/j.ecolind.2019.105838

Were, D., Kansiime, F., Fetahi, T., Cooper, A., & Jjuuko, C. (2019). Carbon sequestration by wetlands: a critical review of enhancement measures for climate change mitigation. *Earth Systems and Environment*, *3*, 327-340.

Werther, C. (2022). Leveraging Landscape: The First Four Years of UNESCO Global Geopark Odsherred. In V. Braga et al. (EDs.), Economics and Management of Geotourism (pp. 47-64). Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-89839-7_3

FACULTEIT WETENSCHAPPEN

MASTER OF SCIENCE IN GEOGRAPHY AND GEOMATICS

A TALE OF TWO LANDSCAPES

EVALUATING THE HIGH NATURE VALUE OF AGRICULTURAL AND REWILDED AREAS

Word count: 6.211

Jeanne Annendyck, Marie Dhondt, Lennert Van de Vyver, Emma Vanhaverbeke
Student number: 02312863, 02003605, 02103090, 01908212

Responsible lecturer: Prof. dr. Veerle Van Eetvelde

Assisting lecturers: MSc Lars De Sloover, Dr. Maite Dewinter, MSc Seppe De Wit, MSc Kiara Haegeman

Course: Integrated International Project Work

Academic year: 2023 - 2024

UNIVERSITEIT GENT

Roskilde Universitet

UNIVERSITY OF COPENHAGEN

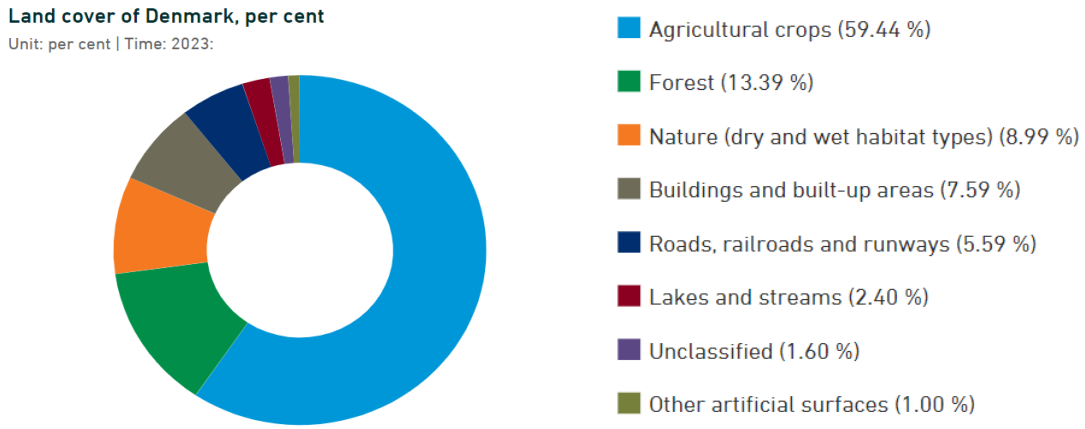
1. INTRODUCTION

1.1. Context of the research

Since the Middle Ages, European agricultural production has grown, leading to the gradual conversion of natural into agricultural lands (Strijker, 2005). Arable fields and pastures now cover almost 60% of Danish territory (Figure 1) (Statistics Denmark, 2023). This expansion of agriculture has improved food security and shaped cultural landscapes. Of the total agricultural activities in Denmark, half is occupied by intensive grain production (Figure 2) (Statistics Denmark, 2024). However, the conversion of natural areas into intensively cultivated lands and pastures has had a negative impact on biodiversity (Rey Benayas et al., 2007). Intensive agricultural practices, the industrialization of agriculture, and urbanization on the outskirts of cities pose risks to biodiversity (Vejre & Brandt, 2004). Habitat loss and fragmentation are caused by intensive agricultural practices, resulting in negative consequences for natural ecosystems and wildlife populations in cultivated areas. The impact of farmlands on biodiversity in Denmark is complex. Balancing agrarian production with environmental conservation is necessary to preserve natural ecosystems and diverse wildlife populations. Introducing conservation plans in areas with extensive agriculture can help minimize the negative impact on biodiversity (Ejrnaes et al., 2012).

Figure 1:

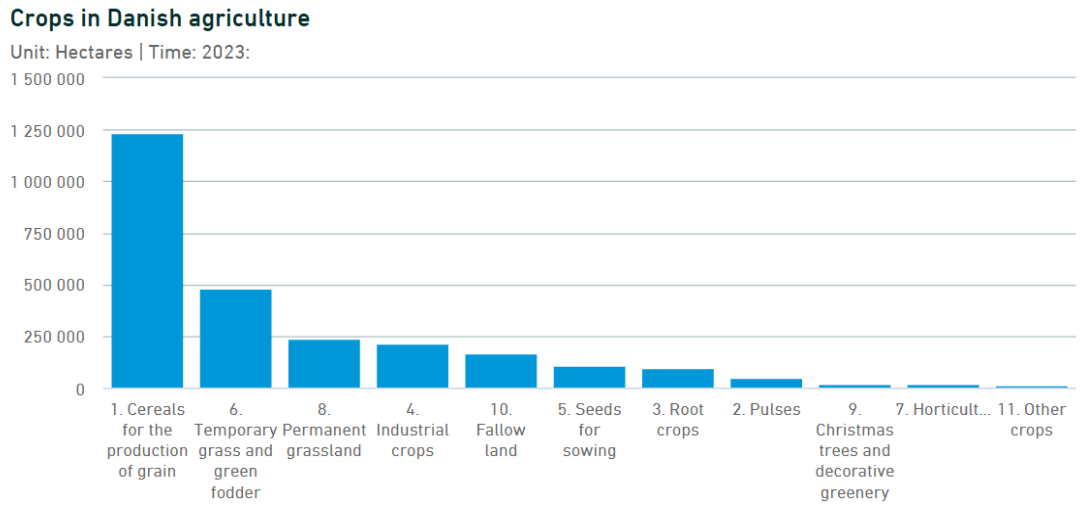
Land use distribution in Denmark



Noot. Acquired from *Land use accounts,* by Statistics Denmark, (2023), https://www.dst.dk/en/Statistik/emner/miljoe-og-energi/areal/arealopgoerelser.

Figure 2:

Crop distribution of agricultural production in Denmark



Noot. Acquired from *Cropland,* by Statistics Denmark, (2024), https://www.dst.dk/en/Statistik/emner/erhvervsliv/landbrug-gartneri-og-skovbrug/det-dyrkede-areal.

Small landscape elements play a crucial role in maintaining the balance between agricultural areas and biodiversity. These elements are small uncultivated areas with permanent or semi-permanent vegetation or the presence of water. Small landscape elements serve multiple purposes, such as providing habitats for wildlife, marking boundaries of agricultural parcels, and contributing to landscape beauty and cultural values of the landscape. The development and changes in small landscape elements over the years have had a significant impact on biodiversity in agricultural areas. The disappearance, establishment, and changes in the structure and density of these elements influence the availability of habitats and the survival and diversity of plant and animal species (Agger & Brandt, 1988). It is essential to include small landscape elements in monitoring agricultural areas to maintain biodiversity. Recording, protecting, and enhancing these elements ensures preserving biodiversity and maintaining healthy ecosystems (Hou & Walz, 2013).

The High Nature Value (HNV) farming indicator is used to analyze the balance between the natural environment and agricultural activities in agrarian areas. This indicator factors in the diverse natural elements and biodiversity within agricultural areas. A high HNV score suggests effective biodiversity conservation, indicating that agricultural activities are considerate of the natural environment. On the

other hand, a low HNV score suggests that agricultural practices are dominant and do not prioritize biodiversity conservation (Brunbjerg et al., 2015).

To monitor the biodiversity near agricultural lands, the HNV farming indicator score is calculated, and small landscape elements are mapped over time in two study areas (Figure 3). The first study area is an agricultural region measuring two by two km² located in Sønderød. Two Danish researchers previously mapped the small landscape elements of this agricultural area. The first mapping took place between 1981 and 1996, and the second mapping occurred between 2008 and 2015. This over twenty-year monitoring provides a clear representation of how the small landscape elements have changed over the years. In this study, the mapping was completed by further mapping the elements from 2015 to the present state.

The second study area is a nature reserve in Kattrup, covering 800 hectares. Previously, the lands in this nature reserve were managed according to traditional field and forest management practices. However, since 2021, these management activities have changed. A rewilding project has been initiated, marking a new phase that respects the area's history and character. The goal is to implement a new form of agriculture, focusing on extensive and climate-friendly farming practices that enhance biodiversity (Kattrup Vildnis, n.d.). A smaller area, roughly the size of the first agricultural study area, was selected from this nature reserve. Similar to the first study area, the small landscape elements in this rewilding area are mapped from just before the rewilding to the current state, where the area has been maintained extensively for several years. This approach allows for an examination of how the small landscape elements evolve with management changes.

Figure 3:

The location of the agricultural and rewilding study area of this research

Finally, the HNV farming indicator score for both areas is calculated, compared, and evaluated over time creating a time series. When comparing the HNV scores between the two study areas, the focus is on the impact of management on biodiversity. This demonstrates how changes in management practices lead to changes in small landscape elements and biodiversity.

1.2. Research questions

To better understand the biodiversity within the two study areas, the High Nature Value (HNV) farming indicator is computed. There are different techniques for calculating this value, all of which use different variables to come up with the final HNV score. This study compares the three main methods for calculating the HNV: the farming system, land cover and species approach, to determine which method is most suitable for the study areas (Strohbach et al., 2015). The Danish government has implemented a standard approach for determining HNV across the country, combining the farming system and the species approach. This research aims to find out whether this broad approach accurately represents HNV at a national level or if a more targeted approach would be better for smaller, specific areas.

The current research environment faces a challenge in determining the most suitable approach for assessing the HNV of a particular study area. The issue at hand is determining the most appropriate method for a specific context: either the broad method such as employed by the Danish government, or a method tailored to a particular situation. This study addresses the uncertainty in choosing the appropriate method by evaluating them. Based on the problem setting and research gaps, several research questions are formulated.

- How do the HNV value and the small landscape elements in the two study areas change between 2012 to 2024?
    - What is the evolution of the HNV in the agricultural and rewilding area?
    - Is the transition from agricultural to rewilding visible in the HNV for the Kattrup study area?
    - Is the farming system approach suitable for the identification of rewilding?

- How do the approaches for determining the HNV used for the Danish nationwide map differ from the one used for the two study areas?
    - Which approach is most suitable for both study areas?
    - Is it better to use a very specific approach or a combination of several?

Maps are created to show how the HNV farming indicator score and the small landscape elements in the areas have changed over time in order to answer the research questions. Furthermore, a thorough examination of the pros and cons of the techniques employed for determining the HNV is included. The parameters are evaluated for their utility, determining those that were excessively detailed and those that were either too broad or unrelated to the two research areas.

1.3. Workflow

To address the research questions, the workflow shown in Figure 4 was followed. Through a literature review the fundamental ideas of biodiversity, HNV and small landscape elements were gathered. The data for this research was obtained from the Danish environmental portal's data repository and satellite images of the two research sites. Subsequently, a GIS analysis was started. By using satellite images, a

chronological sequence of small landscape elements was established and mapped from 2012 to 2020. The HNV farming indicator scores for both study areas were determined over the same timeframe.

Figure 4:

Workflow consists of five steps

The next step in the process was fieldwork. An on-site survey of the current conditions of the two research sites was conducted, paying close attention to the small landscape elements and how the land parcels were being utilized. Then QGIS was used to map the current study areas and calculate the HNV based on the field data. The findings show how the HNV has changed over time and illustrate the distribution of small landscape elements from 2012 to the present. Finally, the findings were analyzed in order to address the research questions.

2. THEORETICAL FRAMEWORK

2.1. HNV farming indicator

The first theoretical concept that needs to be explained is the HNV farming indicator. It can be seen as an indicator that was brought to life to determine the integration of nature value, environmental services and even cultural heritage within farming systems practiced in a landscape. Like this, the indicator is a tool used to help preserve the diversity and wildlife in a landscape while also making sure that farming can be performed in the long run as a low-intensive land management practice (Andersen et al., 2004). Thus, the HNV farming indicator focuses on these farming areas, characterized by specific farming systems, that are expected to have a good influence on the preservation or generation of places with a high biodiversity (Strohbach et al., 2015).

In 2000, it was obliged that all European Union countries must calculate the HNV farming indicator (Strohbach et al., 2015). The score for this indicator is used to decide which areas will be assigned a subsidy, encouraging farming practices that are characterized by preserving the biodiversity and the natural elements in the landscape (Brunbjerg et al., 2015).

In the whole European Union, more than 40 approaches exist on how to calculate the HNV farming indicator, but these are always an application of one out of three specific approaches, namely the farming system, land cover and species approach, or a combination of two or three of these approaches. Each is characterized by different sub-indicators, within several variables, that are used to eventually calculate the score of the HNV farming indicator (Strohbach et al., 2015). No decisions have been made addressing the specific variables that are preferably used to calculate the HNV farming indicator. This leads to different countries using different variables making it difficult to compare the final score of the HNV farming indicator (Brunbjerg et al., 2015).

The approach that will be used during this research is the farming system approach as this seems the most suitable methodology. As already mentioned, the agricultural study area is still under agricultural use, but the rewilding study area is not anymore from 2021. Hence, the farming system approach will still be applied. Through this, it will be possible to verify whether the rewilding activities can be observed by changes in the HNV farming indicator despite not using the most suitable approach. This will answer one of the research questions.

2.2. The farming system approach

The methodology for the calculation of the HNV farming indicator using the farming system approach is based on the methodology explained in the paper of Pointereau et al. (2007). Specific sub-indicators and variables in the context of farming activities, characteristics of the farmland and small landscape elements are taken into account.

Three sub-indicators, each with several variables, make up the final score of the HNV farming indicator. Each sub-indicator is calculated separately using a specific equation, which consists of the different variables, and the resulting scores are in the end summed together which will give a final score on 20.

The first sub-indicator is the crop diversity and will give a score on 10. It is calculated by the following equation:

$$I_1 = 10 + (1 - C_1)/(UAA * 10) + (1 - C_2)/(UAA * 10) + ...$$

Where C_1, C_2... is a crop covering a total area larger than 10% of the Usable Arable Area (UAA).

The second sub-indicator contains all the variables linked to extensive agricultural practices and their level of intensity. It will give a score on 5 and has thus a lower weight in the final score of the HNV farming indicator than the first sub-indicator. It is calculated using the following equation:

I_2 = 5 * (level of mineral fertilization under 50 units * area of productive permanent grassland)/(UAA + area of common pastures) + 5 * (area of low productive permanent grassland + area of common grassland)/(UAA + area of common pastures) + 5 * (extensively managed crops/UAA)

Crops that belong to the extensively managed crops are for example triticale and legume fodders such as alfalfa. These crop types were present in the study areas for several researched years.

Lastly, there is the sub-indicator taking into account small landscape elements, namely the area of fruit trees, wood edges, hedges and the number of ponds. This sub-indicator will give a score on 5. Depending on the portion of the area of the traditional fruit trees, hedges and wood edges compared to the UAA, a score on 5 is given. The specific score given for a certain ratio is all documented in the paper of Pointereau et al. (2007). The score of the ponds depends on the quantity. The scores of the small landscape elements added together give a number on 20 so this needs to be re-weighted to a score on 5.

2.3. Nationwide methodology of Denmark for the calculation of the HNV farming indicator

Apart from calculating the HNV farming indicator, using the farming system approach, this chosen approach will be compared to the used methodology for the development of the nationwide HNV farming indicator map of Denmark. This methodology is a combination of the farming system approach and the species approach as the sub-indicators take species and habitat-related variables into account as well as sub-indicators about small landscape elements and extensive practices. Each variable will be represented

by a layer where each location is given a specific score for that specific variable based on statements made in the paper of Ejrnaes et al. (2012). This paper describes which sub-indicators and associated variables were chosen to develop the HNV farming indicator score.

The variables fall into one of four types of sub-indicators. The first sub-indicator consists of variables linked to landscape characteristics that indicate nature-rich landscapes. Coastal proximity is a variable that falls within this sub-indicator together with lowlands areas, such as river valleys, and areas with steep topography, such as moraine hills.

The second sub-indicator is about habitats and thus variables that represent (proximity to) protected nature areas. More specifically, a variable indicating the proximity to protected nature and a variable for the proximity to small landscape elements is used.

Variables about extensive farming are gathered in the third sub-indicator. These include fields in extensive operation, thus fields characterized by permanent grassland or fallow agricultural land and fields cultivated by organic farming practices.

The last sub-indicator consists of several variables that tell something about the occurrence of vulnerable and endangered species. The variables are the following: occurrence of at least one red list species, more than three red list species and at least six star species. Areas where a species has been registered in the Habitats Directive, areas that have a species above 0,6 or areas that have a species status above 0,8 are also variables of the last sub-indicator.

The final score is calculated by performing an overlap analysis of all the layers consisting of the scores of the variables used. Like this, all the scores on a specific place will be added together and this will give a score on 13.

2.4. Small landscape elements

A second theoretical concept that needs to be explained, before actually performing the research, is the small landscape elements. Having a clear knowledge of what is seen as a small landscape element is important for detecting them efficiently in the research areas during the fieldwork and making a good reconstruction through time using aerial photos.

In the paper of Czúcz et al. (2022) small landscape elements are described as 'small fragments of non-productive natural or semi-natural vegetation in an agricultural landscape which provide ecosystem services and support for biodiversity'. For example, woody landscape elements, such as hedges and tree rows, play an important role in agricultural areas as these are utilized as habitats for fauna and flora and can be used as ecosystem service, for example by limiting soil erosion, but they also act as dispersal corridors for a wide range of species (Vallé et al., 2023). Apart from hedges and tree rows, small landscape elements consist of several other features such as ponds, ditches, field margins, terraces, dry stone or earth walls, individual trees, springs or remnants of canal networks (Czúcz et al., 2022). As can be derived from the definition of the small landscape elements and the former enumeration of the different types, small landscape features consist both of (semi-) natural vegetation but also features created by humans.

3. METHODOLOGY

3.1. Mapping of the small landscape elements

To reconstruct the evolution of small landscape elements for the period 2012-2020, aerial images will be used (Danmarks Miljøportal, 2023). Based on this, maps will be drawn up for the years 2012, 2016 and 2020. The current state of the small landscape elements will be mapped through fieldwork.

Table 1 shows the various types of small landscape elements that will be mapped. The elements can be divided based on different characteristics. The first distinction is based on the condition of the soil, which is either wet or dry. The second difference is the shape of the small landscape element, it is either a line or a patch. The last distinction is based on the function of the small landscape elements. The mapped ponds, hedges and wood edges will also be used for the calculation of the HNV farming indicators.

Table 1:

Legend of mapped small landscape elements

Soil conditions	Shape	Functional	Symbol
Dry	Linear	Tree row	
		Shrub row	
		Thicket	
		Hedgerow	
		Dikes	
		Hollow road	
	Patch	Deciduous forest	
		Coniferous forest	
		Mixed forest	
		Shrubs	
Wet	Linear	Ditch	
		River	
	Patch	Puddle	
		Marl pit	

On the aerial images, it is not possible to detect all the different types of small landscape elements. Therefore, all tree and shrub rows will be mapped as thicket and all forest areas will be mapped as mixed forest. A reference map of small landscape elements occurring in the agricultural study area will also be used to decide where to look for hedges and wood edges in the study area. Thus, the current year's mapping will be more specific than previous years because it will be possible to go into the field and describe the elements in detail.

3.2. Calculation of the HNV farming indicator

Based on the methodology of Pointereau et al. (2012), that used the farming system approach, and additional information gathered during desktop analysis on the official website of the Denish Ministery of Food, Agriculture and Fishery, the HNV farming indicator score of both study areas for the researched years can be calculated. On this website, the necessary information can be found, namely the cultivated crops and other types of agricultural land use for each parcel through time. Based on the available information that could be extracted from the website and information gathered during the fieldwork, several adaptations had to be made in the variables of the sub-indicators to be able to calculate the HNV farming indicator score. It was not possible to gather all the data on the variables that were needed.

Because the different, individual crops present in the study area do not have a total area of more than 10% of the UAA, similar types of crops, such as different types of cereals, were taken together for the determination of the score of the first sub-indicator. This was necessary as otherwise this value could not be calculated.

Just as with the first sub-indicator, adaptations had to be done for the second sub-indicator to be able to calculate the score. It was decided to not take into account the fertilization variable despite knowing that this variable is considered an important factor. A low level of fertilization is namely one of the crucial elements for conserving and protecting the biodiversity in an agricultural area (Pointereau et al., 2007). The reason for discarding the variable was because it was not possible to transform the values that were given in kilogram nitrogen per hectare, on the Danish website for Food, Agriculture and Fishery, to the wanted units. A distinction between the different types of permanent grassland was also not possible so all the grasslands were gathered in the same variable of the extensively managed permanent grassland. It was also not possible to verify whether a grassland was common or not, therefore it was decided to drop this variable. If there were commonly managed grasslands, these would be gathered in the variable of the extensively managed grasslands. The same is true for the common pastures so these were gathered in the variable of the pastures.

For the third indicator, the variable of the traditional fruit trees was removed as there were none in the study areas. A buffer of 10 meters had to be created around the hedges and wood edges for the calculation of their variables because based on the portion of these variables compared to the UAA a score is given.

Table 2 gives an overview indicating how the variables for each sub-indicator were adapted to be able to calculate the HNV farming indicator score.

Table 2:

Overview of the sub-indicators and their variables

Sub-indicators	Theoretical variables	Practical variables
Crop diversity	Crop covering with an area larger than 10% of the UAA	Cereals
		Corn
		Rapeseed
		Other crops
		Intensely managed grassland
Extensive practices	Level of mineral fertilization under 50 units	Area of extensively managed crops
	Area of productive permanent grassland	Area of extensively managed grassland
	Area of common pastures	Area of pastures
	Area of low productive permanent grassland	
	Area of common grassland	
	Area of extensively managed crops	
Landscape elements	Area of hedges	Area of hedges
	Area of wood edges	Area of wood edges
	Number of ponds	Number of ponds
	Area of traditional fruit trees	

4. RESULTS

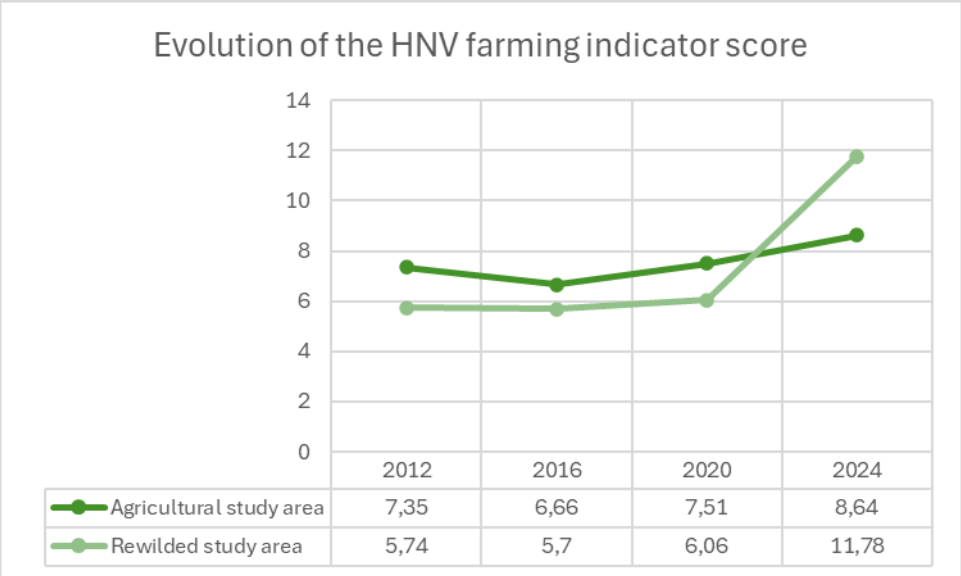
4.1. Evolution of the HNV farming indicator score

In Figure 5, the evolution of the HNV farming indicator score, calculated during the four researched years, is visualized for both study areas. For the agricultural study area, the scores remain low over time. The lowest score was calculated in 2016 and from then on, the score kept rising until a maximum score of approximately 9 in 2024. For the rewilded study area, the scores remain stable around approximately a score of 7 but in 2024 it rose to a score of approximately 12 which is significantly higher than the previous years and the scores of the researched years in the agricultural study area.

Thus, both study areas are characterized by significantly low scores over time. Only for 2024 in the rewilded study area, the score hit above half.

Figure 5:

Evolution of the HNV farming indicator score from 2012 till 2024



The evolution of the sub-indicators of the HNV farming indicator is visualized in Figures 6 and 7. In these evolutions, more variety can be seen from year to year than in the evolution of the final HNV farming indicator score.

In the agricultural area there has been a small rise in small landscape elements and a similar evolution can be observed in the extensive practices. For the crop diversity, there was a decline in 2016. In the rewilded area, all three sub-indicators remain approximately the same throughout the first three researched years but from 2020 to 2024 both the extensive practices and the small landscape elements have significantly risen with around three points, indicating the rewilding activities taking place during this period. The crop diversity remained the same through time.

Figure 6:

Evolution of the sub-indicators of the HNV farming indicator in the agricultural study area.

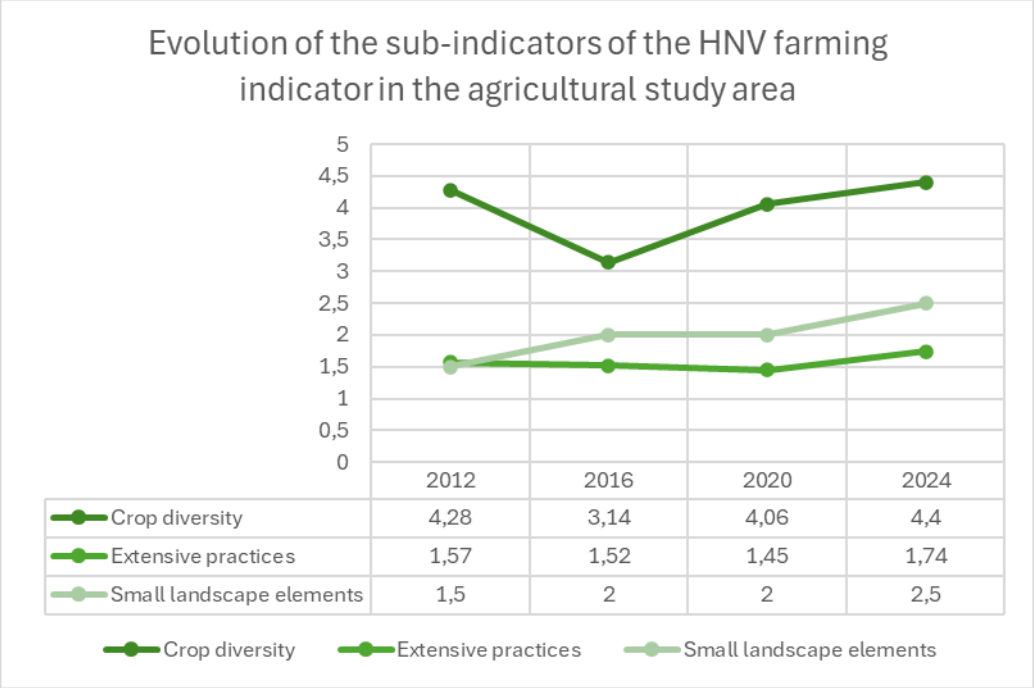
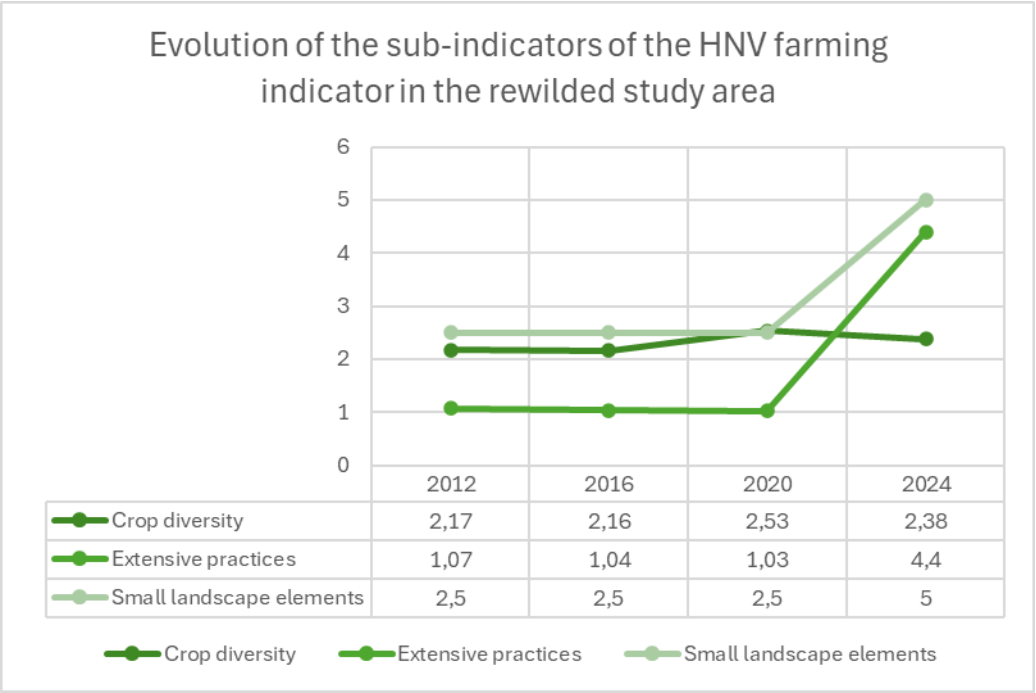


Figure 7:

Evolution of the sub-indicators of the HNV farming indicator in the rewilded study area.



4.2. Evolution of the small landscape elements

4.2.1. Agricultural area 2012 - 2016

Figure 8 shows the small landscape elements in the agricultural area in 2012. Throughout the area, there are forested areas and thickets that divide the plots. When Figure 8 and Figure 9 are compared, several changes can be noted. In the northern part of the agricultural area, there are more thickets in 2016 than there were in 2012. The forested areas are roughly the same. On the southwest side of the river a puddle appeared, and dikes were added on the northeast side of the river.

Figure 8:

Small landscape areas in the agricultural area in 2012

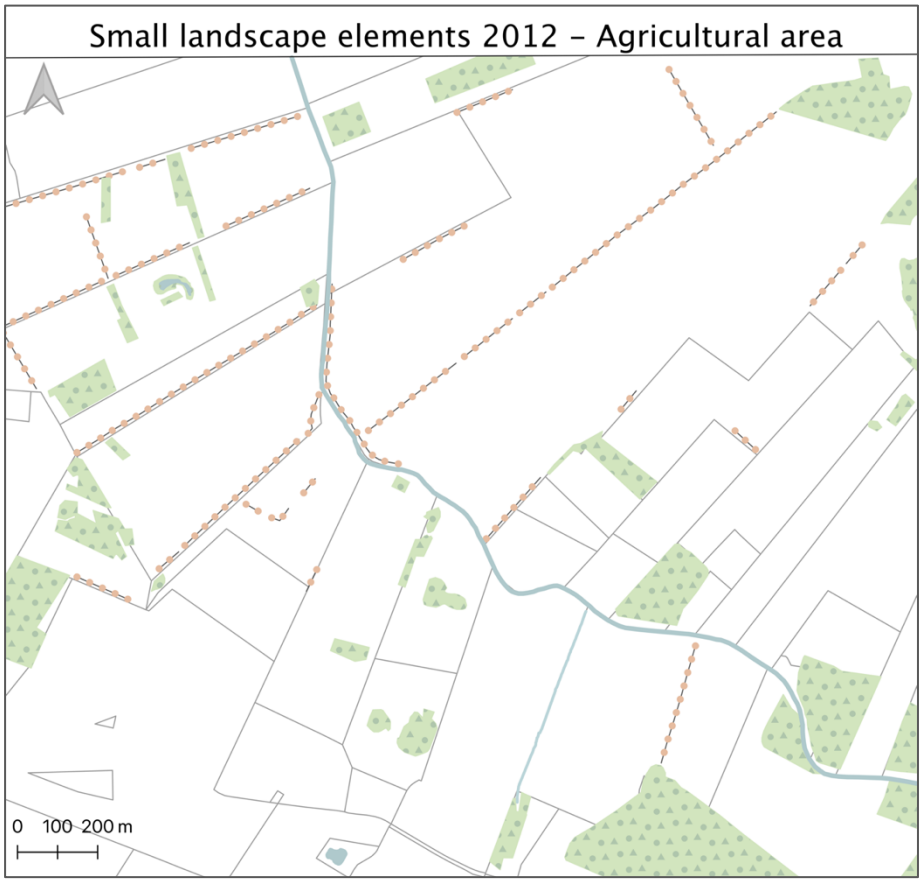
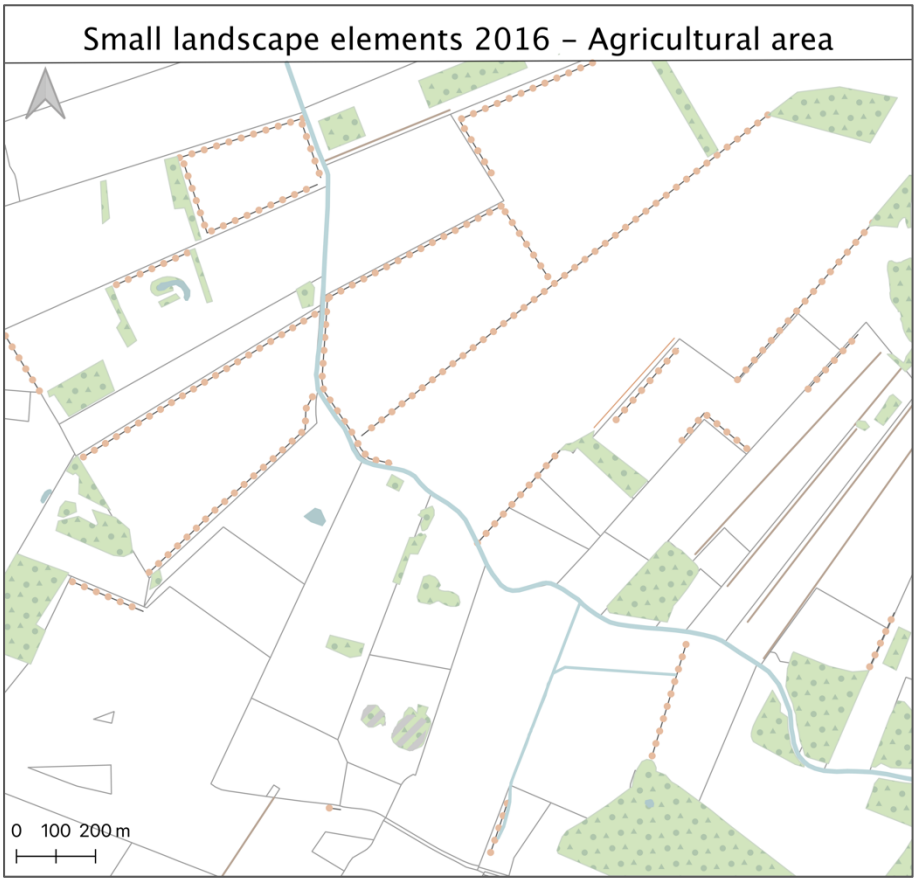


Figure 9:

Small landscape areas in the agricultural area in 2016

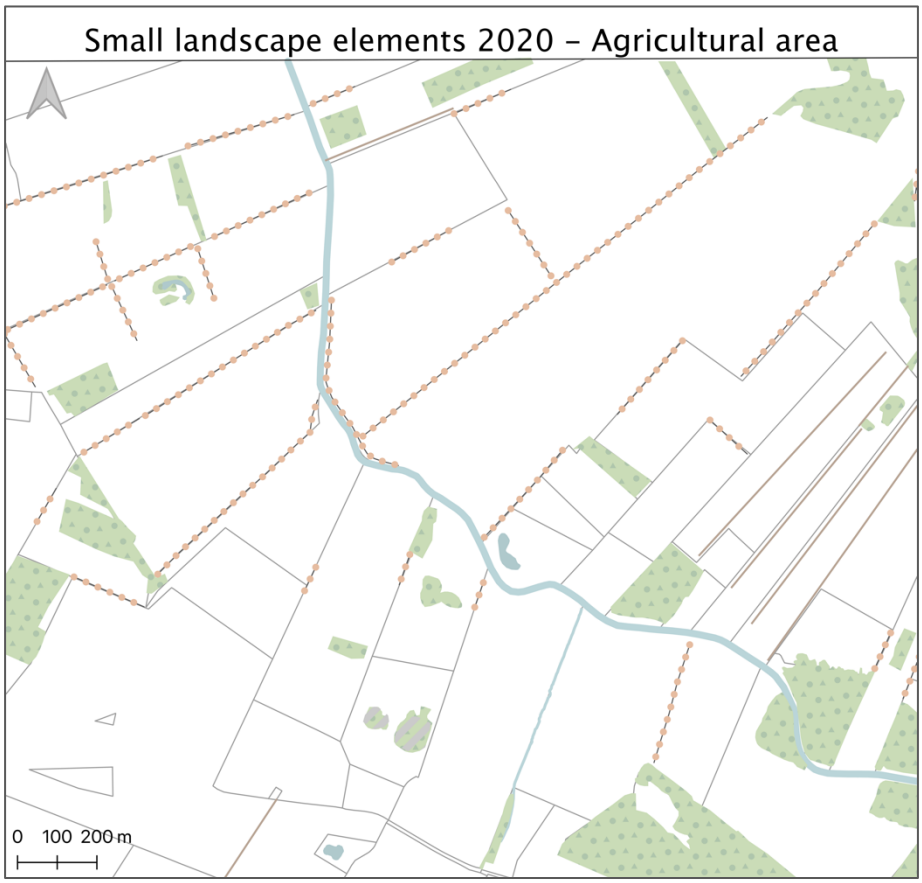


4.2.2. Agricultural area 2016 – 2020

In Figure 10 the small landscape elements in 2020 are presented. When they are compared with the small landscape elements in 2016 various changes can be observed. The puddle on the southwest side of the river disappeared. However, a new puddle appeared on the north side of the river in the center of the agricultural area. On the northeast side of the river, several thickets were removed. Yet, on the west side of the river, more thickets appeared. The forested areas are nearly the same, only in the southern part of the area a piece of the forest had been cut down.

Figure 10:

Small landscape elements in the agricultural area in 2020

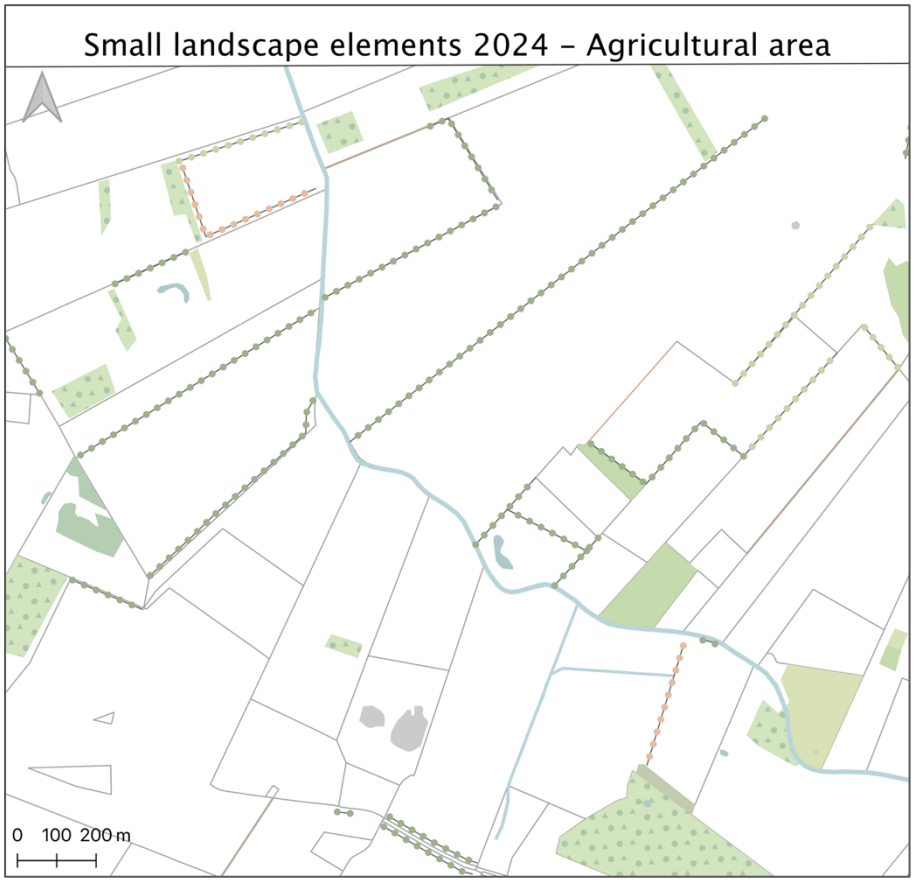


4.2.3. Agricultural area 2020 - 2024

Figure 11 shows the current state of the agricultural area. Since the small landscape elements were mapped on the field a division could be made between forested areas and the tree and shrub rows. In 2024 there are fewer forested areas because the areas observed on the field as part of a garden have not been mapped. In the northern part of the agricultural area, a few thickets were removed. Together with a few thickets and forested areas in the centre of the area on the south side of the river. The dikes in the eastern part of the area were also less prominent.

Figure 11:

Small landscape elements in the agricultural area in 2024



4.2.4. Rewilding area 2012 – 2016

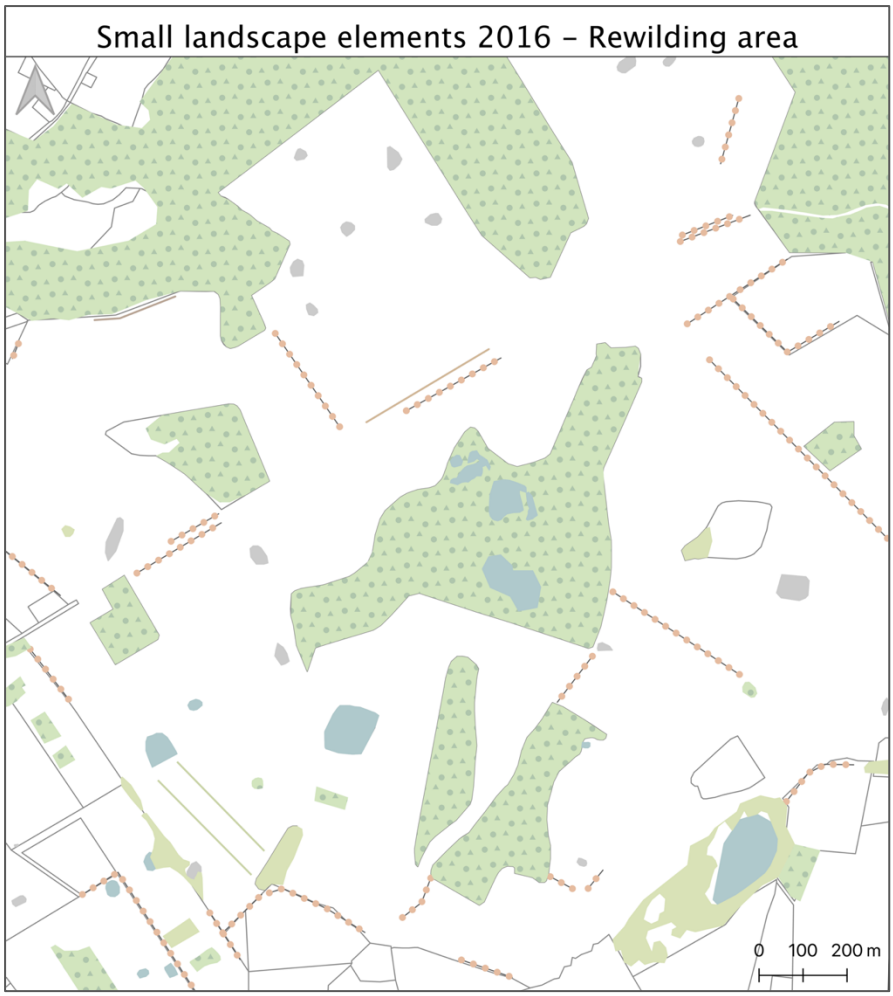
Figure 12 shows the small landscape elements in the rewilding area in 2012, the area was then still an agricultural area. Nevertheless, there are a lot of forested areas and thickets everywhere in the area. When the state of the area in 2012 is compared with the state in 2016, Figure 13, little changes can be noticed. A few marl pits in the northern part of the area disappeared. In the southern part of the area, the empty spaces in the forested areas were filled in.

Figure 12:

Small landscape elements in the rewilding area in 2012

Figure 13:

Small landscape elements in the rewilding area in 2016



4.2.5. Rewilding area 2016 – 2020

When Figure 13 and Figure 14 are compared several changes are noticeable. In the northern part of the area, more marl pits have disappeared. In the eastern part, a patch of shrubs became visible. In 2016, the two forest patches in the south of the area were not connected, but Figure 14 shows that they have become one. By 2020 there were also hedges added in the southwest part of the area.

Figure 14:

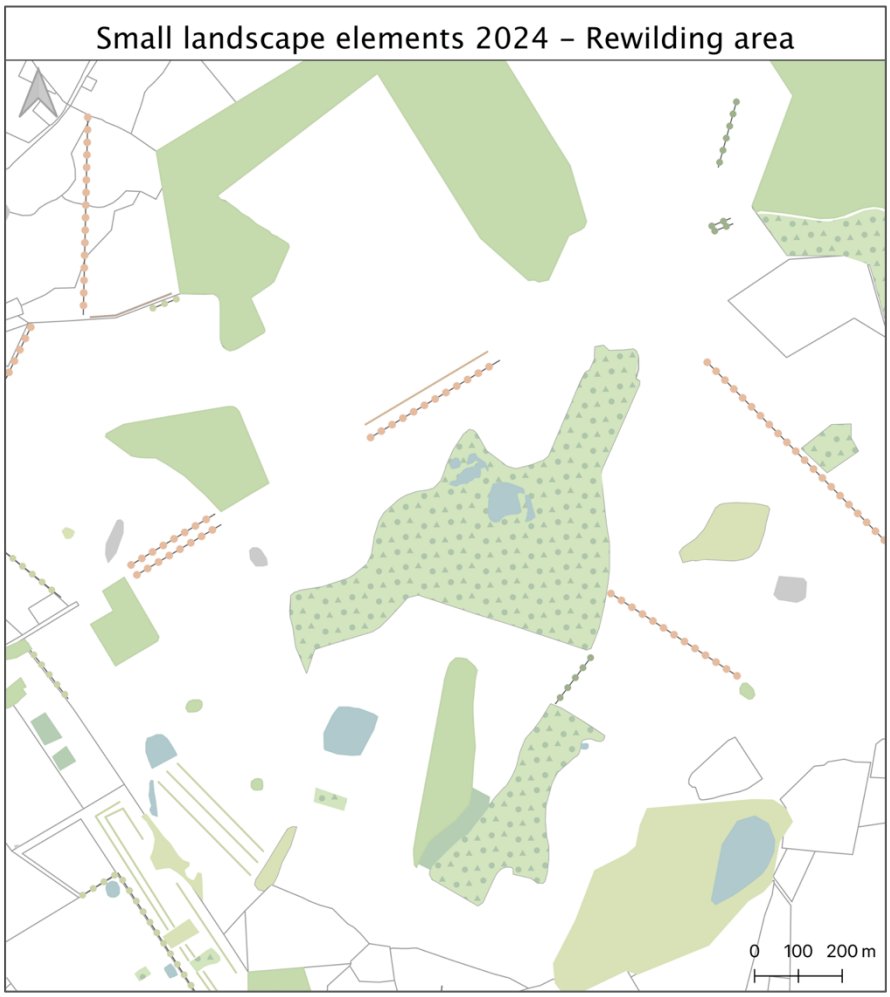
Small landscape elements in the rewilding area in 2020

4.2.6. Rewilding area 2020 – 2024

Figure 15 shows the current state of the rewilding area. From 2021, no agricultural activities will take place in the area. Therefore, several changes can be observed. In the northwest corner of the area a forest patch has been cut down to give nature more space. In the northeastern part of the area in the centre and corner, the shrub area visibly increased. In 2024 there are even fewer marl pits and in the south of the area a few tree rows were cut down. In the southeast corner of the area there was even a forest cut down.

Figure 15:

Small landscape elements in the rewilding area in 2024



5. DISCUSSION

5.1. Interpretation of the evolution of the HNV farming indicator score

In this chapter, the feedback to the research questions will be discussed. As can be seen in Figures 16 and 17, there is an increasing trend in the cultivation of extensively managed grassland, which leads also to an increase in the value of the extensive practices sub-indicator and thus an increase in the final HNV value farming indicator score (Figures 6 and 7). Especially in Kattrup, the rewilded area, a significant rise can be perceived since 2020, due to the rewilding project that was initiated in 2021. But also, in Sønderød, there is a slight reduction in the cultivation of cereals and an increasing trend in abandonment of some of the

flood-prone parcels near the river, as was noticeable on the terrain, due to the presence of *Urtica dioica* (stinging nettle), *Anthriscus sylvestris* (cow parsley), *Symphytum officinale* (comfrey) and other tall forb herbs on several fields.

As for the HNV farming indicator score, Figure 7 shows a clear transition from agricultural to rewilded area for the rewilded study area in Kattrup. The HNV value increases from approximately 6 under agricultural use to around 11 in a rewilded situation. Remarkable is how both scores are rather low, especially for a rewilding case. This score doesn't match the intuitive value as could be noticed during terrain visits. As can be seen in the maps under 'Chapter 4: Results', both study areas are characterized by a significant amount of small landscape elements. Concluding from this, the used method might not be the most suitable method for these cases, despite being developed for agricultural areas as both study areas are or were.

Figure 16:

Evolution of the cultivated crops in the agricultural study area

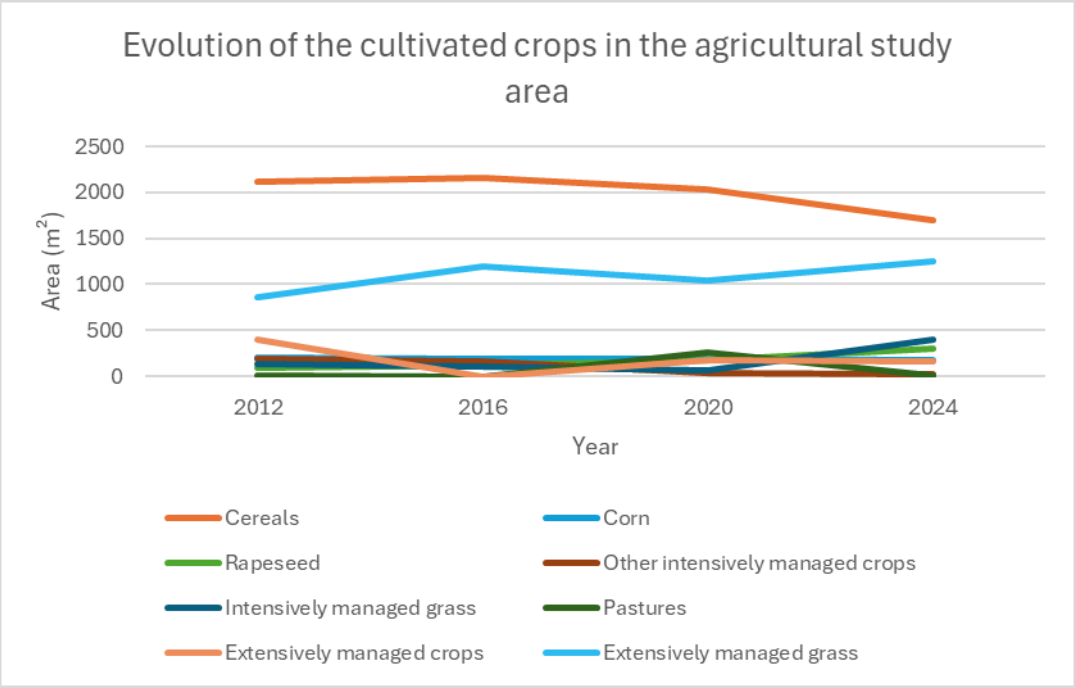
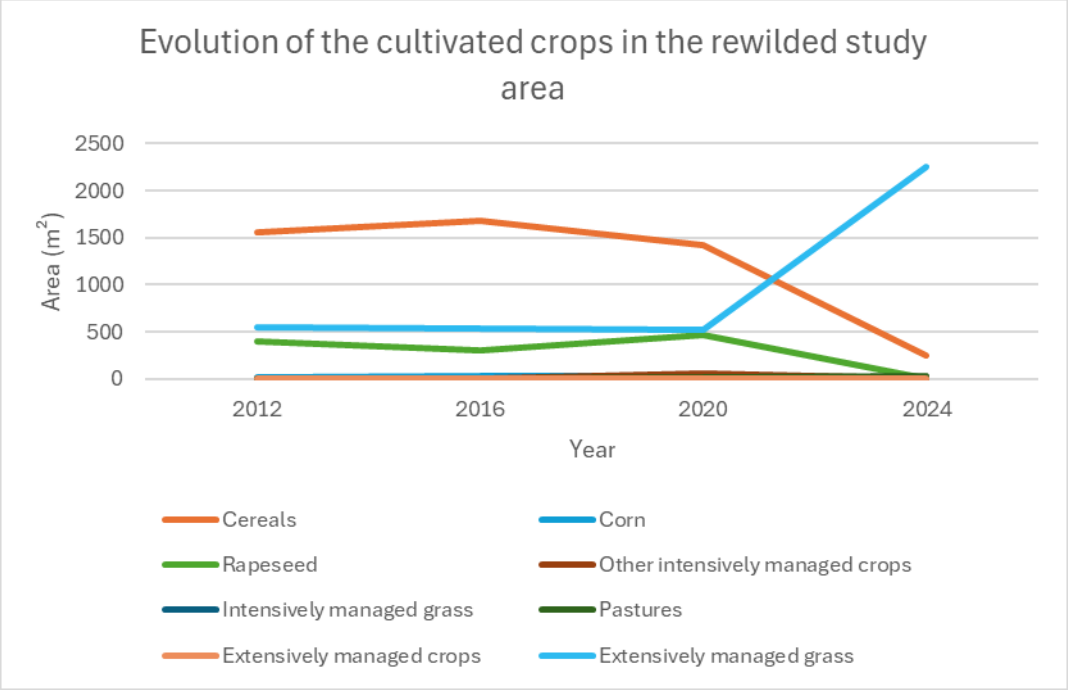


Figure 17:

Evolution of the cultivated crops in the rewilded study area



The used method does not take the presence of forests into account, while they have a great contribution to the ecological value of areas. Hedges and tree rows are only included in the calculation, as they cover a minimum percentage of the total area, while they are already valuable starting from any percentage. The parameters of diverse indicators are often too specific, which makes the values of the variables hard to find or calculate. Therefore, in the performed calculation for the HNV of both study areas, there were some adjustments and eliminations of the variables. Maybe this could be a reason to explain the extremely low values.

From the findings collected during the site research, a higher HNV was expected than was calculated, as a lot of wild animals could be observed (e.g. pheasants, hares, deer, birds of prey, etc.). However, even with the presence of a multitude of woody plants in the small landscape elements and wildflowers on abandoned fields, this perceived ecological value was not translated into the outcome of the HNV calculation, as this was rather low.

Furthermore, there is no certitude as to what the motives for land abandonment and rewilding were in these specific areas. Conversations with locals could have contributed to understanding the incentives. While abandoned parcels in Sønderød were associated with locations near the river, there is no certainty this is because of flood risk. In-depth interviews or panel discussions with local farmers or other stakeholders could help gain insights in these aspects. It is assumed that to score higher for the farming system approach, a successful collaboration between intensive cultivation and an abundance of small landscape elements needs to be reached.

5.2. Interpretation of the evolution of the small landscape elements

The changes of the small landscape elements in the agricultural area are rather limited. The most notable changes are in the northern part the decrease in thickets and in the southern part the decrease in forest cover.

In the rewilding area, the changes are also limited before 2024. There is a decrease in marl pits. This may be because they were less clearly visible in the orthophotos and not always accessible in the field. This could also be due to the fact that they have over time become overgrown with shrubs and trees and are thus not recognizable as marl pits anymore. Before 2024, some empty spaces were filled in a forested area. More obvious changes have taken place since the 2021 rewilding project. The shrub area clearly increased, and a large piece of the forest was cut down. So, since the start of the project, a few changes have been visible in the landscape. More changes can be expected in the coming years.

In both areas, small landscape elements were mapped in greater detail in 2024 than in the other periods. This is because during fieldwork it was possible to distinguish between shrub and tree rows and between different forest types. This is not observable in the orthophotos. It was also possible to locate puddles that were not visible on orthophotos. This is the reason why it seems that between 2020 and 2024 small landscape elements disappeared, while in reality, this is not the case. For the calculation of the landscape element indicator, this gives differences in the score for the years 2012 to 2020 and 2024.

5.3. Comparison of the nationwide methodology and the farming system approach

When comparing the used method in this report with the nationwide Danish methodology, a difference in applied scale is noticed. The nationwide method uses a scale of 9,6 x 9,6 meters. This method also manages more diverse variables. As discussed in Chapter 2.3, this method takes protected areas and endangered species into account. These are important to take into consideration, as biodiversity of areas is based on fauna and flora. Some of the variables in the nationwide method are, however, not relevant for the study areas in this report (e.g. coastal proximity). Furthermore, the nationwide Danish method doesn't take agriculture into account, except for two extensive variables. This is a topic for discussion, because Denmark exists for almost 60% of arable land and pastures, which makes it almost incomprehensible that a factor this important isn't included in a nationwide nature value analysis.

The farming system approach, applied in this report, is supposed to better suited for the described areas, although this shoe doesn't exactly fit either as the calculated HNV farming indicator scores do not quite stroke with reality. The resulting score exists of one value for the whole area, and that leads to a distorted picture of the true ecological value.

The conclusion is thus that neither of both methods is better fitting than another. A better method would be to choose the most suitable variables from the three methods as described in Chapter 2 and determine the score with the selected variables. This corresponds to the nationwide method, but it would be better to use more relevant parameters which leads to a more specific location-based value. The use of different variables for different areas, however, also implies that standardizing values for comparison is not possible.

6. CONCLUSION

This research aimed to assess the impact of agricultural management and rewilding efforts on biodiversity through the mapping of small landscape elements and analyses of the High Nature Value farming system approach over time in two study areas: Sønderød, an agricultural region and Kattrup, a region where rewilding initiatives have taken place. The study unfolds from the abundant agricultural land use in Denmark, which causes threats to and significant losses of biodiversity in various areas, through the disappearance of small landscape elements and the conversion of potential habitats to intensively cultivated lands and pastures.

The HNV farming indicator is a system that is used to determine the integration of nature values in farming systems in a landscape. Out of two usable methods, the farming system approach and the nationwide methodology, the first one seemed most suitable to perform the comparison of the HNV of both study areas. To get a good image on the evolution, small landscape elements were mapped and the HNV was calculated for four different moments in time, in a period of 2012 until 2024. For the years 2012, 2016 and 2020, the mapping was based on aerial images. The 2024 mapping happened during terrain visits. The HNV value for each of these four moments were calculated with the following sub-indicators: crop diversity, extensive practices and landscape elements. There were some adjustments made in the used method compared to the method described in the literature.

In the evolution of the HNV, an increase in both areas is noticeable (Figures 6 and 7). For the rewilded area, the current value is well above the values of past years, as the rewilding initiatives have taken place since 2021. For the agricultural area, the value stays more or less constant, although there can also be observed a slight increase. This is due to a higher number of abandoned fields along the riverbanks. For the small landscape elements, the change over the years is rather limited. In the agricultural area, a decrease in most element types can be observed, while in the rewilded area some forested spots were added. For both areas counts that the 2024 situation was mapped in greater detail, as an effect of the fieldwork.

It can be concluded that the used method was not optimal for determining the HNV of these areas, as they both scored rather low. This contradicts the experience on the field, where a lot of wildflowers and native animals could be observed. A better method and more suitable method can be created by combining and adjusting the nationwide method and the farming system approach.

7. BIBLIOGRAPHY

Agger, P., & Brandt, J. (1988). Dynamics of small biotopes in Danish agricultural landscapes. Landscape Ecology, 1(4), 227-240. https://doi.org/10.1007/BF00157695

Andersen, E., Baldock, D., Bennett, H., Beaufoy, G., Bignal, E., Brouwer, F., Elbersen, B., Eiden, G., Godeschalk, F., Jones, G., McCracken, D., Nieuwenhuizen, W., van Eupen, M., Hennekens, S., Zervas, G. (2004). Developing a High Nature Value Farming area indicator.

Brunbjerg, A. K., Bladt, J., Brink, M., Fredshavn, J., Mikkelsen, P., Moeslund, J. E., Nygaard, B., Skov, F., & Ejrnæs, R. (2015). Development and implementation of a high nature value (HNV) farming indicator for Denmark. Ecological Indicators, 61, 274-281. https://doi.org/10.1016/j.ecolind.2015.09.027

Czúcz, B., Baruth, B., Angileri, V., Lopez, A.P., Terres, J.M. (2022). Landscape features in the EU Member States. Luxembourg: Publications Office of the European Union.

Danmarks Miljøportal. (2023, mei 25). DMP Data Catalogue.

Ejrnaes, R., Forest, F., Bladt, J., Fredshavn, J., Nygaard, B. (2012). Development of a High Nature Value (HNV) indicator. Aarhus University: DCE – National Center for Environment and Energy.

Hou, W., & Walz, U. (2013). Enhanced analysis of landscape structure: Inclusion of transition zones and small-scale landscape elements. Ecological Indicators, 31, 15-24. https://doi.org/10.1016/j.ecolind.2012.11.014

Kattrup Vildnis. (n.d.). *Kattrup Vildnis.* https://www.kattrupvildnis.dk/, accessed on 10 June 2024.

Ministeriet for Fødevarer, Landbrug og Fiskeri. (n.d.). Jordbrugsanalyser. https://lbst.dk/landbrug/kort-og-markblokke/jordbrugsanalyser#c51135, accessed on 17 May 2024.

Ministeriet for Fødevarer, Landbrug og Fiskeri. (2023). Vejledning om gødsknings- og harmoniregler: Planperioden 1 august 2023 til 31 juli 2024. København: Ministeriet for Fødevarer, Landbrug og Fiskeri.

Rey Benayas, J. M., Martins, A., Nicolau, J. M., & Schulz, J. J. (2007). Abandonment of agricultural land: An overview of drivers and consequences. CABI Reviews. https://doi.org/10.1079/PAVSNNR20072057

Strijker, D. (2005). Marginal lands in Europe—Causes of decline. Basic and Applied Ecology, 6(2), 99-106. https://doi.org/10.1016/j.baae.2005.01.001

Pointereau P., Paracchini, M.L., Terres, J.-M., Jiguet, F., Bas, Y., Biala, K. (2007). Identification of High Nature Value farmland in France through statistical information and farm practice surveys. Luxembourg: Office for Official Publications of the European Communities.

Statistics Denmark. (2023, January). *Land use accounts.* https://www.dst.dk/en/Statistik/emner/miljoe-og-energi/areal/arealopgoerelser, accessed on 10 June 2024.

Statistics Denmark. (2024, June). *Cropland.* https://www.dst.dk/en/Statistik/emner/erhvervsliv/landbrug-gartneri-og-skovbrug/det-dyrkede-areal, accessed on 10 June 2024.

Strohbach, M. W., Kohler, M. L., Dauber, J., & Klimek, S. (2015). High Nature Value farming: From indication to conservation. *Ecological Indicators*, *57*, 557-563. https://doi.org/10.1016/j.ecolind.2015.05.021

Vallé, C., Le Viol, I., Kerbiriou, C., Bas, Y., Jiguet, F., & Princé, K. (2023). Farmland biodiversity benefits from small woody features. Biological Conservation, 286, 110262. https://doi.org/10.1016/j.biocon.2023.110262

FACULTEIT WETENSCHAPPEN

MASTER OF SCIENCE IN GEOGRAPHY AND GEOMATICS

FROM SEA TO SHORE: EXPLORING CHANGES IN SJÆLAND'S FISHING ACTIVITY

Word count: 7589

Gitta Galle, Matthias Bourgeois, Maxime Willaert, Yolan Bosteels
Student number: 01907465, 02008811, 02207881, 01903718

Responsible lecturer: Prof. Dr. Veerle Van Eetvelde
Assistants: Dr. Maite Dewinter, MSc. Lars De Sloover, MSc. Seppe De Wit & MSc. Kiara Haegeman
Course: Integrated international project
Academic year: 2023 – 2024

UNIVERSITEIT GENT

1 INTRODUCTION

Globally, many fishing communities are currently facing a shift in fish populations (Engelhard et al., 2014), which has a potential impact on these communities. Therefore, it is important to know what impact this shift has on these communities. Additionally, identifying the factors causing these changes is imperative, so it is possible for a future vision to be mapped out in order to reduce the negative impact.

In Denmark, several local communities have a rich fishing history and therefore they rely heavily on fishing activities for employment and income. For instance, in Odden, a fishing port was constructed in 1908 and 1909 (Madsen, n.d.) to support the rising tuna fishing industry after the cessation of seal hunting. As tuna became endangered in 1960, there was a switch to other fish species (Madsen, n.d.), which are still fished today.

With this integrated international project, we aim to investigate the impact of shifting fish populations on communities along the north coast of Sjælland. The social and economic impacts of the shifts will be investigated by conducting interviews with local fishermen and literature review. Spatiotemporal changes in the locations of fishing areas used by local fishermen will be investigated. The Automatic Identification System data (AIS) from relevant vessels will be examined for this purpose. Through these interviews, we also aim to determine if there have been noticeable changes in the types of fish caught.

Furthermore, the factors causing the shift in fish populations will be investigated through literature review. An obvious factor could be climate change (Engelhard et al., 2014), but other factors may also be at hand. A logical next step is then to investigate the challenges faced by the fishing community and the prospects for the future. These implications will be investigated in the scientific literature and from interviews.

2 RESEARCH QUESTIONS

The goal of this study, as stated in the introduction, is to get a better understanding of what the impact of the migration of fish populations is on the local fishing communities (as seen on *Map 1*). To achieve this, one main research question and several sub-questions were formulated.

Main research question:

- Which impact do shifts in fish populations have on the local fishing communities?

Sub-questions:

- What temporal and spatial changes have occurred in fishing activities?
- What factors lead to shifts in fishing activities?
- What are the prospects and challenges for the fishing industry?

3 THEORETICAL FRAMEWORK

3.1 Study area

For this study, we focus on the easternmost part of Denmark, an island called Sjælland (Zealand). In the northern part of this island, within the municipalities of Odsherred, Halsnæs, and Gribskov, there are several fishing villages that we will examine more closely. To select these ports, we applied several criteria. First, we considered which areas were accessible by car, which allowed us to go to the location and return to the accommodation the same day with enough time left to conduct the interviews on-site. Within this area, we searched for ports where fishing boats were still active. This was done using AIS data. From these ports, we chose those that were as spatially distributed as possible and also showed a variation in the number of active fishing boats. The locations of the harbors of these villages can be seen on *Map 1.*

Map 1: Locations of the visited ports

Odden havn, located in the town of Havnebyen, offers permanent moorings for about 141 boats. The site consists of both an authentic fishing harbor, with a shipyard and a slipway for large boats, and a marina. This harbor was built in the early 20th century and has been continuously modernized. Throughout the summer, numerous activities take place here, such as the mackerel festival and exhibitions about tuna (Odsherred Kommune, n.d.).

Next, we have two nearby harbors, Hundested and Lynæs.

Hundested havn, built in 1862, has evolved from a small fishing harbor into a significant port divided into three distinct sections. The northern section, which is the oldest, is a place for yachts and recreational fishermen. The middle basin is dedicated to fishing activities, and in the southern section serves as the freight area. A notable presence in Hundested havn is the company O.V. Jørgensen, established in this harbor since 1935. The company is specialized in selling fresh fish from Danish waters to both the local community and the European markets (Hundested Havn, n.d.).

On the other hand, the harbor of Lynæs is more focused on leisure and recreation due to its location near the Isefjord (Lynæs Havn, n.d.). Here, kayaks and surfboards can be rented, and regarding fishing activities, there are mainly mussel boats that go fishing in the fjord.

Finally, we have Gilleleje havn, the largest fishing harbor in Zealand. This accommodates around 220 yachts, with a separate area for the active fishing harbor (Gilleleje Havn, n.d.). In *Table 1,* the approximate number of active fishing boats present in each harbor is indicated.

Table 1: Amount of active fishing boats in each port

Port name	Amount of active fishing boats
Odden Havn	± 1
Hundested Havn	± 4
Lynæs Havn	± 1
Gilleleje Havn	± 10

The area around these harbors includes small fishing villages that rely on the sea for their way of life. These villages have a long history of fishing which is deeply connected to their local culture. The harbors serve as important centres where fishermen bring in their catches and where fish are processed and distributed. Overall, the relationship between the harbor and the surrounding villages is vital for the region's economy and traditions.

3.2 Factors causing shifts in fish populations

In addition to global warming, which has been extensively researched and undeniably impacts fishing activity, there are other significant factors that emerged from in-depth interviews with fishermen in three different harbors. These factors are not extensively covered in existing literature, highlighting the importance of in-depth interviews in our research. Finally, the regulatory rules of the ‘Maritime Spatial Plan’ are discussed, which also affect where fishermen can fish and what activities they are permitted to conduct in certain areas.

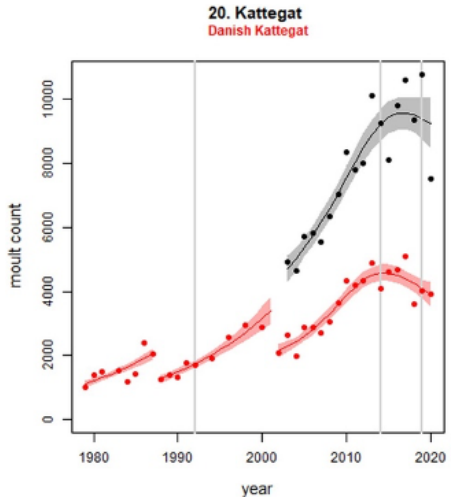
3.2.1 Global warming

The temperature of the oceans worldwide has been rising since the 1970s without significant decline. From 1971 onwards, the ocean surface has been warming by more than 0.1°C per decade globally, down to depths of at least 3000 meters. Between 1971 and 2010, the oceans absorbed 93% of the excess energy resulting from climate warming. This trend has significant implications for fishermen, because various fish species are migrating along with the temperature. This entails that species previously predominant in Denmark are now moving towards more northern, colder areas resembling Danish temperatures before 1971 (Klimaat.be, 2024). The shift of the fish species towards colder water may be related to changes in the distribution of key zooplankton prey animals for fish larvae (Beaugrand & Kirby, 2010).

3.2.2 Increasing population gray seals

Graph 1 shows that the grey seal has significantly increased since the 2000s (Banga et al., 2022), and this has significant implications for certain fish species such as cod, consequently affecting the economic situation of fishermen themselves (Harwood & Croxall, 1988).

From 1889 to 1927 there was a culling programme (Galatius et al., 2018). The hunters could collect a bounty for every seal that was shot. The seal hunting has been banned since 1972. This prohibition applies to all seal species found in Danish waters, including the common seal (Phoca vitulina) and the gray seal (Halichoerus grypus). The ban was implemented due to concerns about declining seal populations and to ensure the protection of these animals. Under this legislation, seal hunting is illegal, and strict penalties are imposed on individuals who violate it (Galatius et al., 2018).



Graph 1: Amount of seals in Kattegat and Danish Kattegat form the late 1970's till 2021 (Banga et al., 2022)

3.2.3 Seals catching fish in the net

Because of the rapidly growing seal population the seal-induced damage in the traditional trap-net fishery increased dramatically at the end of the previous century (Kauppinen et al., 2005). The amount of gear damage followed the trend of catch damage in each region, while the estimated yearly growth rate for the gray seal population in the Baltic Sea is 10% and that of the ringed seal 6%. (Kauppinen et al., 2005).

3.2.4 Contracaecum osculatum infection

Seals are the primary hosts for Contracaecum osculatum, a liver parasite (Valtonen et al., 1988). The larvae of this liver worm penetrate the stomach of seals and then migrate to the liver. It is known that this liver parasite can be transmitted through the feces of seals. Small marine creatures, such as plankton, consume these feces and thereby ingest the liver parasite (Valtonen et al., 1988). Subsequently, these creatures are eaten by small fish, which are in turn consumed by larger fish, primarily causing issues in the livers of cod *(Figure 1).*

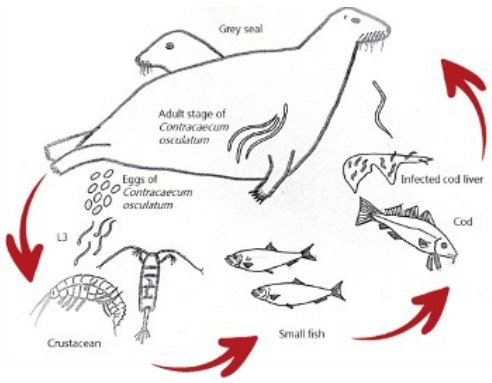


Figure 1: Infection of cod with contracaecum soculatum by seals (marnis, 2021)

Recent research indicates that cod in the central Baltic Sea is more affected by this parasite than elsewhere. This could partly be due to lower salinity levels in the Baltic Sea. However, many of these cod migrate to more northern areas such as the Kattegat, where they are then caught with the liver parasite. These cod are often severely weakened because the liver regulates various essential metabolic functions and serves as the main energy reserve for fish. Consequently, the high infection levels may contribute to the current decline or disappearance of cod in the Kattegat over the last 5 to 10 years.

3.2.5 Increasing population of crabs

When the temperature of the environment increases, the growth rate of the crab also increases (Green et al., 2014). This leads to a higher occurrence of larger crabs. An increase in temperature also lead to a shorter incubation period of the eggs, faster larvae development and accelerated sexual maturity. This in turn causes

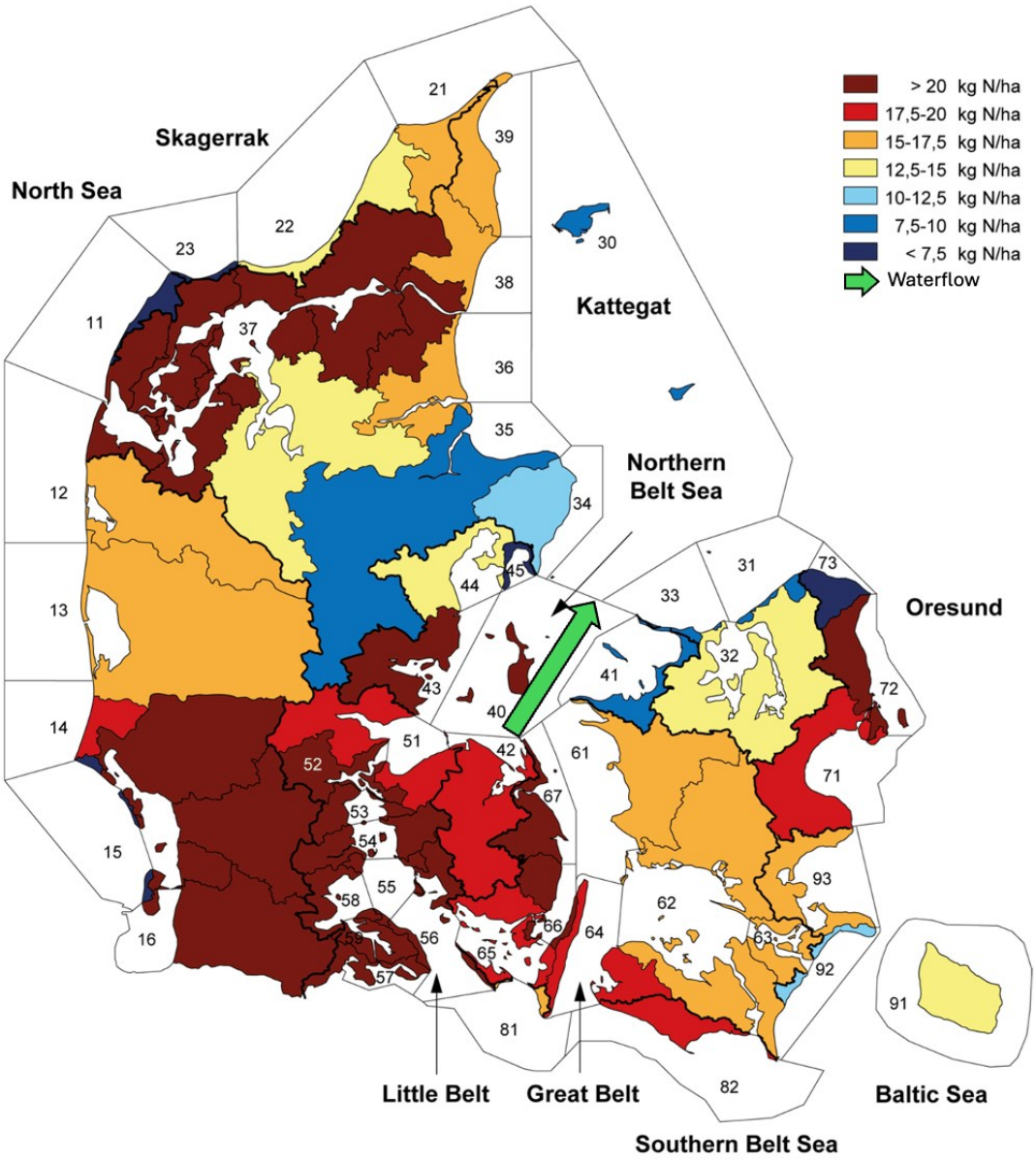
a larger number of crabs (Green et al., 2014). They are a bycatch during fishing and can damage the fish caught during their presence in the net (Godøy et al., 2003).

3.2.6 Increasing population of cormorants

The transboundary environmental conflict between the great cormorant and the European fisheries is another example of a twin global challenge of biodiversity conservation and sustainable natural resource management (Carss et al., 2013). This fish-eating bird is mobile, opportunistic and is expanding its European range since the introduction of several protection programs. One of these programs was the protection of wetlands in the 1970s by European legislation. In 2006 an estimation of 232,300 pairs was made in Europe. As this bird migrates, it can cause damage to the fish population on different locations (Carss et al., 2013).

3.2.7 Nitrogen pollution

Nitrogen pollution is an ongoing and growing problem in many rivers and estuaries of Europe and Denmark (EEA, 2018). The largest source of pollution to Denmark's coastal marine ecosystems comes from the use of nitrogen fertilizer and manures from agricultural sources (MST, 2023). We can see on *Map 2* that our study area is relatively low impacted by nitrogen pollution on land. The nitrogen pollution in the waters of our study area actually originates from the southwest of Denmark, where there is a lot of nitrogen pollution. This pollution is carried by the waterflow from the southwest to our study area.



Map 2: Kg N/ha pollution in Denmark (Cruz et al., 2019)

3.2.8 Legislation

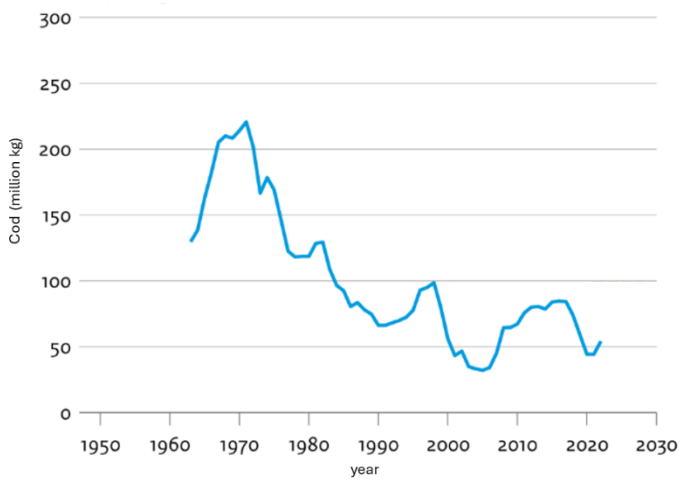
Several legislative restrictions are placed upon fishing activity in our study area (Pascual-Fernández et al., 2020). Both to protect the fishing industry itself and to protect the natural resources of Denmark and Sweden. Most of the legislation is on the European level, but countries still have some autonomy in setting legislation for their natural reserves. Generally speaking, fishers have to buy fishing rights in an open market and are only allowed to sell the number of fish they were allowed to catch by their fishing quota. Additionally, the fishing quotas are restricted by area. Given that even the industrial fishers often don't manage to achieve

their fishing quota which they often pay millions for, it is suspected that the legislation has failed to achieve sufficient protection for some species, like cod, and that quota should be tightened (Möllmann et al., 2021). In 2018, additional legislation was introduced to better protect the small-scale local fishing industries that are in steep decline all over the EU (Said et al., 2020). Additional protection of cod was also introduced in 2020-2023 with cod fishing being banned in the Øresund straight and restricted to a symbolic one cod per week per fishing vessel in the Kattegat. More importantly however are the bans on trawling that were introduced in the Øresund straight and several other environmental protection zones. Preliminary results suggest that only the combination of a trawling ban and cod fishing ban are capable of reversing the cod population decline (Öresund - Effects of the Trawl Fishing Ban, 2022).

3.3 Evolution fish stocks

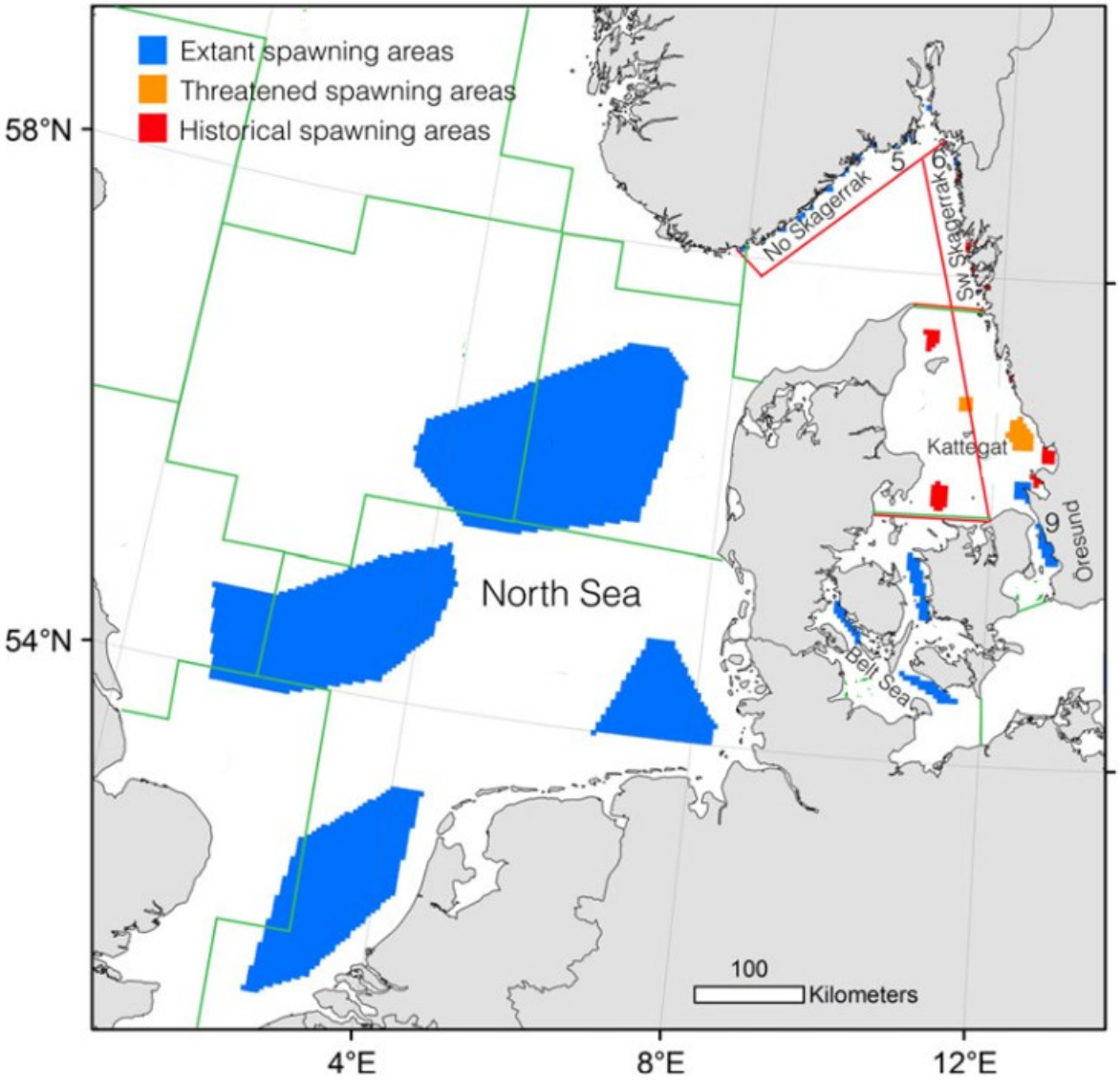
3.3.1 Cod

Since the 1970s, cod stocks in the North Sea, including Kattegat and Skagerrak, have declined dramatically (André et al., 2016). There is a sporadic increase in juveniles, but this does not restore the stocks. The oceans are overfished, and some stocks have not recovered despite various measures. This may indicate that overfished populations have lost much of their resilience (André et al., 2016). *Graph 2* shows the evolution of the amount of cod in the North Sea in million kilograms from 1963 to 2022.



Graph 2: Evolution of the amount of cod in the North Sea (source: ICES, 2023)

The young cod caught in the Kattegat usually originates from the spawning grounds in the central North Sea, such as the Dogger Banks (André et al., 2016). It is suspected that these young cod return to their place of birth to spawn, which is why the stock in the Kattegat is not being restored and is on the verge of extinction. *Map 3* shows the current, threatened and historical locations of the spawning grounds in the North Sea and Kattegat (André et al., 2016).



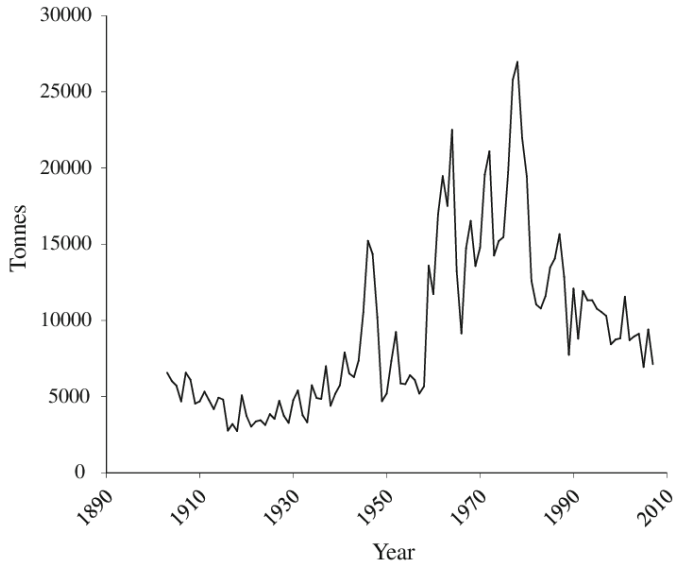
Map 3: Overview of the spawning grounds in the North Sea and Kattegat (source: © 2016 John Wiley & Sons Ltd, Fish. Oceanogr., 25:3, 210–228.)

The adult cod stock has shown a downward trend between 1971 and 2006 (CBS, PBL, RIVM, WUR, 2024). Since 1984, the stock has been below the precautionary limit and sustainability target of almost 98 million kg and in the periods 1990-1992 and 2000-2010 below the limit of almost 70 million kg of fish. The latter means that there are so few adult cod swimming in the North Sea that there is an increased risk of limited reproduction. After a historic low of around 33 million kg in the years 2003-2006, the cod stock has increased again. After a peak in the stock size of almost 85 million kg in 2016, the stock size has decreased again in the years that followed. From 2019, the stock is again well below the limit at almost 59 million kg and in 2022 it will have decreased further to over 54 million kg. Given that the stock is still below the limit in 2022, ICES advises a maximum catch of 26 million kg in 2023. With this advice, it is expected that the cod stock in the

North Sea can recover and that the stock will be above the limit again in 2024 (CBS, PBL, RIVM, WUR, 2024).

3.3.2 European plaice

The Swedish Marine Research Institute and its predecessors started national scientific trawl surveys in Kattegat-Skagerrak in 1901 (Bartolino et al., 2009). Since then, surveys in this area have been conducted almost annually. This database provides an opportunity to estimate population size, recruitment and size structure going back to the beginning of the 20th century. This extends the available time series of data considerably and provides insight into the dynamics of plaice in this area and an opportunity to redefine the management basis for this stock (Bartolino et al., 2009). *Graph 3* shows the collected data of the total catch in tonnes of plaice in Kattegat-Skagerrak from 1902 to 2007. The increase in catch until about 1980 is a result of the growth of the fishing fleets and increasing efficiency (Bartolino et al., 2009). Thereafter, there is a decrease due to overfishing. However, in the most recent years of this period, strong peaks have been observed in recruitment, which is the process by which young fish reach the adult fish population within a given ecosystem. This process encompasses the period from hatching to reaching a size and age where they become part of the adult population available for activities like fishing (Bartolino et al., 2009).



Graph 3: Total catch in tonnes of plaice in Kattegat-Skagerrak from 1902 to 2007 (Bartolino et al., 2009).

3.3.3 Common Sole

According to Lindegren et al. (2013) climate change has affected the catches and distribution of sole (Solea solea). Due to rising sea temperatures, the amount of sole in the catches has increased relative to plaice (Pleuronectes platessa), a species that thrives in colder waters. This indicates that sole thrives better in warmer waters. Long-term data from commercial catches and juvenile fish surveys around Denmark show that the amount of sole in catches has increased since the early 1980s. The changes in the amount of sole are linked to sea surface temperatures, Northern Hemisphere temperature anomalies, and the North Atlantic

Oscillation, a climate indicator. For example, a rise in Northern Hemisphere temperature anomalies explained 43% of the variation in juvenile sole catches relative to plaice. Despite the rising temperatures, the number of plaice remains relatively constant, suggesting that sole benefits more from the warmer water. The dietary flexibility of juvenile sole, which has more varied food sources, possibly gives them an advantage over other flatfish in changing environments. The increase in the sole population due to ocean warming has a significant impact on the composition of commercial fish catches in the area around Denmark (Lindegren et al., 2013).

3.3.4 Atlantic herring

According to *Table 2*, which was compiled from data obtained from the Danish Fisheries Agency, significant quantities of herring were still caught in the Kattegat at the turn of the millennium. However, these quantities decreased dramatically. The study by Gibson et al. (2014) attributes this decline to overfishing. Atlantic herring comprised 62% of the estimated unreported commercial catch, which totalled just under 753,000 tonnes. Their reported landings data from 1950-2010 indicate that Atlantic herring, together with sand eel and European sprat, dominated the reported landings, with 40%, 14% and 13% respectively. The reconstructed total catch for Danish fisheries from 1950-2010 also shows that Atlantic herring accounted for 14% of the total catch. The researchers found that young Atlantic herring was mainly used for reduction purposes in earlier decades, this is before 1970. This means that the herring was caught and processed into fishmeal and fish oil, rather than directly for human consumption. These products are often used as feed in aquaculture, agriculture, for animal feed and in some cases for the production of margarine. The adults were harvested for human consumption. This extensive fishing pressure led to a collapse of the stock and as a result the herring fishery was closed for about 10 years in the 1970s (Gibson et al., 2014).

Table 2: Landings in Sjaelland (Denmark) of atlantic herring in time (Danish Fisheries Agency, 2024).

Atlantic herring catch									
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
landed weight (kg)	149736	1212	1192158	1000824	455479	16047	17075	579	87565
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
landed weight (kg)	29595	29	64	110	199	20	13	153	942
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
landed weight (kg)	743	458	29	12	15181	0	251	400	0

3.3.5 Atlantis mackerel

When comparing the data in *Table 3 with the data in Table 2*, the trend for mackerel catches is the opposite of that for herring. The average catch of mackerel in Denmark per year in the ten years before 2011 was 20.6 kg, while in the ten years after 2011, it increased to 2155.6 kg.

The distribution of mackerel in the Northeast Atlantic is influenced by environmental factors (Carvalho & Kats, 2023). This distribution has been linked to sea temperature and less to the presence of food, such as meso-zooplankton. Mackerel, which thrive in warmer waters, have moved further north, increasing their presence in the Kattegat. In addition, changes in fishing practices over the years have also contributed to this increase. Fishermen have adjusted their efforts and methods in response to changes in fish populations and regulations, resulting in a greater focus on species such as mackerel (Carvalho & Kats, 2023).

Table 3: Landings in Sjaelland (Denmark) of Atlantic mackerel in time (Danish Fisheries Agency, 2024).

Atlantic mackerel catch									
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
landed weight (kg)	65	780	58	24	23	3	0	19	76
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
landed weight (kg)	14	9	3	10	59	13	63	2289	813
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
landed weight (kg)	1406	3383	2540	4206	1875	2059	469	251	852

3.3.6 Blue mussel

Mainly dredge fisheries of wild populations account for the production of blue mussels in Denmark (Geitner et al., 2021). This is a less common production technique because on-bottom culture of blue mussels, where mussel seed is translocated from natural beds to designated culture areas, is widely practiced. The Danish government has made significant efforts to transform the fishing sector into a sustainable mussel farming practice, considering both economic and ecological interests. Therefore, the Danish Mussel and Oyster Policy (MOP) was adopted in June 2013 and evaluated in 2017, leading to a revised policy in May 2019. This policy aims to balance the development of the shellfish sector with environmental protection using scientific tools. Fishing in Natura 2000 areas is strictly regulated, including the use of a “black box” system on fishing vessels to accurately monitor fishing activities. This system records fishing activities at 10-second intervals, helping to assess the impact of fishing on different ecosystems. The Danish Mussel Committee, established in 2003, plays a central role in defining the conditions for mussel and oyster farming to promote sustainable production. This committee consists of representatives from the Danish government, conservation organizations, researchers, and the shellfish industry (Geitner et al., 2021). *Table 4* shows an explosion in mussel catches since 1999.

Table 4: Landings in Sjaelland (Denmark) of Atlantic herring in time (Danish Fisheries Agency, 2024).

Blue mussel catch									
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
landed weight (kg)	0	0	0	82115	723124	2576303	222761	524489	701020
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
landed weight (kg)	2940835	2491218	2866678	2732040	1427994	1191364	865215	900108	1026033
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
landed weight (kg)	908911	1024313	676183	2321322	2935722	2337862	2207875	3752586	1619655

3.3.7 Norway lobster

Since the 1960s, the Norway lobster fishery has developed and has since become economically important for the fishery (Hornborg et al., 2017). Because this species lives in burrows in muddy sediments and is mainly fished with demersal trawls, fishing has a major impact on the seabed habitats and the species that live there. This has a major impact on the recovery of depleted fish stocks. It is known worldwide that this type of fishing is one of the most energy-intensive fishing practices. Consequently, it also causes problems with the regulations for sustainable fisheries. In 2014, the total landing of Norway lobster in the Skagerrak-Kattegat area was 4150 tonnes (Hornborg et al., 2017). *Table 5* gives an overview of the Norway lobster catch in Zealand per kilogram. For each tonne of Nephrops landed, 21 to 40 km² of seabed surface has to be swept (Hornborg et al., 2017).

Table 5: Landings in Sjaelland (Denmark) of Atlantic herring in time (Danish Fisheries Agency, 2024).

Norway lobster catch									
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
landed weight (kg)	4694	7578	10104	17125	17005	6217	14364	7109	8673
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
landed weight (kg)	7756	5715	14960	9354	4037	12915	22444	16159	21155
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
landed weight (kg)	12743	9356	3061	18778	18797	13425	28768	29879	20082

4 METHOD

4.1 AIS data

4.1.1 Introduction

AIS, or Automatic Identification System, is a position-sharing system present on almost all large-sized vessels and fishing boats. Since 2010, AIS has been mandatory for fishing boats in all the EU waters. Therefore, historical data from 2010 onwards provides a great deal of information about changes in fishing activity. Global Fishing Watch aggregates AIS-derived fishing intensity data, visualized on a map (Drakopulos et al., 2022). On this map we can see how fishing intensity is shifting from the Øresund region to the Kattegat and Isefjord (GFW | MAP, 2024). However, the data is coarse and more importantly doesn't differentiate between different types of fishing, nor does it distinguish between local and foreign fishers. It does however track illegal fishing (fishing boats that are not sending AIS-signals) and it tried its best to differentiate between fishing boats engaged in fishing and fishing boats that are just travelling, using AI algorithms (Drakopulos et al., 2022). We used raw AIS data from the Danish maritime authority (Web AIS Data, 2024) to build our own fishing intensity map, which has more detail and has more background information than the global fishing watch map. However, our map doesn't differentiate between "fishing" and travelling fishing boats. Therefore, it contains even more false positives than the global fishing watch map.

4.1.2 Differentiating between local and non-local fishing vessels

Most fishermen in the waters of our study area were of Danish origin and were mostly active in the Sjaelland/Kattegat area. Fishing vessels that weren't of local origin were filtered out of the database, because non-local fishermen usually have different fishing rights and therefore operate in different fishing areas. The term 'local fishermen' refers to fishermen who visit Gilleje, Havnebyen, Hundested, Lynaes, Helsingor or Helsingborg the most frequently and sail under the Danish flag. To assess if boats were of local origin we monitored their tracks on marinetraffic.org and searched for news articles about each individual boat. The additional open-source information (AIS Data: Vessels, n.d.) we found about the ships was added into a PostgreSQL environment, together with the AIS-data and analyzed through a connection with a Python environment.

4.1.3 Data scraping and wrangling

The AIS-data was downloaded using a Python-BS4 data scraping script. While downloading the data, another script was running simultaneously to import a filtered version of the data into a Postgres environment. Only the positional data of local fishing vessels within our study area was stored not to overload the memory of the computer. Filtering based on the study area was not only useful for computer memory reasons but also filtered out most of the erroneous position data. Additional filtering was performed on AIS-data coming from

within a harbor area. This includes mostly stationary ships. Further filtering could be useful but given that visually the trajectories made sense we concluded that it wouldn't affect our end result in a meaningful way. We could have started calculating speeds and removing unrealistic speeds, between all consecutive points. However, this would require a very large amount of processing power and a significant amount of coding.

Trajectories were generated from the AIS point clouds using PostGIS and were split after each hour of fishing. This allows us to see how many hours of fishing boat activity occurred during certain periods of time in a certain area. More importantly, it accelerates the upcoming heatmap generation process from multiple days to less than 30 minutes. The heatmap algorithm is significantly more efficient at processing numerous small line segments compared to fewer larger ones.

4.1.4 Heatmap generation and interpretation

The AIS data points couldn't be used for the heatmap because some ships have more frequent GPS fixes than others. To take this weighting problem into account, trajectories were generated from the AIS-point clouds using PostGIS. The trajectories were split after each hour of fishing. This allows us to see how many hours of fishing boat activity occurred during certain periods of time in a certain area. More importantly however, it accelerates the upcoming heatmap generation process from multiple days for less then, 30 minutes. As the heatmap/line density algorithm is much more efficient in processing large amounts of smaller lines than processing fewer larger lines.

The line density map is achieved by calculating the length of all intersecting lines within a radius of 0.015 degrees around the centre point of each pixel with a size of 0.015 degrees divided by the search area (Raffler, 2020). The main implication is that each pixel captures data from its own area and parts of neighbouring pixels, resulting in a smoothening effect on the map and sometimes higher values than appropriate for the pixel area itself.

As a last step the density values of 2015 and 2023 are standardized and subtracted from each other. The result of which is a difference map that provides insight into where fishing intensity is decreasing and increasing. No absolute fishing intensity values could be achieved, because we couldn't guarantee we found all 2015 local fishing vessels. As data about those ships was more elusive. With a complete dataset however, it would be possible to provide estimated fishing intensities as calculated in total hours of fishing activity, using a linear correction on the line density values.

4.2 Fieldwork

4.2.1 In-depth interviews

The fieldwork involved visiting four harbors in Sjælland to conduct interviews with local fishermen. The primary aim was to gather insights into how fishermen perceive changes in their industry and to validate trends observed on our AIS fishing intensity maps (such as *Map 5*) and causes of shifts we found in the literature. Specifically, we sought information about changes in fishing locations and quantities over time, as well as the social and economic impacts of these shifts. Given the limited number of fishermen available for interviews, this method - conducting interviews instead of distributing surveys - proved more effective than using structured questionnaires. We found that fishermen were more willing to engage in discussions in a casual, non-professional setting. This approach was particularly beneficial because the topic is sensitive, deeply intertwined with their culture and livelihood. By avoiding a formal, professional setting, we were able to create an environment where they felt comfortable sharing their thoughts and experiences.

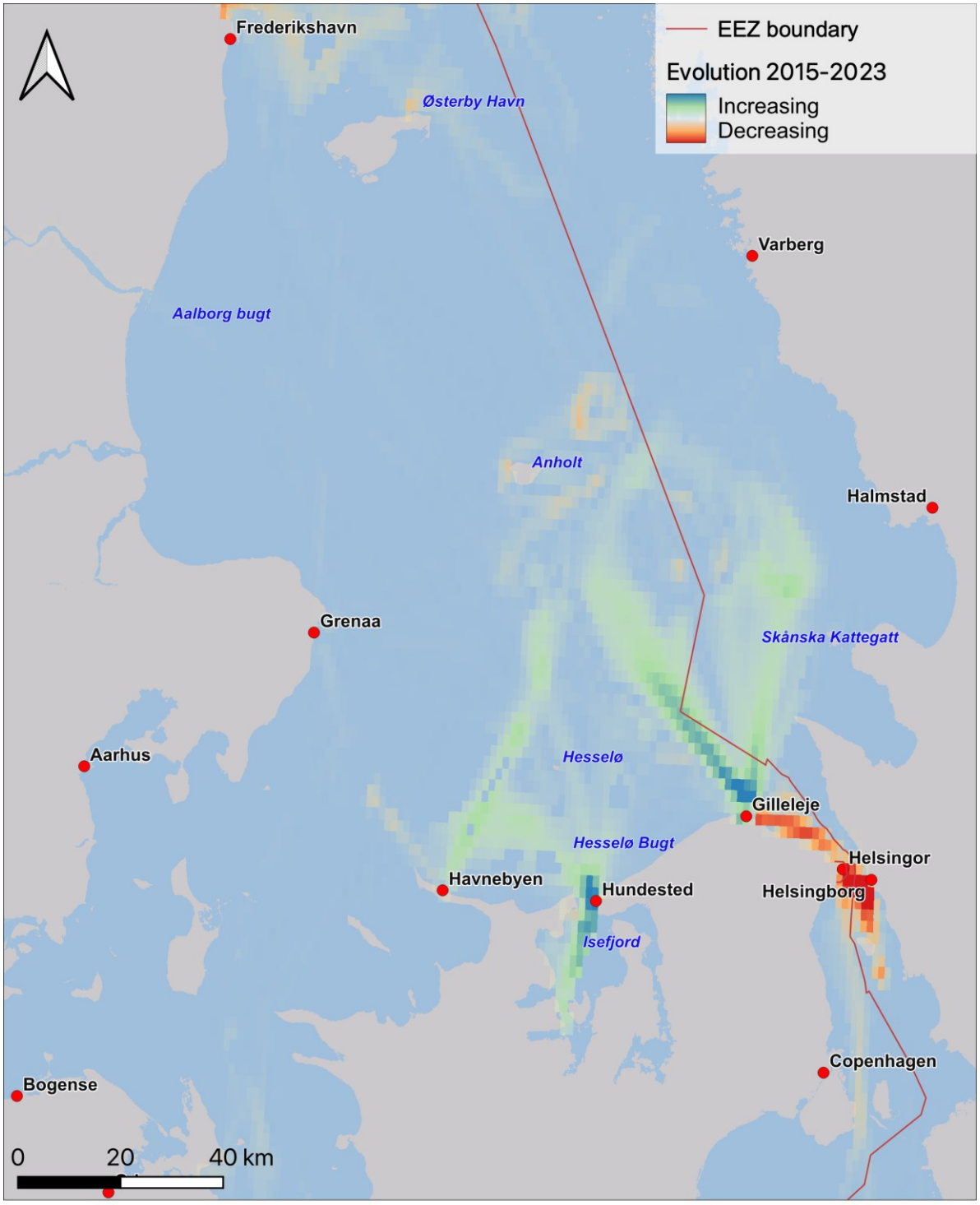
We were able to have a conversation with approximately nine fishermen and a woman that works in a fish shop. More specifically, three fishermen were interviewed in Odden Havn, and four in Gilleleje, along with the woman in the fish shop. Additionally, we have interviewed two recreative fishers who fish in the bay west of Odsherred.

5 RESULTS

5.1 AIS-data

The fishermen are moving away from the Øresund strait at Herlsingor and Frederikshavn (as visible on *Map 4*). Instead, they are increasing their activity North of Gilleleje and in the Isefjord. This spatial change reflects a shift from fishing on fish to the fishing of molluscs (Isefjord) and lobsters (north of Gilleleje). Especially the collapse in the traditional cod fishing areas of the Øresund straight is very dramatic. With close to no fishing still happening there in 2023, down from being the most active fishing area in the entire study area. Also very notable were more small-scale differences in fishing activities. The shallow waters and sand banks where flatfish are usually caught are experiencing a steep decline in fishing activity whereas the deeper waters that are more lobster-oriented are experiencing increasing amounts of fishing activity. This is especially clear near Havnebyen. To the northwest of this port town, large areas of shallow waters exist in a ridgeline that was intensively fished in 2015. In 2023 this sandbank experienced little fishing, but the deeper waters to the northeast are experiencing a large increase in fishing activity. We couldn’t explain why the Isefjord mollusc fishing increased over the past few years as we didn’t interview fishers in this field of the industry, but a 2008 research paper from Wageningen university cites Isefjord as a major export hub for live molluscs to fish farmers in the Netherlands (Wijsman & De Mesel, 2008). Demand in this field could have risen.

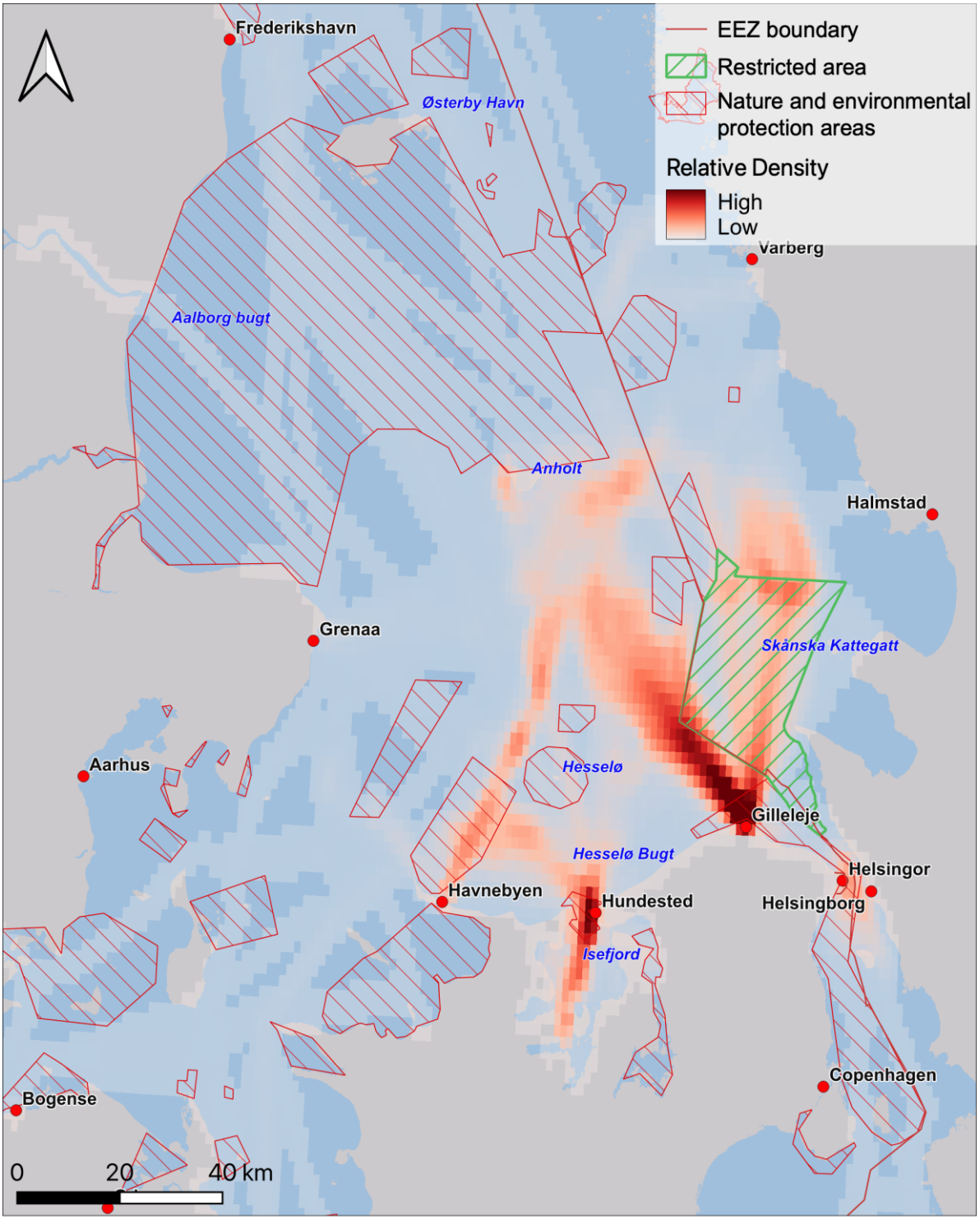
Important to note here again is that our heatmap doesn’t differentiate between travelling fishing boats and fishing boats that engaged in fishing. Which causes the interpretation to be fairly hard. Near the ports, indicated with red dots, concentrations are artificially large. And also, on the way towards fishing areas, some funnel effects might be present. However, it should also be noted that at Gilleleje most fishers go way and back in a straight line. The area that seems like a funnel here is therefore not necessarily only a funnel, but also a very active fishing area.



Map 4: Changes in the amount of fishing vessel activity from 2015 compared to 2023

5.2 Legislation

Not all environmental protection areas have a similar amount of protection. The designated area north of Havnebyen for example doesn't seem to have a significant role. When a local fisherman was asked about this zone, however he didn't know what we were talking about. The havnplan, a maritime spatial plan of the Danish government, is also very opaque about legislation per area. There is no central overview of legislation per plot and all the restrictions are announced in individual government reports. However, certain areas significantly impact fishing activities, notably the nature and environmental protection area northeast of Gilleleje, referred to as the 'restricted area' on *Map 5*. It is clearly visible that the Danish fishermen travel through the area, only to start fishing in the buffer zone all the way up North in the restricted area. When looking at the trajectories of two German trawling boats that are also active at Gilleleje, but not included in the density map as they are not local fishermen, it becomes clear that they do have permission to fish well within the restricted zone and therefore don't have to travel as far as the Danish fishers. A considerable competitive advantage. This loophole in the legislation was only introduced in 2022 (Ny Fiskeriregulering I Udpegede Beskyttede Havområder I Kattegat Er Trådt I Kraft Den 11. Juli 2022) and is illustrative of the competition that remains in the industry despite close to all regulations now being decided on the European level.



Map 5: The fishing activity intensity of 2023 overlaid with the most recent havnplan

5.3 Responses of fishermen

Interviews show that the primary concern among fishermen is the impact of parasites carried by seals from the Baltic Sea. These parasites infect cod, leading to a decline in the cod population. Consequently, with fewer cod to prey on them, crab populations increase. Increased crab predation on fish eggs further diminishes fish numbers, creating a negative cycle, as described by the fishermen. Fishermen in Gilleleje mentioned that cod were still present about six years ago, whereas fishermen in Sjællands Odde even talked about 20 years ago. There are now fines for catching cod, adding to the challenges faced by the fishermen. Another significant problem that emerged from the interviews was the predation of fish in the nets by seals and cormorants. When the water is warmer, there is also predation by crabs. These crabs were seen as the main problem by two recreational fishermen. Because of the seals, fishermen regularly have to change fishing areas because the seals chase the fishermen. The problem with seals occurs only when catching flatfish. These forms of predation affect at least half of the fish catch, according to fishermen.

It was also mentioned several times during the interviews that German fishermen have better quotas due to a Swedish-German alliance, German vessels also have to travel less far to reach good fishing areas. Danish vessels have to sail three to four hours for a good fishing spot. Confirming the results from section 5.2. Overall fishermen were relatively satisfied with the legislative framework surrounding the fishing industry. No larger vessels are not allowed in Kattegat and the Danish local fishers are shielded from the open fishing quota market. However, one fisherman in Sjællands Odde indicated that it is no longer profitable to fish and that he is looking for other work. However, most fishermen indicated that it is still profitable to fish, but only when focussing on the lobsters that are also caught in Gilleleje. In Gilleleje, one fisherman told us that only one boat still exists in the area that still exclusively fishes for flatfish, the others primarily fish for lobsters. Interviews also revealed that the Danish government gives money to fishermen to get rid of their boats as a measure for the poor harvest. One fisher claimed that this policy was not a sufficient support and demanded for subsidies for small-scale fishers. Interviews with fish shops also revealed that the price of fish has risen by roughly 50 percent in the past five years due to the decline in supply.

6 DISCUSSION

6.1 Potential for Improvements to the AIS-data analysis

There are several ways in which AIS-data research could be improved. The three most important domains in which improvement could be achieved are listed below:

1. It is possible to distinguish boats that are engaged in fishing from boats that are underway (Ferreira et al., 2022). To do this however, it is necessary to apply some complex AI algorithms, that use the shape of the trajectory to predict vessel behavior. Applying a model to our data that classifies the behavior of

our ships could significantly improve the interpretability of our fishing intensity maps. However, it would require a load of additional coding and licenses to use known models.

2. If there was access to large volumes of AIS-data storage and processing power, more comprehensive pattern recognition could be performed. It would be possible to compare more than two years of AIS-data and make a separate intensity map for non-local fishing vessels. Additionally, more processing power could provide better insight into seasonal variations in fishing activity.

3. The last big improvement could be achieved by gathering more metadata about the fishing vessels. This could create a more complete overview of all the local fishing vessels, as well as provide boat sizes. Both factors have significant influence on the fishing intensity distribution. A large boat size should be weighing more heavily on the fishing intensity map than small vessels. The main benefit of having all fishing vessels in the data is that absolute intensity values could be estimated (in hours of fishing). Additionally, it could clear up gaps in the dataset.

6.2 Strentgts of the AIS-data analysis

With general and global fishing intensity maps, like global fishing watch, it wouldn’t have been possible to see the difference between the behavior of the German fishermen and the local fishermen. Additionally, the high spatial resolution (0.015 degrees) of the density map provided insight into how fishing is changing from the shallow waters into the deeper waters. The additional metadata proved to be very useful as well. Due to information about ship types, we could identify that the increase of fishing activity in the Isefjord was due to mollusc fishing and that the increase near Gilleleje was driven by trawl fishing.

6.3 Fieldwork

The weaknesses of our study were mainly due to not being well-prepared for the interviews. We had planned to use a survey to ask each fisherman individually about their routes and point out their fishing grounds on a map utilizing Participatory Geographic Information Systems (PPGIS) so that fishermen could visually communicate their locations over time. However, during the interviews, we realized the fishermen didn't have much time, so we couldn't complete the survey. Instead of this we had informal conversations and included the questions in those talks.

Finding a fisherman was sometimes difficult. We often had to wait for a fishing boat to arrive or for someone to be seen cleaning their nets. Communication was also tough because many of them didn't speak much English. Some fishermen returned very early and had already sold their fish to the market or local shops and had gone home.

Despite these problems, the interviews gave us good insights into the reasons for the decrease in the fish population, confirming what we had already found in the literature. Given the small number of fishing boats (about sixteen), we were able to interview a relatively large number of fishermen (nine).

6.4 Results

The main factor for the reduced fish catches causing the decrease of the fishing fleet in Sjælland was found to be that the fish were infected by the seals with the liver parasite *Contracaecum osculatum.* More research into the parasites, their life cycle and the interactions between seals and fish populations can help to find effective solutions. For this, the fish stocks should be monitored regularly to follow the spread of parasites and to understand how these vary over time and between different areas. Perhaps treating seals against parasites could be a direct way to reduce the parasite pressure. Further research can show whether this is feasible.

It also emerged that the seals come to eat the fish from the nets. The reason for this behavior can probably be found in the fact that there are fewer fish available to hunt and that there is an increase in the number of seals. In order to find a solution to this depredation, research can be conducted into means to keep the seals at a distance or to make the nets themselves resistant to this.

The crabs cause a lot of damage to the fish in the fishing nets. Further research into fishing techniques that catch more selectively is indicated here. In addition, a spatiotemporal study can also be conducted regarding the presence of the crabs. The question can be asked here whether there are fishing grounds where the crabs are less present and whether there are seasons when there are fewer crabs.

7 CONCLUSION

There is a lot changing in the fishing industry, both locally and on the European level. Fish stocks are in steep decline, and this is hitting the local Danish fishing industry very hard. An ecosystem collapse caused by a variety of reasons is making it hard for any fishing industry remains economically sustainable. Additionally, new legislation that tries to protect the ecosystem is further harming fishermen’s interests. In the course of this research, we found only two fishermen that were still primarily hunt fish in our study area. In contrast with over 30 vessels still fishing for lobsters or molluscs. The local fish hunting industry has already collapsed and if lobster stocks were to plunge, only a handful of mollusc fishers would still be able to make profits.

The decline of cod, which is one of the most lucrative fish on the market, has caused particular hardship for the fishing industry. With the species now close to extinction in all Danish waters expect the Oresund straight. Global warming is thought to be one of the primary reasons for the decline in cod populations, but the story is more complex. Historical overfishing has also contributed significantly to the problem. Both because of the catch of too many fish and because of the destruction of the seabed by trawl fishing. A third factor contributing to the cod population decline is the increased distribution of parasites by an ever-increasing amount of seals.

It is not clear how important these factors are relative to each other, but research suggests that multiple of these problems have to be addressed before cod populations start to increase again.

Other fish species are becoming less numerous as well, although less dramatically. With estimations for some species varying from a 47% up to a 97% decline it is hard to make statements about this. The most important fish species are the flatfish and the landings of these species are down over 95% since the year 2000, in Sjaelland. This reduction is largely a result of the decreasing number of fishermen itself. We identified several challenges that are driving these fishermen to quitting or changing over to lobster fishing. A relatively elusive problem is nitrogen pollution, which causes oxygen levels deplete and fish to die. Other pollution coming from the Baltics and global warming are also influencing the population dynamics, but these relations are not yet fully understood. In coastal waters, where flatfish fishing takes place not only the fish stock is a problem. Most of the fishers complained about seals, crabs and cormorants stealing large parts of the fishermen's catches. Which causes them to move more frequently, as a way to hide from these predators, causes them to quit entirely or move to the deeper waters where the lobsters and molluscs are present. This shift from shallow to deep waters was clearly visible in the fishing activity intensity map. In terms of legislation, local fishermen overall felt sufficiently protected. However, some complained about German fishermen receiving quota, for more nearby fishing areas. Giving them unfair advantage over Danish fishermen. The government is not allowing industrial scale fishing anymore, in our study area. Additionally, the government helps the struggling fishermen going after new jobs by buying their boats. Both measures were appreciated by the fishermen we interviewed. Although one fisherman still argued the government was doing too little and should subsidize the fishing industry, similar to the agricultural industry.

8 REFERENCES

8.1 Scientific papers

André, C., Corell, H., Jonsson, P. R., Moksnes, P. O., Svedäng, H. (2016). Recent decline in cod stocks in the North Sea–Skagerrak–Kattegat shifts the sources of larval supply. *Fisheries Oceanography,* 25(3), 210-228.

Beaugrand, G., Kirby, RR. (2010) Climate, plankton and cod. Global Change Biology, 16, 1268–1280.

Carss, D. N., Cheyne, I., Marzano, M. (2013). Managing European cormorant-fisheries conflicts: problems, practicalities and policy. *Fisheries Management and Ecology*, 20(5), 401-413.

Carvalho, G., Kats, M. (2023). Mapping essential fish habitats of herring (Clupea harengus) and mackerel (Scomber scombrus) in the North East Atlantic.

CBS, PBL, RIVM, WUR (2024). Visbestanden in de Noordzee, 1947-2023 (indicator 0073, versie 21, 11 december 2023) www.clo.nl. Centraal Bureau voor de Statistiek (CBS), Den Haag; PBL Planbureau voor de Leefomgeving, Den Haag; RIVM Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven; en Wageningen University and Research, Wageningen.

Cruz, S., Cordovil, C. M., Pinto, R., Brito, A. G., Cameira, M. R., Gonçalves, G., ... & May, L. (2019). Nitrogen in water-Portugal and Denmark: Two contrasting realities. *Water*, *11*(6), 1114.

Drakopulos, L., Silver, J. J., Nost, E., Gray, N., & Hawkins, R. (2022). Making global oceans governance in/visible with Smart Earth: The case of Global Fishing Watch. *Environment and Planning. E, Nature and Space*, *6*(2), 1098–1113. https://doi.org/10.1177/25148486221111786.

Engelhard, G. H., Righton, D. A., Pinnegar, J. K. (2014). Climate change and fishing: a century of shifting distribution in North Sea cod. Global change biology, 20(8), 2473-2483.

Ferreira, M. D., Spadon, G., Soares, A., & Matwin, S. (2022). A Semi-Supervised Methodology for Fishing Activity Detection Using the Geometry behind the Trajectory of Multiple Vessels. *Sensors*, *22*(16), 6063. https://doi.org/10.3390/s22166063.

Galatius, A., Härkönen, T., Olsen, M.T. (2018). The history and effects of seal-fishery conflicts in Denmark. *Marine Ecology Progress Series*, 595, 233-243.

Geitner, K., Kristensen, K., McLaverty, C., Nielsen, M., Nielsen, P., Olsen, J., Petersen, J. (2021). Management of bivalve fisheries in marine protected areas. *Marine Policy*, 124, 104357.

Gibson, D., Ueberschär, B., Zeller, D., Zylich, K. (2014). Preliminary reconstruction of total marine fisheries catches for Denmark in the Kattegat, the Skagerrak and the North Sea (1950-2010).

Godøy, H., Furevik, D., Løkkeborg, S. (2003). Reduced bycatch of red king crab (Paralithodes camtschaticus) in the gillnet fishery for cod (Gadus morhua) in northern Norway. Fisheries Research, 62(3), 377-384.

Green, B. S., Gardner, C., Hochmuth, J. D., Linnane, A. (2014). Environmental effects on fished lobsters and crabs. Reviews in Fish Biology and Fisheries, 24, 613-638.

Harwood, J., Croxall, J. P. (1988). THE ASSESSMENT OF COMPETITION BETWEEN SEALS AND COMMERCIAL FISHERIES IN THE NORTH SEA AND THE ANTARCTIC1. Marine Mammal Science, 4(1), 13–33. https://doi.org/10.1111/j.1748-7692.1988.tb00179.x

Hornborg, S., Jonsson, P., Lövgren, J., Ritzau Eigaard, O., Sköld, M., Ulmestrand, M., Valentinsson, D. (2017). New policies may call for new approaches: the case of the Swedish Norway lobster (Nephrops norvegicus) fisheries in the Kattegat and Skagerrak. *ICES Journal of Marine Science*, 74(1), 134-145.

Kauppinen, T., Siira, A., Suuronen, P. (2005). Temporal and regional patterns in seal-induced catch and gear damage in the coastal trap-net fishery in the northern Baltic Sea: effect of netting material on damage, Fisheries Research, Volume 73, Issues 1–2, Pages 99-109, ISSN 0165-7836, https://doi.org/10.1016/j.fishres.2005.01.003.

Lindegren, M., Mackenzie, B., Sparrevohn, C. (2013). Climate-induced response of commercially important flatfish species during the 20th century. *Fisheries Oceanography*, 22(5), 400-408.

Madsen, P. V. Tunfiskeri med krog og harpun. *Folk og kultur, årbog for dansk etnologi og folkemindevidenskab*, 3(1), 117-122.

Möllmann, C., Cormon, X., Funk, S., Otto, S. A., Schmidt, J. O., Schwermer, H., Sguotti, C., Voss, R., & Quaas, M. (2021). Tipping point realized in cod fishery. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-93843-z

Marnis, H. (2021). *Contracaecum osculatum larvae in Baltic cod (Gadus morhua): Effects on growth and immune response* [PhD thesis, University of Copenhagen]. Department of Veterinary and Animal Sciences, section for Parasitology and Aquatic Pathobiology.

Pascual-Fernández, J. J., Pita, C., & Bavinck, M. (2020). *Small-Scale fisheries in Europe: status, resilience and governance*. Springer Nature.

Said, A., Pascual-Fernández, J. J., Amorim, V. I., Autzen, M. H., Hegland, T. J., Pita, C., Ferretti, J., & Penca, J. (2020). Small-scale fisheries access to fishing opportunities in the European Union: Is the Common Fisheries Policy the right step to SDG14b? *Marine Policy*, *118*, 104009. https://doi.org/10.1016/j.marpol.2020.104009

Valtonen, E. T., Fagerholm, H. P., Helle, E. (1988). Contracaecum osculatum (Nematoda: Anisakidae) in fish and seals in Bothnian Bay (northeastern Baltic Sea). *International journal for parasitology*, 18(3), 365-370.

Wijsman, J., & De Mesel, I. (2008). Risk analysis on the import of mussels from the Limfjord and the Isefjord (Denmark) to the Oosterschelde. *Client: Association of Shellfish Importers*, *C068/08*. http://library.wur.nl/WebQuery/wurpubs/370154

8.2 Internet sources

Forside - Lynæs Havn. (z.d.). Lynæs Havn. https://lynaes-havn.dk/

Gilleleje havn. (z.d.). gillelejehavn. https://gillelejehavn.com/

Odden Havn - Odsherred kommune. (z.d.). Odsherred Kommune. https://www.odsherred.dk/da/opleve-og-vaere-aktiv/ud-i-naturen/odsherred-havne/odden-havn/

Yachts - Hundested havn. (z.d.). Hundested Havn. https://hundestedhavn.dk/en/yachts/

AIS Data: Vessels. (n.d.). Retrieved March 14, 2024, from https://www.marinetraffic.com/en/ais/home

GFW | MAP. (2024). Global Fishing Watch. Retrieved April 17, 2024, from https://globalfishingwatch.org/map

Ny fiskeriregulering i udpegede beskyttede havområder i Kattegat er trådt i kraft den 11. juli 2022. (2022, July 11). Fiskeristyrelsen.dk. Retrieved June 14, 2024, from https://fiskeristyrelsen.dk/nyheder/nyhed/nyhed/ny-fiskeriregulering-i-udpegede-beskyttede-havomraader-i-kattegat-er-traadt-i-kraft-den-11-juli-2022

Raffler, C. (2020, January 10). *[feature][processing] Add Line density algorithm by root676 · Pull Request #33525 · qgis/QGIS*. GitHub. https://github.com/qgis/QGIS/pull/33525

8.4 Conference presentations

Öresund - effects of the trawl fishing ban (By Sveriges lantbruksuniversitet & Institutionen för akvatiska resurser). (2022, October 18). [Slide show]. Nordisk konferanse om havforvaltning og klimaendringer. https://www.miljodirektoratet.no/contentassets/7c36417607ef4d39905164e2492cbab9/12_ulf-oresund-tralforbud.pdf

8.3 Data

Web ais data. (2024). [Dataset]. Danish Maritime Authority. https://web.ais.dk/aisdata/?fbclid=IwAR1UyDCL7oGYDMWYbUh8Kjs2k_bxWF9fSzMAlp0v3XZDQsv7FTkQuRYqSs0

FACULTEIT WETENSCHAPPEN

MASTER OF SCIENCE IN GEOGRAPHY AND GEOMATICS

ODSHERRED ON THE MOVE?

ANALISING INTERNAL MIGRATION TRENDS AND FUTURE ASPIRATIONS

Word count: 11317

Febe Cromphout, Yarno De Baetzelier, Myrte De Koster, Kato Selis, Luna Vanden Eede
Student number: 02008451, 02003272, 02001200, 02004871, 01912077

Responsible lecturer: Prof. dr. Veerle Van Eetvelde

Course: Integrated International Project work

Academic year: 2023 - 2024

UNIVERSITEIT GENT

Roskilde University

UNIVERSITY OF COPENHAGEN

1. INTRODUCTION

When looking at the projection of the population pyramid of Odsherred between 2010 and 2050, the age group between 20 and 30 is surprisingly small. This made this age group interesting to us, and after further research, we found out that the limited presence of this group is due to migration to other municipalities, most of which are urban (statistics Denmark, 2023a). The outward migration of these young adults has several consequences for Odsherred, such as an ageing population, which the municipality tries to avoid (Odsherred Kommune, 2023). At this moment, there are few studies that cover the migration of these young adults in peripheral municipalities in Denmark, but none of them focus on this area. The goal of this research is to find the migration patterns in this municipality, to explore the push- and pull factors for people to move to or away from four parishes in Odsherred (Nykøbing Sj, Vallekilde, Asnæs and Egebjerg) and to give points of actions for these parishes that could make them more attractive without impacting the current pull factors. This research aims to answer five research questions:

1. What are the migration patterns in Odsherred?
2. What are possible drivers of migration in the municipality and its parishes?
3. What is the impact on the society of Odsherred when young people leave?
4. What are the current efforts of the municipality for attracting young people?
5. How can the municipality work towards retaining and/or increasing the influx of people in the future?

This research consists of a literature review which explains the migration of mostly young adults at different scales, the consequences of this migration and the possible actions that can be taken to reduce the outward migration of young adults. Besides the literature review and mapping of the migration patterns, an on-field survey will provide more information about the push and pull factors in the four parishes. The responses to the survey will be analyzed using a factor analysis and a Chi-square test. The survey will also provide information on a desired scenario in each parish. These scenarios will be developed with scenario modelling based on two axes: accessibility and economy. Lastly, some points of action will be defined for the municipality to help reach the most desired scenario in each parish and increase the inward migration of young adults.

2. THEORETICAL FRAMEWORK

2.1 Migration in Europe, Denmark and rural Denmark

For the last couple of years, there have been some trends in Europe regarding population changes due to migration. According to data between 1 January 2015 and 1 January 2021, there had been a net population growth in the European Union (EU). Despite a decline in natural population change, there was overall population growth due to higher immigration compared to emigration. However, in one-third of rural areas, there could be a negative crude rate of net migration observed. The region to which Odsherred (Vest- od Sydsjaelland) belongs, is one of them. This predominantly rural region reported an average annual crude rate of natural change of -3,3%. During this period, population growth was also much higher in the predominantly urban regions, which was mostly due to different net migration rates (Eurostat, 2022).

Hansen (2020) also saw this trend, noting that for the last decades in Northern Europe, there can be found uneven development across regions, with on one hand thriving urban areas characterized by a rise in population and employment opportunities, and on the other hand declining rural areas. Some challenges that the peripheral and rural areas face (according to data from 2002-2013) are a decline in population, a decline in workplaces and an ageing population (Hansen, 2020). This ageing population and reduction of the working age are partially caused by relatively young people choosing to leave the rural regions in favor of urban regions, for example, to find prosperity and better opportunities (Eurostat, 2022).

The outmigration of rural youth in the "Western world" is not a new phenomenon, but the perceived motives and the research focus have both changed over the years. In the 70's there was a focus on qualitative measurable factors, such as age and gender. In the 90's there was a shift to quantitative factors, and they took experiences and emotions into account, such as a desire to raise their social standing, get better employment or higher education. The migration history of the parents was also paid attention to. In the 00's there was still a focus on employment and education but there was also a shift in attention to personal motives, such as the will to escape their small-town community and, for women, the dominant masculine culture. Leaving became a symbol of making it in life. In the 10's this trend continued, with employment and education still as important factors, and the parents' social class and education were also taken into account. Leaving patriarchal structures, gaining personal freedom and the exotic city life were some personal motivations that were paid attention to. Some trends that continued throughout the decades were that women have been more likely to leave, and that the

main reasons for leaving for both men and women have been employment and education opportunities (Wind, 2017).

To gain insight into more specific possible push and pull factors that contribute to these patterns in rural Denmark, we could look into a study by Svendsen (2018). They examined 120 surveys and 25 interviews conducted in 2012 with adolescents who had recently migrated from Lemvig, to find out why they left, what they left behind and whether they considered moving back. Lemvig is a peripheral municipality in the Western part of Denmark. While Hansen (2020) classifies Odsherred in his article as a more rural municipality and Lemvig as a peripheral municipality (which might indicate some differences between the municipalities in economic activity, infrastructure, accessibility to urban centres, social services, and cultural amenities), important comparisons can still be made.

Svendsen (2018) found that the interviewed outmigrants often had to make a difficult choice between two competing feelings. They often had a strong place and social attachment to their place of birth, which showed in their love for the quiet surroundings, nature and social networks of their municipality. These feelings were in contrast to their sense of personal pride and wish for social recognition, which manifested itself in educational and career ambitions. These latter feelings are often the main reasons for moving: it was common sense to move and get a better job and/or education. The adolescents had to consider moving to achieve cultural (educational) and economic (employment) capital, while being forced to leave social and cultural capital (local community and networks, family, nature, …) behind.

Some of the push factors in Lemvig were the reduction of full-time jobs, the small amount of public services, the decline of associational life, and the feeling that 'nothing ever happens in this small village'. Some of the pull factors that were named in the study were opportunities to further education, more and better employment opportunities, the migrant networks in the city (which made it easier for new migrants to find a job or get a sense of community), pride and the opportunity to increase symbolic capital, the attraction of exotic city life, and the friends or family that already live in the city (Svendsen, 2018).

Since job opportunities are one of the most important factors causing migration, a lot of national policies are often aimed at job creation and attracting highly educated people. However, this might not be the best course of action for the peripheral areas, since these policies are mostly aimed at urban areas. The peripheries need

other policies that are more focused on their local strengths, skills and present industrial structure (Hansen, 2018).

2.2 Migration in Odsherred

The migration patterns in Odsherred are characterised by a small net positive internal migration, meaning more people move to Odsherred from other municipalities than leave. However, the internal migration became negative in 2023. Net migration of young adults (20-29 years) has been negative for years and continues this trend, making this age group small and leading to an ageing population.

The municipality of Odsherred has 13 different parishes (Vallekilde, Hørve, Nykøbing Sj, Rørving, Odden, Højby, Vig, Nørre Asmindrup, Egebjerg, Grevinge, Asnæs, Fårevejle, Lumsås). A discussion of all these parishes would be too extensive, so there will be a focus on four parishes that have something unique: Nykøbing Sj, Vallekilde, Asnæs and Egebjerg.

Nykøbing Sj is the parish that stands out in the migration data. It is the parish with the most inhabitants and the highest migration. The net internal migration of Nykøbing Sj is constant but slightly positive, except for 2016 and 2023 where the net internal migration was negative. Immigration and emigration to and from other countries are both constant and result in a small positive net migration. The year 2022 is characterised by high numbers of inward migration to Nykøbing Sj, leading to a high increase in population (+ 157), while the other years show a small decrease in population due to a natural decrease (Statistics Denmark, 2023b).

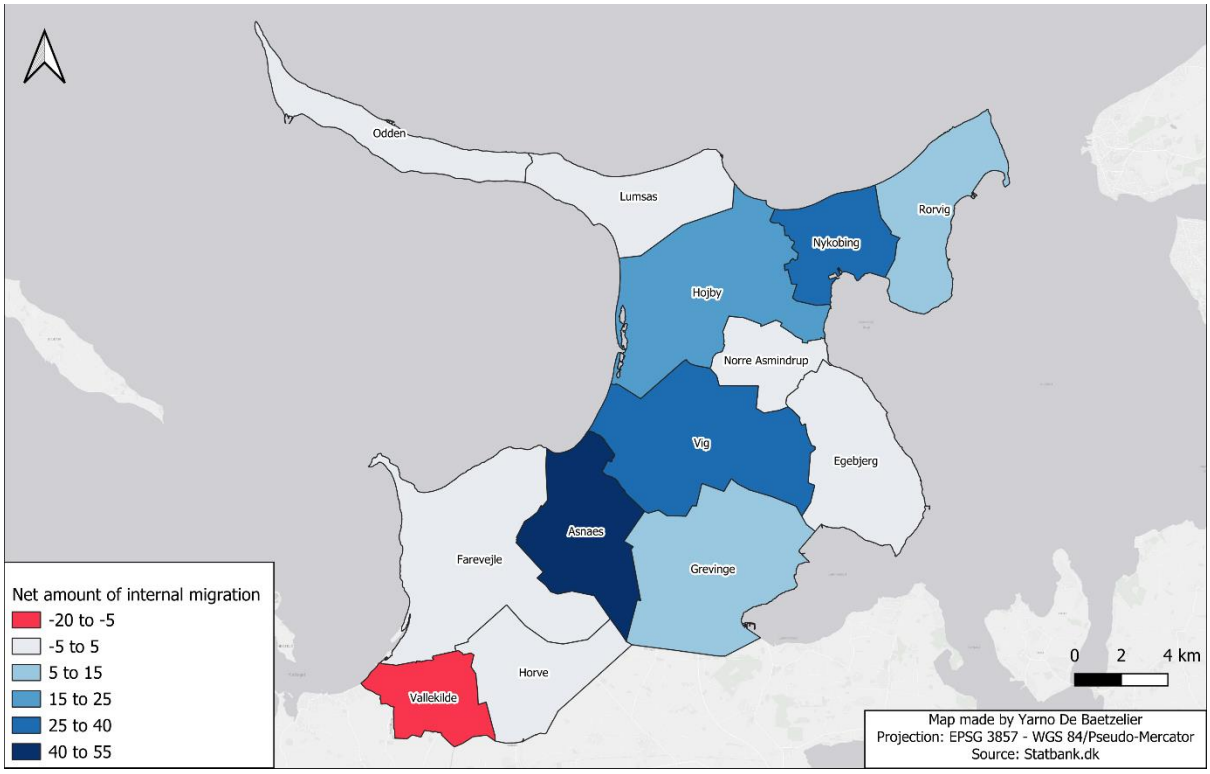
Asnæs is the only parish with an almost constant population increase since 2015. Although it has high negative numbers for natural growth, it has experienced high positive migration during the last nine years. Both the inward and outward migration increased over the years, except between 2021 and 2022. This indicates several push and pull factors in Asnæs (Statistics Denmark, 2023b).

Vallekilde is the smallest parish by population in Odsherred, but it is the only parish with a natural increase since 2015. The parish also has relatively high numbers of migrants compared with its population size. However, the migration numbers, and especially the inward migration, have been declining since 2019. This causes a decline in the already small population of Vallekilde (Statistics Denmark, 2023b).

Egebjerg has experienced slightly fluctuating net migration numbers, but the total population has increased slightly between 2015 and 2023. While its migration numbers are not particularly remarkable, Egebjerg is interesting for its two eco-villages, which have the potential to attract more young adults—a key focus of this study (Statistics Denmark, 2023b). Map 1 shows the mean net internal migration of the parishes in Odsherred. The parish Vallekilde has the highest negative internal migration, while Asnæs has the highest positive internal migration.

Map 1

Mean net internal migration of parishes in Odsherred between 2015 and 2023



2.3 Young adults leaving rural areas

People living in rural areas often enjoy more space, a better quality of life, lower living costs and less pollution, but there are some challenges that outweigh these benefits. These challenges include fewer job opportunities, weaker infrastructure, and poorer access to public and/or commercial services. Therefore, some people search for greater opportunities in other, more urban regions. Those that choose to leave the rural environment are often relatively young (Eurostat, 2022).

The last couple of years the number of young adults in rural areas has indeed decreased in many countries in Europe. This is not only a consequence of low birth rates, but also of the internal and external migration of this age group. This results in an ageing demographic in Europe (Serban & Braziene, 2021). A demographic consequence of young adults leaving a community is the population getting older. Other impacts of out-migration on the community, stated by respondents of Stockdale's research, are the loss of identity and culture in the villages, difficulties in sustaining the rural economy, fewer children (which could result in schools closing), suffering of local shops and trade, and lessening of rural facilities. All this leads to a loss of human and social capital in the rural communities, which could result in even more people leaving and eventually a collapsing rural society (Stockdale, 2004). A trend of young adults leaving a population thus results in population decline and the ageing of the population. The lack of renewal of rural populations could undermine the viability of the region, which is why governments could be worried about the net out-migration of young adults (Hofstede et al., 2022).

2.4 Initiatives to make rural areas more attractive for young adults

2.4.1 Current efforts of the municipality

The municipality of Odsherred has already taken measures with the aim of attracting new generations. They have launched a campaign that focuses on the positive developments and the unique characteristics of this rural area in Denmark. The purpose of this campaign is twofold. On the one hand, the municipality tries to attract even more visitors to this part of Denmark by providing a variety of information on its website about unique experiences, organised activities and magnificent ice age landscapes. On the other hand, the campaign aims to boost the local economy and communities by convincing people to start their life and their businesses in Odsherred. Therefore, the website displays more general information about daily life in the local communities and several business activities and opportunities in the area (Odsherred Kommune, n.d.-b). The municipality introduces itself as a 'thriving and hard-working society' and combines this with personal stories of a lot of local entrepreneurs who set the example.

Besides the focus on entrepreneurship, there are also several interviews with people who have moved to Odsherred from another place in Denmark or another country. They share their motives for moving and their experience in the new community on the website. The municipality also uses their campaign to share useful information for people interested in settling in Odsherred. They address topics, such as the presence of schools

and daycare, available accommodations and the organisation of leisure activities and evening schools. They also provide the possibility to ask questions directly to the municipality's settlement consultant (Odsherred Kommune, n.d.-b).

This campaign and website discussed above are probably a little bit outdated because the look of the website gives this impression and some of the links are no longer operational. However, there is no specific information about the duration of the campaign. Furthermore, the municipality of Odsherred has its own, new and up-to-date website that provides similar information, such as job opportunities and student internships and vacancies (Odsherred Kommune, n.d.-a). This shows that the municipality has been concerned about the outmigration of young working people for quite some time and continues its effort to make Odsherred more attractive to this population group. The municipality specifically addresses young adults on their website by referring to the cultural organisation '*Ung i Odsherred' or* 'Young in Odsherred' that organizes events, workshops and other activities for people between 13 and 25 years old at the two youth centres in Nykøbing and Asnæs. There is also a youth city council connected to this cultural organisation that represents the voice of the young people in Odsherred during debates about new initiatives and developments in the municipality (Ung i Odsherred, n.d.).

Since the start of this year, the municipality has shared their new vision for Osherred on the website, which is titled *'Sammen om Odsherred – naturligvis'* or 'Together for Odsherred – of course' and includes five big focus areas or pillars. The municipality wants to invest in more education and job opportunities in the municipality and a better quality of infrastructure and travel possibilities in order to reach the first focus area of their vision 'a good everyday life and good experiences'. Furthermore, they emphasise the need for the preservation of the unique nature landscape and climate-friendly initiatives in order to sustain these nature experiences for future generations. The third pillar aligns with the first, because it states the importance of the business community in 'the good everyday life'. Odsherred is ready to welcome new entrepreneurs and businesses in all shapes and sizes and promises to give them the support that they need. The next focus area is called 'together for the future of Odsherred' in which the municipality states that it is open to new ideas from the citizens. They are not in favour of the top-down approach and want to share the responsibility of finding solutions with the citizens. The last pillar of the vision is about the working environment. Odsherred wants to be known as 'the country's most flexible and diverse workplace' and puts effort into retaining and attracting talented employees (Odsherred Kommune, 2023).

2.4.2 Inspiration from other places

Despite the current efforts of the municipality, there is still a net outmigration of young adults taking place. When thinking about potential projects to make Odsherred more attractive to young adults, we can find inspiration in other countries or places that experience the same demographic trend.

The Scottish government, for example, developed an 'Addressing Depopulation Action Plan' that addresses the depopulation challenge in rural Scotland in cooperation with an independent 'Expert Advisory Group on Migration and Population'. The action plan consists of three main chapters,each focussed on a specific spatial level: the community, regional and national level. The core of this action plan is a place-based approach when determining which interventions and support measures are needed to encourage young people to remain on or return to the islands (Scottish Government, 2024a). An important factor of the plan is the cooperation with Youth islanders Network (YIN) which provides a platform and a voice for the young people living in island communities. YIN can be compared with the organisation *Ung i Odsherred* in Denmark. They both try to understand the needs of young people by being involved in the local communities and by using social media to reach this age group (Scottish Government, 2024b).

Another example of addressing the problem of youth out-migration in rural areas is the 'Project Comeback' in Canada started by BC Rural Network and the Fraser Basin Council (2014). During this project, a survey was conducted in five different rural communities in the province of British Columbia to analyse the push and pull factors that young adults experience and to get an idea about their 'ideal' community. Based on the survey responses, several critical factors were identified to make a community more attractive for local young adults. Three major themes could be identified: the ability to realise work/life balance, the availability of opportunities to connect with arts, culture, recreation and other people, and the development of a sense of belonging within the community. Afterwards, these survey responses were the starting point for workshops with several community members. The product was a youth-retention action plan based on the issues or opportunities of each specific community. This research method based on bottom-up initiatives and community engagement seems an effective strategy that we want to implement in Odsherred by distributing a survey and asking the opinion of the residents during interviews (Robinson, n.d.).

Not only national governments, but also European organisations are taking initiatives to support the youth in rural areas. Salto-Youth, for example, is an organisation that supports youth workers and youth leaders as part

of the Erasmus+ and European Solidarity Corps programmes. This organisation created a step-by-step manual for attracting young people to rural areas by creating more opportunities for them. According to Salto-Youth, it is important to know why young adults are moving to the city in order to come up with suitable youth projects. If young people leave for education purposes, it is probably a good idea to invest in distance-learning or professional education. If they leave because of a lack of sports facilities or leisure time activities, the youth workers can organise more outdoor activities and social networking opportunities. If youngsters leave because they do not see a future for themselves in their local community or they do not feel that their needs are heard, their participation in decision-making processes has to increase. This can start by, for example, a youth parliament or more interaction with local politicians (Salto-youth, n.d.).

These ideas were also mentioned during the workshops organised by the European Network for Rural Development (ENRD) (2018) with participants from thirteen member states that shared their projects in support of young people in their rural areas. The participants extracted several 'success factors' from the different projects that can be implemented in other contexts. They emphasise that there should be more youth-targeted communication in terms of language and communication channels. They also suggest that stronger cooperation with universities, NGO's and professional networks can increase the link between the urban and rural environments. Furthermore, a good public transport network can also improve this connectivity, which is one of the focus points of the vision of Odsherred kommune (2023) to provide a 'good everyday life' for the inhabitants. Finally, it is important to welcome culture in rural areas and create places to exchange knowledge and experiences between and within generations. In this way, knowledge of the local context can be shared.

3. METHODS AND SOURCES

Our workflow consisted of 5 major steps: data collection, the preparation of the fieldwork, the fieldwork itself, data analyses, and defining points of action.

3.1 Step 1: Data collection

We started our research by conducting a literature study to gain a general frame of knowledge on our research topic. We mainly looked into the general migration trends in Odsherred, the drivers of migration of young people in Europe and Denmark, the impact of young adults leaving rural areas, and factors that attract young adults to

rural areas after leaving them. This research was enriched by official data we could find in policy documents and the Danish Database. These informed us on the demographic situation and migration trends of Odsherred.

Based on the information we collected regarding migration drivers, we created a survey, which catered mainly for adolescents between the ages of 18 and 30, but could be filled in by all residents and even visitors of Odsherred. We contacted people from the municipality and people on Facebook to distribute our survey to as many people as possible. For example, through the municipality we were able to reach several high schools. We also sent the survey directly to different sport clubs and music schools.

The data collected through our survey was meant to inform us of several factors. We wanted it to help us decide in which parishes to conduct surveys during our fieldwork, help us complete the information we collected during our literature study on migration trends and drivers in the municipality, help us get a better sense of the impact of migration of young people in this area, and help us complete our future scenario's. Unfortunately, the survey response was very limited, which made the few responses we received useless. As a result, we based the choice of the parishes to visit during our fieldwork on the mean net internal migration data of the parishes, that are visualized in Map 1.

3.2 Step 2: Preparation of the fieldwork

Based on the information we collected in Step 1, we conducted several desktop analyses and made preparations for our fieldwork in Odsherred itself.

3.2.1 Mapping of the migration patterns

To analyse the migration patterns of Odsherred, we mapped the data collected from Statbank.dk. The map on the net internal migration of the parishes was created through the following steps. Firstly, to map the parishes, data on the geometry of these parishes had to be found. A shapefile containing the geometry of the parishes was obtained. However, this shapefile only had twelve parishes, while the dataset of stabank.dk contained thirteen parishes. In the shapefile, the parishes Lumsas and Hojby were merged. We decided to split these parishes according to the shape of the parishes in the dataset of Statbank.dk. After this first step, the mean net internal migration was calculated with Excel. In addition, an ID was added because some characters, such as 'æ', are hard to read in QGIS. After adding the IDs, the Excel was saved as a CSV and uploaded to QGIS. Then, the CSV

was joined with the shapefile of the parish based on their common ID. Finally, the classes were constructed manually so that negative values had a different hue than positive values.

To map the inward and outward migration, similar steps were taken. First, a shapefile of Danish municipalities was downloaded. After this, the sum of the migration values of the dataset of Statbank.dk between 2006 and 2023 was calculated in Excel. An ID was given to the dataset as well, for the same reason as before. The dataset was then exported to a CSV and uploaded to QGIS where it joined with the shapefile based on their common ID. The municipalities were then divided into five classes based on the 'Natural Breaks (Jenks)' option in QGIS. Both the inward and outward migration maps were given the same class intervals.

3.2.2 Survey for interviews

Based on our research, we created a survey using Qualtrics to be able to easily conduct interviews during our fieldwork in Odsherred. This survey consists of three parts. First, participants are asked some questions about their demographic information, their personal experience with the movement of people out of and to Odsherred, and their environment's experience with this topic. Second, participants are presented with several statements they can rate based on their own opinions. The first part of the statements concerns the economy of the area, and the second part concerns the accessibility of the area. Third and lastly, participants are asked to share their opinions on the future scenarios we created, which are explained in the next paragraph. The participants are asked to give their opinion and select a preferred and an expected scenario.

We ensured that our English survey and scenarios were translated in Danish to make our survey accessible to as many people as possible. The prepared questions are added to this paper as an attachment at the end of the document.

3.2.3 Future scenario modelling

Scenario planning and forecasting can be a valuable source of information for policymakers regarding depopulating rural regions in Europe (ESPON, 2020). We created four future scenarios, based on the two axes of high-to-low accessibility and thriving-to-declining economic situation. These axes were chosen based on careful consideration of which factors would be of significant influence on the migration patterns of young people in Odsherred. In addition to deciding on the two axes which represent the uncertainties, three important certainties

were defined that had to be taken into account: climate change, the ageing population and the ICT-evolution. When the uncertainties and the certainties were decided upon, the four scenarios could be described. Each scenario was interpreted based on the guidelines tourism, nature, housing prices, services and residents. These scenarios were summarised to show during our survey, so the participants could answer the third part.

Based on these scenarios, we hypothesised we could find out what the biggest problem areas are in Odsherred, and which actions could steer the municipality towards a more desirable future scenario.

3.3 Step 3: Fieldwork

During our fieldwork in Odsherred, we conducted interviews with residents of four parishes, using the survey we created using Qualtrics. We filled in this survey while having a conversation with the interviewees, leaving the opportunity to write down extra information given by them. Each chosen parish was selected because of a characteristic that differentiates them from the others.

- Vallekilde (Monday May 13)
  This parish is characterized by the highest net out-migration.
- Asnæs (Tuesday May 14)
  This parish is characterized by the highest net in-migration.
- Nykøbing Sj (Wednesday May 15)
  This is the biggest village in Odsherred, and is characterized by an overall stable migration.
- Egebjerg (Tuesday May 14 and Wednesday May 15)
  This parish has ecovillages that attract young families, which is unique in Odsherred.

3.4 Step 4: Statistical analysis interview responses

The analysis of the data collected through our interviews consisted of two parts: a qualitative and a quantitative analysis.

3.4.1 Qualitative analysis

For the qualitative analysis, we manually processed the responses to the questions from the first and third part of the survey we created for conducting interviews. Firstly, we gathered information on the characteristics of the performed interviews: the location where each interview was conducted and the age of the interviewee. Second, to get a better insight into the reasons for and perception of out- and in-migration, we gathered data concerning four topics: motives for moving out of Odsherred, motives for moving to Odsherred, perception of in- and out-migration and the expected and preferred future scenarios. For each group, we counted the frequency of specific answers within each parish and/or age group. We used Excel to create charts of these data, providing a clear visual representation that enhances our understanding of the most common answers.

3.4.2 Quantitative analysis

Within the second part of the statistical analysis, the quantitative analysis, we performed a factor analysis on the data gathered within the second part of the interviews, which focused on statements concerning the economy and accessibility of the study area. A factor analysis could help us identify the underlying patterns in a dataset. Using this method, we grouped both the statements on economy and accessibility based on high correlations between the statements within each group. First, a scree plot and the Kaiser criterion were used to determine the number of factors. A scree plot shows the eigenvalues of the factors, which indicate how much variance each factor explains in the data. The point where the slope of the graph flattens is known as the 'kink point' (also referred to as the 'knee' or 'elbow'). The eigenvalues of the factors before this point are relatively large and explain a significant amount of variance. After the kink point, the eigenvalues are relatively small and explain less variance. Therefore, the kink point helps determine the optimal number of factors. The Kaiser criterion is a different way to determine the optimal number of factors, which is also based on the eigenvalues. According to the criterion, only those factors that have an eigenvalue greater than 1 are retained, because those factors explain at least as much variance as a single variable in the dataset.

Using a Chi-square test, the relation between the newly formed factors/groups and multiple variables was tested, which included the origin of people (rural or urban areas or foreign countries), the parishes where the respondents currently lived, and the age group to which respondents belonged (children (0-17 years), young adults (18-30 years), working adults (31-64 years) or seniors (65+ years)). To perform a Chi-square test, some assumptions must be observed. The data should be categorical (nominal or ordinal), the observations in the data

set should be independent of each other, the expectation frequency should be at least 5, and the sample size should be sufficiently large (at least 20 observations). The null hypothesis states that there is no relationship between place of origin/age group/current place of residence in the municipality and the factors on economy/accessibility. If the significance level of the Pearson Chi-square test is less than 0.05, the null hypothesis can be rejected, meaning that there is a significance relationship between the two categorical variables tested.

Lastly, as part of the quantitative analysis, a Chi-square test was also conducted to check whether there is a significant relationship between the expected and preferred future scenarios and the different age groups. In other words, if the results are significant, the choice may depend on the age of the respondent. The null hypothesis states that there is no relationship between the age group of respondents and their choice of expected/preferred future scenarios.

3.5 Step 5: Defining points of action

The last step of our research was defining points of action for the four parishes. These points of action were based on the literature and the responses from our interviews. The goal of each point of action was to make the parish more attractive for young adults, without changing the current pull factors in the parish.

4. FUTURE SCENARIO MODELLING

In this section, we first elaborate on both the uncertainties and certainties which form the basis for the scenario modelling. Then, the selected guidelines are explained and finally, these guidelines are used to describe and evaluate four possible future scenarios for the municipality of Odsherred.

4.1 Uncertainties

The uncertainties were chosen based on the new vision of Odsherred Kommune (2023) which defined five focus areas for future policymaking. These focus areas are very diverse and ambitious and have not been implemented yet. It is therefore uncertain to what extent this will happen in the future, and that is the reason why they form a good starting point for our scenario modelling. We selected two pillars that we think will strongly influence the position of young people in Odsherred: the economic situation and the accessibility of the area. There are

different possible future scenarios based on the choices that the municipality will make regarding these two uncertainties.

4.1.1 Declining / thriving economy

The municipality is eager to welcome young entrepreneurs who can start a business in Odsherred. They state that these new businesses will get the support that they need throughout the whole process. Furthermore, the municipality wants to create a pleasant working environment to become the "country's most flexible and diverse workplace". This positive attitude towards economic development makes a more thriving economy possible in the future. We define a 'thriving economy' as a situation with different job opportunities for a diverse group of people, a dense network of businesses from different sectors, a strong connection between the urban and rural environment, and an educational and professional training system for the youth. Besides those business-related concepts, we think a thriving economy can also be characterised by opportunities to connect with culture, arts, recreation and other people (ENRD, 2018; Odsherred kommune, 2023; Robinson, n.d.).

Despite the positive attitude from the municipality their goals are relatively vague and can be pursued in many different ways. We have to take into account the possibility that Odsherred will not have reached these economic goals in 2050. Furthermore, the current trend of outmigration of young people is mainly based on the lack of opportunities that they experience in this rural area (statistics Denmark, 2023a). If this trend continues, a declining economy can shape the future of Odsherred with few job opportunities and few business start-ups. We think that, due to its remoteness, the municipality can become a secluded rural area with a lack of connectivity between places and people. A declining economy can also reduce the opportunities for cultural and recreational activities due to a poor financial situation.

4.1.2 Low / high accessibility

In their new vision, the municipality also emphasises the role of mobility in a good everyday life for the people. More specifically, Odsherred wants to improve the quality of the infrastructure and increase the travel possibilities within the municipality. We state that, if these plans are carried out in the future, Odsherred can become more accessible. 'High accessibility' means to us that people can reach different places within the area using a diverse set of travel modes, such as private car, public transport, shared mobility and active transport modes. To know the needs of the population in terms of mobility, the municipality can cooperate with the

inhabitants and let them participate in the decision-making process. Furthermore, accessibility looks different for different age groups, so these different groups with their specific characteristics should all be represented when creating a highly accessible municipality.

On the other hand, the construction or the quality improvement of infrastructure costs a lot of money that the municipality possibly wants to invest in other focus areas of their new vision. Without investment, the area will not become more accessible. A lack of citizen participation in the decision-making process can also negatively influence the outcome of the project. Although Odsherred Kommune (2023) claims to prefer the bottom-up approach, we think a top-down approach may be applied when making mobility decisions or that only a selected group of society is involved in the process. This discrepancy between the policy decisions and the mobility needs of the inhabitants can result in low accessibility of certain areas in the municipality.

4.2 Certainties

4.2.1 Climate change

Like all places, Denmark will not be left in peace by climate change. The actual impact of climate change in about 25 years can be fairly hard to predict since it depends on a lot of factors, for example countries' abilities to keep their promises regarding strategies, plans and goals to reduce the impact of climate change. However, there are some general trends we can predict with some certainty about Denmark, and in consequence about Odsherred. The future risk of coastal flooding and coastal erosion in Denmark will be severely impacted by climate change, which implies that Odsherred will also have to deal with a rise in coastal flooding and erosion in 2050. By 2070 coastal flood risk will have increased by a factor of 1.5, and the number of people affected will have increased by 1.2. This will have a huge impact on the coastal communities, summer houses, and cities of Denmark, which in many cases might have to move land inwards, along with the moving coast.

It has been predicted that in the future there will be a high increase in summer precipitation in Northern regions and a decrease in Central, Eastern and Southern Europe. Since Denmark falls in the middle of these regions, the summer precipitation is fairly hard to anticipate. However, there is a high probability that summers will be characterised by longer dry periods and short periods with heavy rainfall. Because of global warming, Denmark will face an increase in extreme weather events such as heatwaves, wildfires and storms with an increased surge height. The growing season will increase, while the number of frost days will decrease (Climate Adapt, 2023).

Despite the negative effects this will have on nature, such as the biodiversity and ecosystem processes of fauna and flora, and the people affected by extreme weather effects, this might have a positive effect on Denmark's tourist industry. The currently popular Mediterranean destinations will attract fewer tourists because of the extreme heat and weather events. This will make Denmark more attractive since Denmark will still have a temperate climate with moderate temperatures and an extended tourist season. In addition, flooding might in the long term make room for coastal meadows, since these areas will be rendered unsuitable for agriculture (Climate Adapt, 2023).

Another effect of climate change is the growing climate migration crisis. It is expected that the large-scale migration from vulnerable regions will keep increasing, and that there will be more international as well as internal displacement of people due to climate change (Noonan & Rusu, 2022).

4.2.2 Ageing population

It has been projected that the median age of the European Union will increase by 4.5 years between 2019 and 2050, and reach 48.2 years. This increase will also develop in Denmark, however, Denmark is on the side of the curve with a slower pace of this increase: in Denmark, the median ages are projected to rise by 3.0 to 4.0 years, from 42 to 45 years. By 2050, Denmark's old-age dependency ratio will almost reach 50% (from 34% in 2019). This means that there are only just 2 people of working age for every person who is over 65 years old (Eurostat, 2024). Rural areas are more likely to attract older people. However, these areas also suffer from less access to public transport, and a low provision of services, public as well as commercial. This might form a problem since older people often rely more on social services such as healthcare (Eurostat, 2024).

4.2.3 ICT-evolution

Technology has been evolving faster and faster these past decades. This will have an important impact on the use of vehicles for example. According to the base scenario predicted by McKinsey (2023), 37% of newly sold cars in Europe will be vehicles with advanced autonomous features. While this number could be lower (17%) or higher (57%) depending on whether the sale of autonomous vehicles follows their projected delayed case scenario or their accelerated case scenario instead of this base scenario, autonomous vehicles (AVs) are predicted to have a big impact on our society. AVs have the potential of changing the way consumers experience mobility since

people will have the opportunity to spend their time in a different way and more productively if they want. Travel time might become a much less important deciding factor for the residential location or employment location choice. In addition, less mobile people will have more resources to easily move themselves without help (Deichmann et al., 2023).

While there has not been such a huge increase in telework in Denmark as in other European countries since the pandemic, Denmark already had a well-regulated widespread telework culture. In 2021 it was the seventh-highest country in the EU, with almost 40% of the employees usually or sometimes working from home. Workers and employers experience much greater flexibility and less commute time, however, there is also a higher risk of working overtime (Kahancová & Williams, 2023).

While there was a slight average decline in 2022, telework will keep following an upward trend across the EU. This is mainly due to technological developments that increase the means of remote working and the number of teleworkable jobs (Llave et al., 2023). In addition to teleworking, the pandemic also led to a rise in e-bike popularity. The global as well as the European market for e-bikes are still projected to grow by 2030 (Statista Research Department, 2024).

4.3 Guidelines

Within the concept of scenario modelling, the evaluation and description of the future scenarios are based on several guidelines. We have selected the guidelines tourism, nature, housing prices, services and residents to explain our interpretation of the four possible future scenarios in Odsherred. Each of these scenarios will be characterised by different evolutions of the guidelines and the interactions between them.

4.3.1 Tourism

The securities and insecurities can influence the tourism sector in Odsherred. Based on the economic situation and the accessibility there can be changes in the number of people that visit the Geopark, for example, which is a major tourist attraction in Denmark. Odsherred is also known for its large number of summer houses, located near the coast. Several characteristics of the summer houses can change in the future, such as the amount, the state or the location of the summer houses.

Tourism is also connected with a lot of jobs and the attractiveness of the municipality. On the other hand, investments in favour of the tourism industry do not always have positive consequences for the area's inhabitants

4.3.2 Nature

The beautiful open nature and the glacial landscapes characterise Odsherred, but these features may change when the economic situation and accessibility evolve. The preservation of natural landscapes can become an issue when there is not enough financial support, or the landscapes can change due to expanding industrial areas or new transport infrastructure.

4.3.3 Housing prices

Affordable housing is very important for young people who want to settle in Odsherred. However, housing prices are very unstable and can be influenced by different changes or developments in the area. The housing prices are currently relatively low, but they can go up or down in the future and this can have consequences on the kind of people that can afford to buy a house in the municipality.

4.3.4 Services

We see the number of services that are available in the area as a representation of the economic situation and the accessibility of the area. Also, a good distribution of services across the municipality makes Odsherred more attractive to young adults. The possible services are divided into six categories: education, healthcare, entertainment, commerce, living and working. Some types of services can be approached as social networking opportunities, like bars, cafés, restaurants, shops, theatres, cinemas, etc. These services are all part of the entertainment category, but also the category 'living' includes several opportunities to meet people, like a park, a playground or a public meeting place.

4.3.5 Residents

The last guideline reflects the consequences of the future economic situation and accessibility on the people who live in Odsherred. These insecurities can influence the demographic characteristics of the inhabitants and

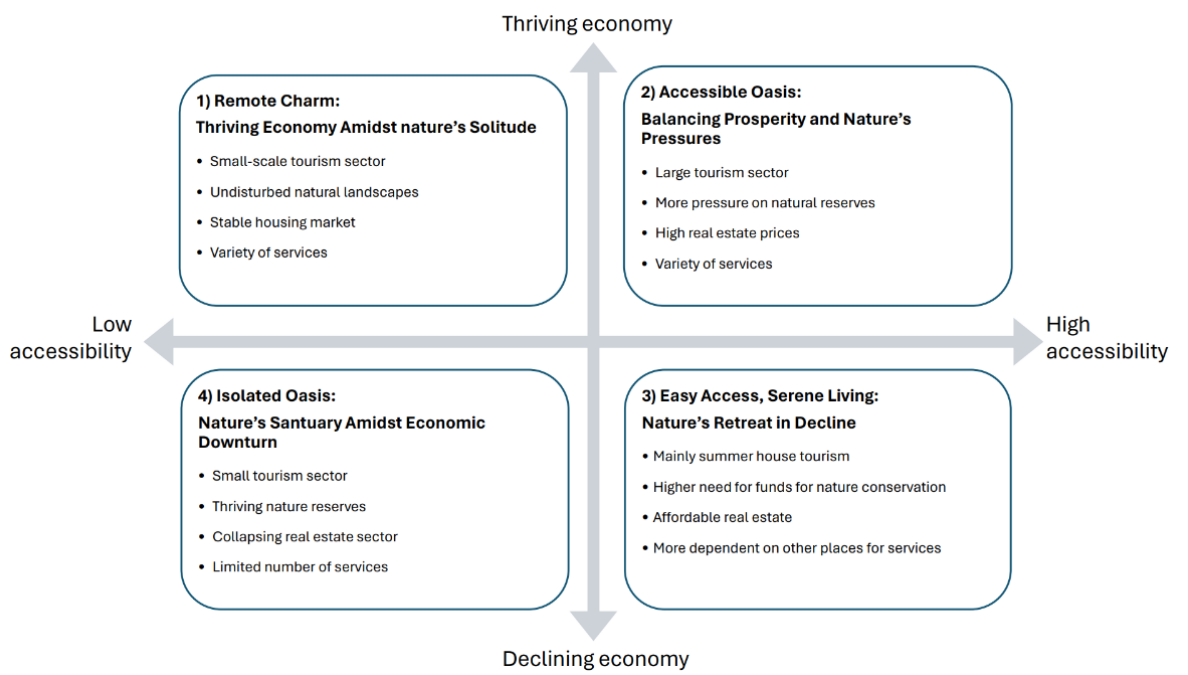
can create a living environment that is more suitable for a certain group of people. This guideline also focuses on the situation of the young adults in the scenarios. Based on the other guidelines, there will be an assessment of the future and the opportunities that Odsherred can offer to young adults.

4.4 The four scenarios

Figure 1 summarizes the four possible scenarios and their characteristics towards which the municipality of Odsherred can evolve in the future. The scenario depends on the choices that the municipality makes regarding the accessibility and the economy in the area. Attachment 9.3 offers a more detailed explanation about our perception of the evolution of the guidelines in each scenario.

Figure 1

Diagram of the four plausible future scenarios, with the two axes of economy and accessibility, and the most important points of each scenario.



5. RESULTS

In order to answer our research question, our goal was to produce the following results:

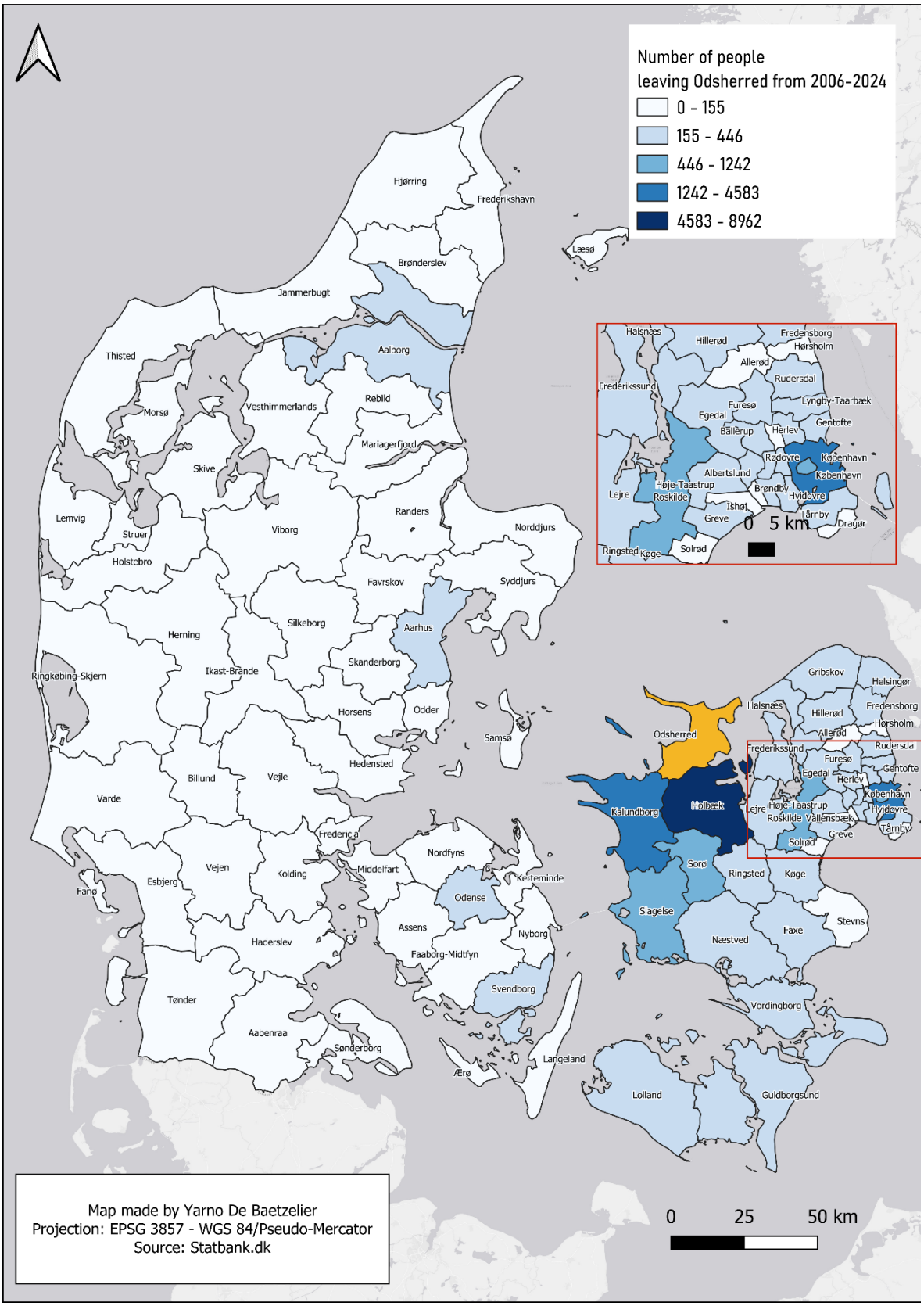
- An analysis of the migration patterns in Odsherred
- The drivers and perception of migration in Odhserred
- The results of a factor analysis of the statements on economy and accessibility
- An evaluation of the four possible future scenarios
- Proposed points of action for the studies parishes

5.1 Migration Patterns in Odsherred

Map 1 illustrates the net internal migration of parishes in Odsherred, but does not specify the origins or destinations of these migrations. Unfortunately, such data at the level of parishes wasn't found. However, data at the municipality level was accessible. Map 2 illustrates the outward migration from Odsherred between 2006 and 2023, representing all the people who moved from Odsherred to another Danish municipality. Conversely, Map 3 shows the inward migration, representing people who moved from another Danish municipality to Odsherred.

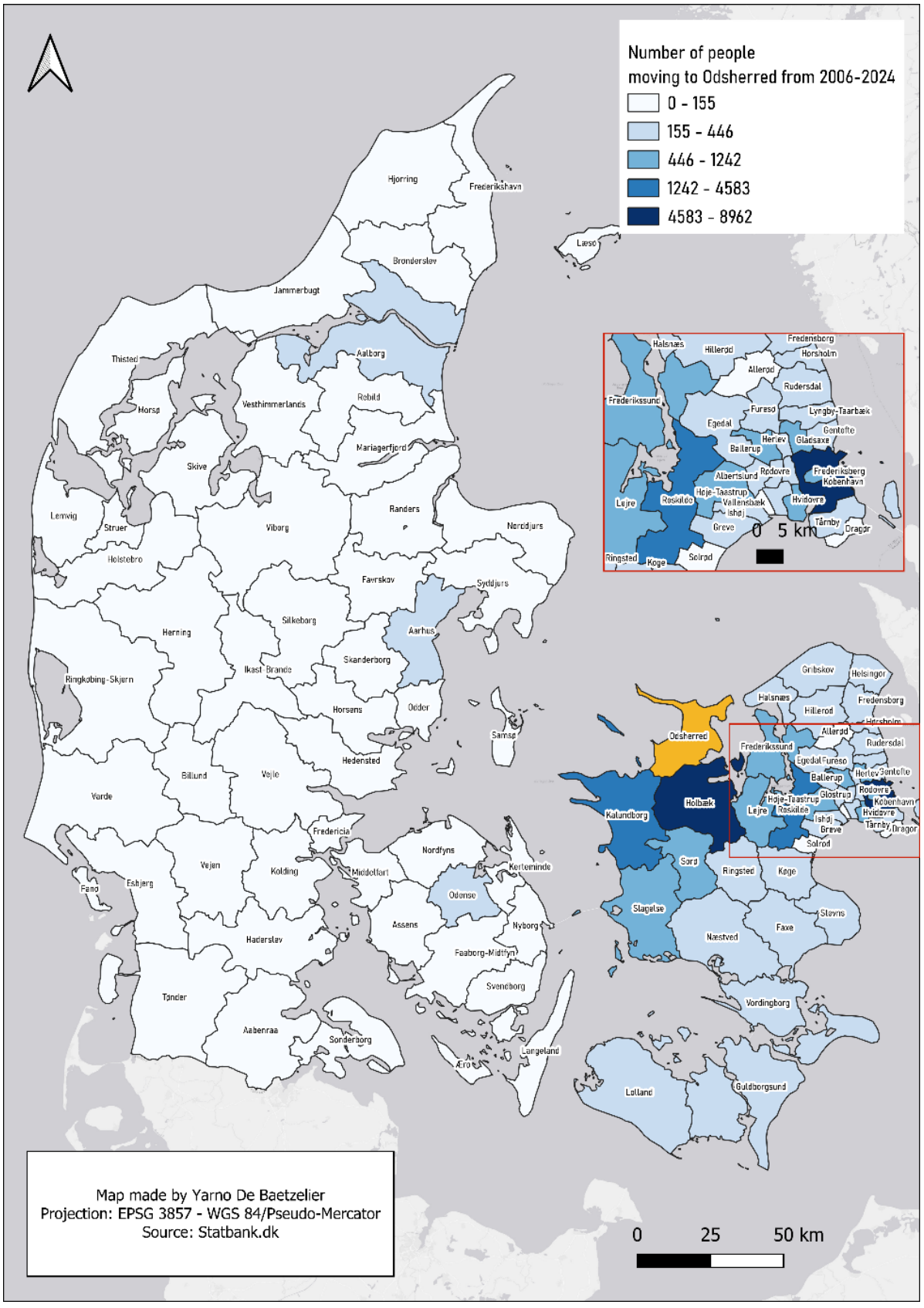
Map 2

Outward migration Odsherred



Map 3

Inward migration Odsherred



Both maps look very similar, indicating that people mostly move to and from the same municipalities. These municipalities are primarily those close to Odsherred, with Holbæk being the most common destination and source of migration. This trend could be due to the higher access to facilities in Holbæk and its good accessibility by both car and train. Other municipalities demonstrating significant migration relationships with Odsherred are those with the biggest Danish cities. In particular, Copenhagen has high migration numbers with Odsherred. Many survey respondents indicated that young people move from Odsherred to Copenhagen, while many elderly people move from Copenhagen to Odsherred. These elderly people often have a summerhouse in Odsherred where they can legally reside permanently.

5.2 Statistical data analysis interview responses

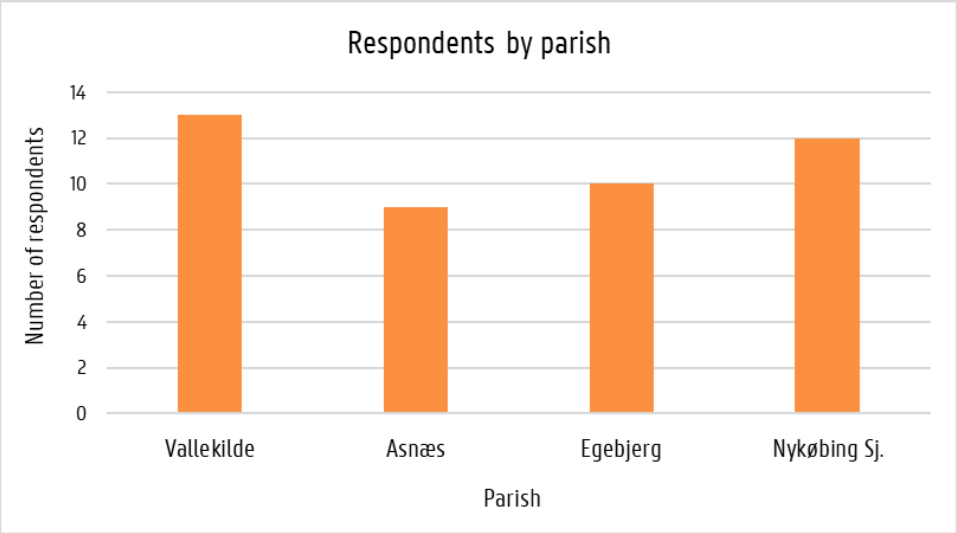
5.2.1 Qualitative analysis

5.2.1.1 Interviews characteristics

We aimed to reach a same number of interviewees in each parish, but due to differences in liveliness within the parishes, the number of interviews varies between nine in Asnaes to thirteen in Vallekilde. In Asnaes, where we spent most of our time around a shopping centre, many people were in a hurry, which limited the number of willing participants. In Nykøbing, although also a shopping area (for leisure shopping), we were able to conduct more interviews. In Egebjerg, we interviewed people in the parking lot of a local supermarket and in the ecovillages. In Vallekilde, most of our interviews were conducted with students from a folkeskole.

Graph 1

Number of respondents per parish



Because we conducted our interviews during the working hours of the day, there is a bigger variation in the age of our respondents. It was difficult to find students and working people that were able to answer our questions. Because of this, 'older' young adults and the 'youngest' working adults are not really represented within our data. We got the most responses from seniors.

Graph 2

Number of respondents by age class

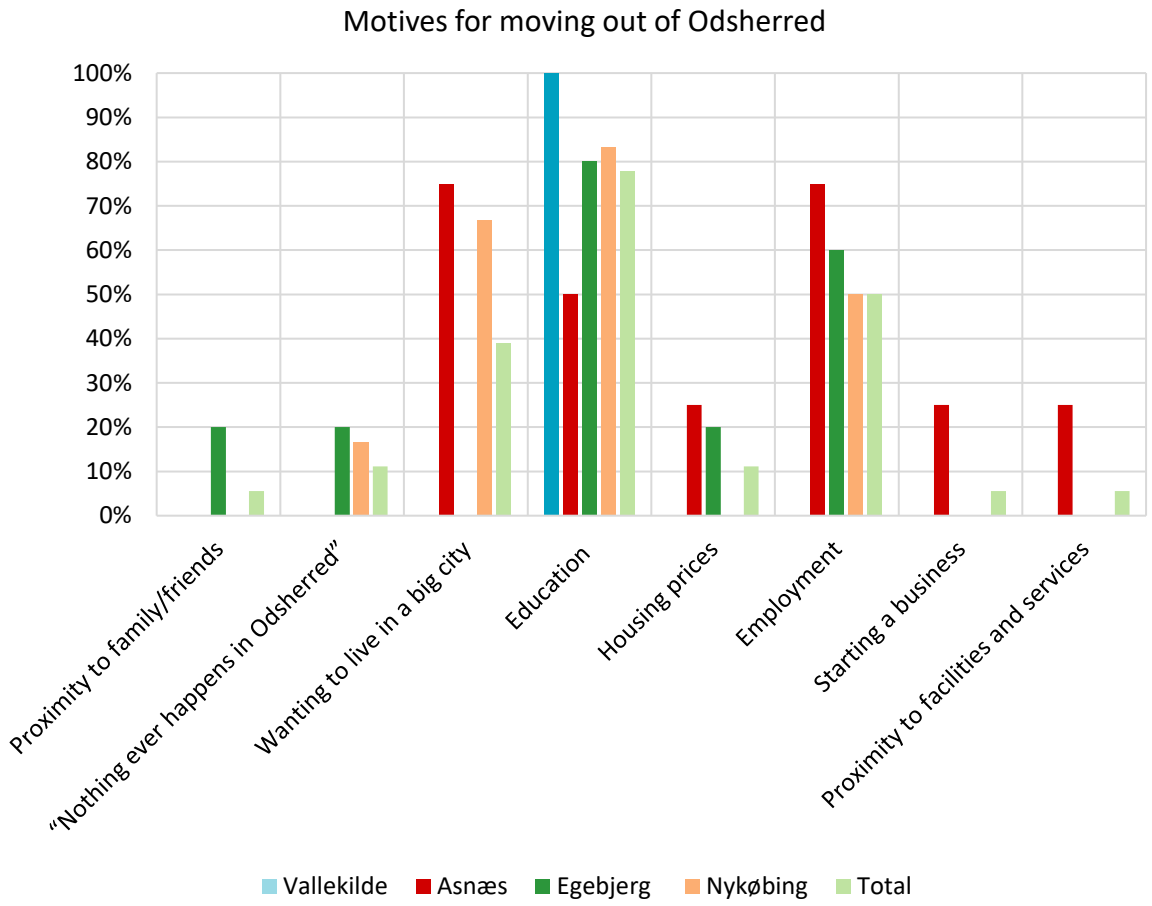
5.2.1.2 Motives for moving out of Odsherred

Graph 3 visually represents the percentage of interviewees who notice people moving out of Odsherred and selected a certain reason for moving away out of all interviewees who notice people moving out of the municipality. The results are shown for each parish individually, as well as for all parishes combined. The motives 'Education' and 'Employment' are the two most recurring reasons. According to some of the interviewees, the lack of sufficient schools, particularly for higher education, and limited job opportunities contribute significantly to this trend. For instance, in Vallekilde, every respondent who notices people leaving the municipality attributes it to education. No other motive was chosen as a reason for leaving the municipality within this parish. This may be because Vallekilde has a very tight community, and its mostly elderly residents enjoy a happy and peaceful life in this rather small parish.

The third most common motive that was chosen as a reason for moving away is 'Wanting to live in a big city'. Interestingly, this reason is exclusively chosen by residents of Asnaes and Nykøbing, the most urbanized areas in the region. Understandably, individuals living in these urbanized areas might aspire to move to even larger urban centres. People choose to live in rural or urban areas based on personal preferences and the availability of facilities and services in a certain place. In line with this, the motives 'Starting a business' and 'Proximity to facilities and services' were also only indicated as a reason for moving away by residents of Asnaes.

Graph 3

Frequency motives were indicated as a reason for moving out of Odsherred



5.2.1.3 Motives for moving to Odsherred

Graph 4 is similar to G*raph 3*, but focuses on the motives for moving to Odsherred instead of moving out. 'Housing prices' emerged as the most important reason. People often stated they were able to enhance their living conditions by relocating from Copenhagen to Odsherred, as they could buy a house in Odsherred with the money from selling their apartment in the city. The second most chosen motives are 'Proximity to family/friends', 'Peace and quiet' and 'Proximity to nature'. These reasons indicate the qualities of the area.

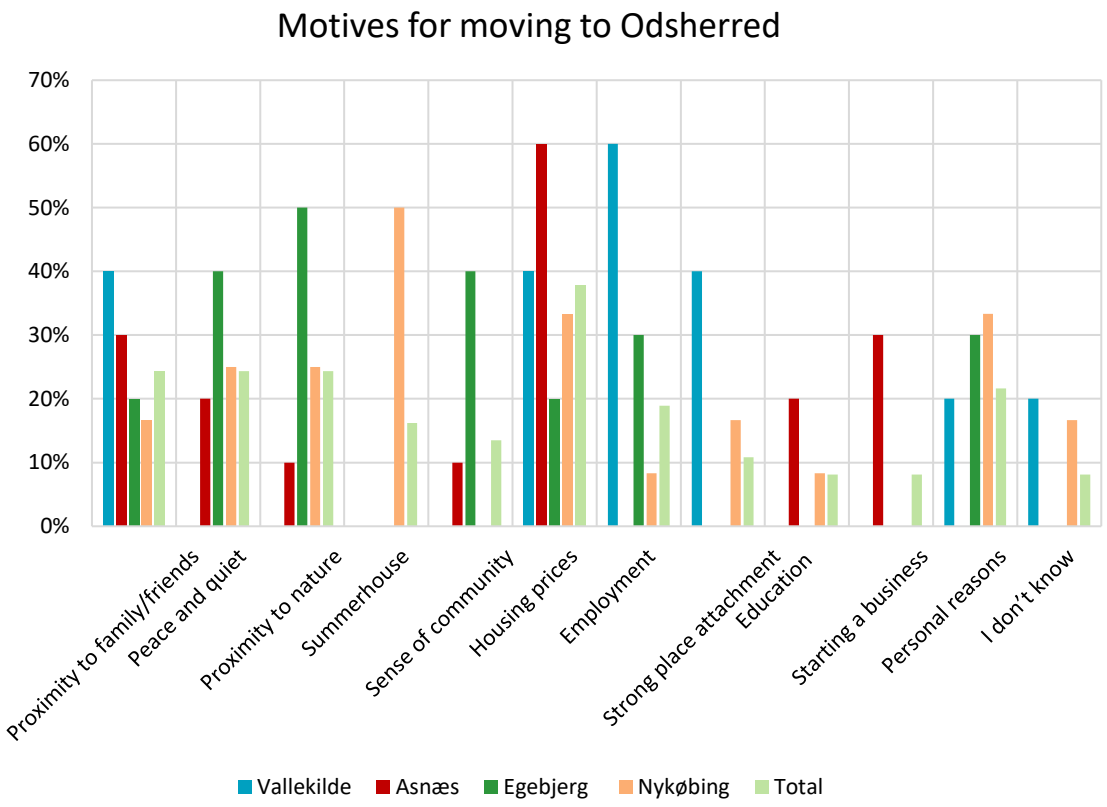
The motive of 'Summerhouse' was only and frequently chosen as a reason for moving to Odsherred by the interviewees from Nykøbing. Owners of a summerhouse are, once they reach a certain age, able to place their domicile on their summerhouse. Because of this, they can sell their other house or apartment and permanently move to their summerhouse. A lot of the respondents in Nykøbing own a summerhouse (Steineke, n.d.).

The motives 'Peace and quiet', 'Proximity to nature' and 'Sense of community' were frequently chosen as a reason by the inhabitants of Egebjerg, particularly those living in the ecovillages. These reasons hold the essence of the existence of these tight-knit communities.

Aligned with the idea that people choose to live in rural or urban areas based on personal preferences and the availability of facilities and services in a certain place, the motives 'Education' and 'Starting a business' were once again chosen as reasons for moving by inhabitants of Asnaes, but this time for moving to Odsherred instead of leaving it. In this context, the interviewees from Asnaes considered individuals living in rural areas who might move to Odsherred, more specifically the more urbanized region of Asnaes. According to the interviewees, the reasons driving these people to move in would be linked to the availability of facilities and services, such as education and business opportunities.

Graph 4

Frequency motives were indicated as a reason for moving to Odsherred

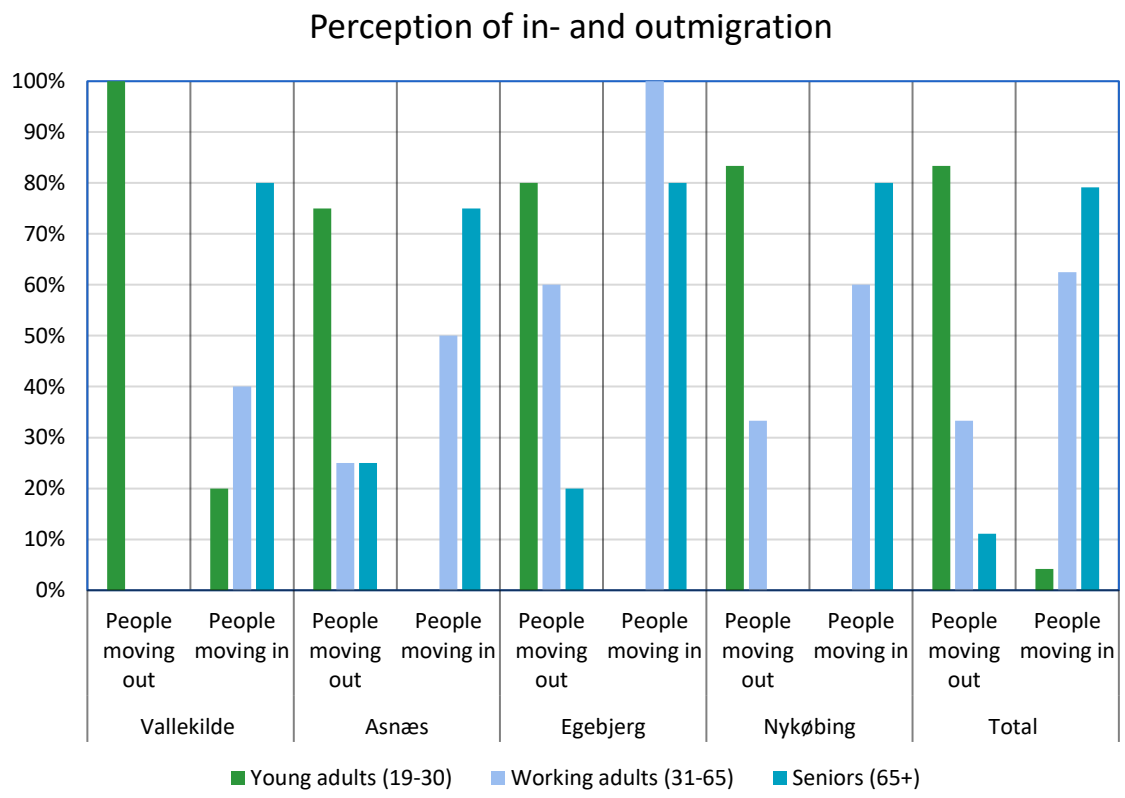


5.2.1.4 Perception of in- and out-migration

Graph 5 illustrates the respondents' perception of the in and outmigration. In each parish, the perception of outmigration is highest for the category of young adults, while the perception of immigration is highest for the category of seniors (except for Egebjerg). According to respondents who notice people moving out of and/or to the municipality, a main reason for young people leaving the municipality is the lack of higher education. In contrast, a key reason for seniors moving in is their decision to permanently settle in their summer houses. Concerning the migration of working adults, the perception of immigration is consistently higher than the perception of outmigration.

Graph 5

Perception of in- and out-migration by respondents



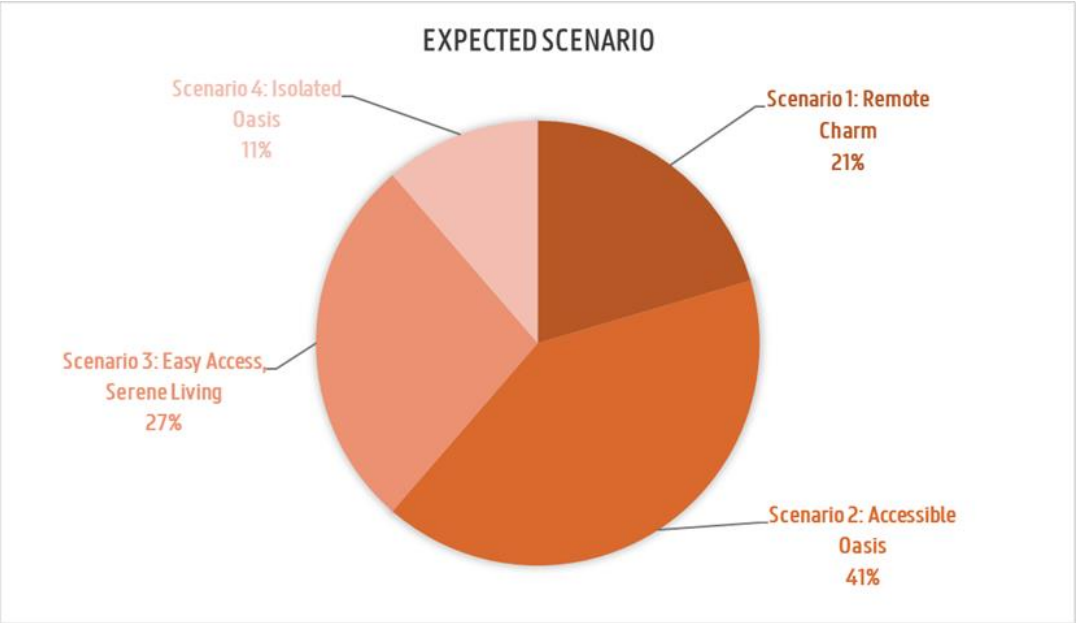
5.2.1.5 Most and least expected and desired future scenarios

Graph 6 and *Graph 7* show the percentages of scenarios one, two, three or four that were chosen as the expected and preferred scenarios, respectively. The scenario chosen most frequently as the expected outcome was

scenario 2, characterised by high accessibility and a thriving economy. The most preferred scenario was scenario 1, characterized by a thriving economy but low accessibility. This scenario was selected more than 50 per cent of the time. In both cases, scenario 4, characterised by low accessibility and a declining economy, was the least chosen one.

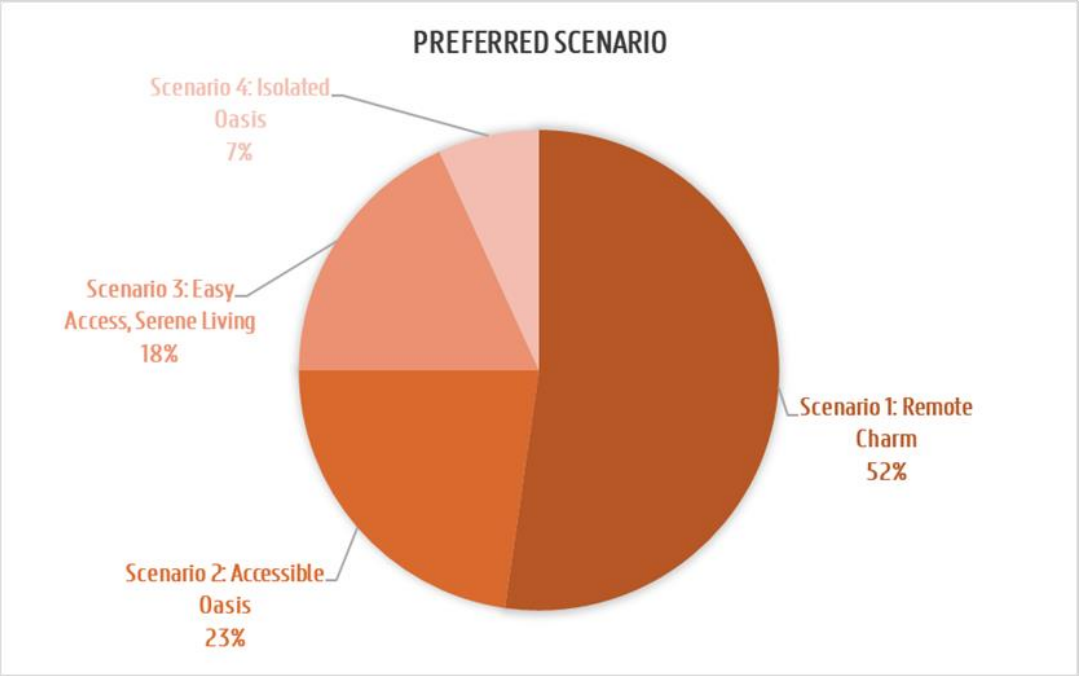
Graph 6

The percentages the different scenarios were chosen as the expected scenario



Graph 7

The percentages the different scenarios were chosen as the preferred scenario



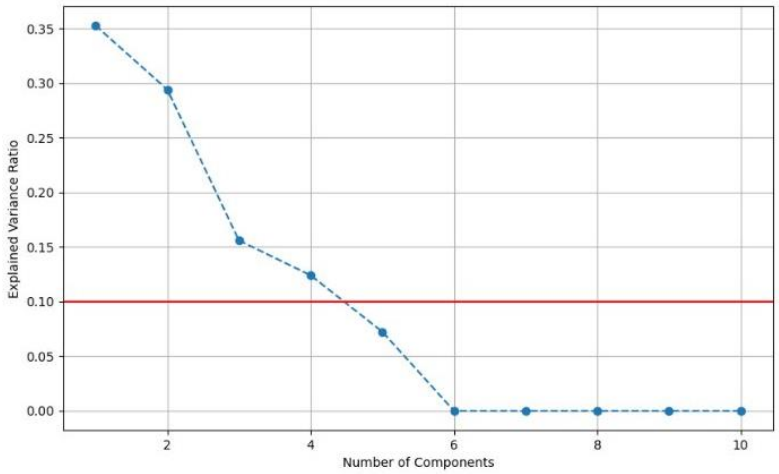
5.2.2 Quantitative analysis

5.2.2.1 Factor analysis on statements on economy and accessibility

Since there was a correlation between the statements regarding accessibility and economy, we performed a factor analysis to divide the statements of each category into groups. To determine the number of groups or factors, we used both a scree plot and the Kaiser criterion. Graph 8 shows the scree plot, with indicated Kaiser criterion, for the statements on accessibility. Graph 9 illustrates the same for the statements on the economy.

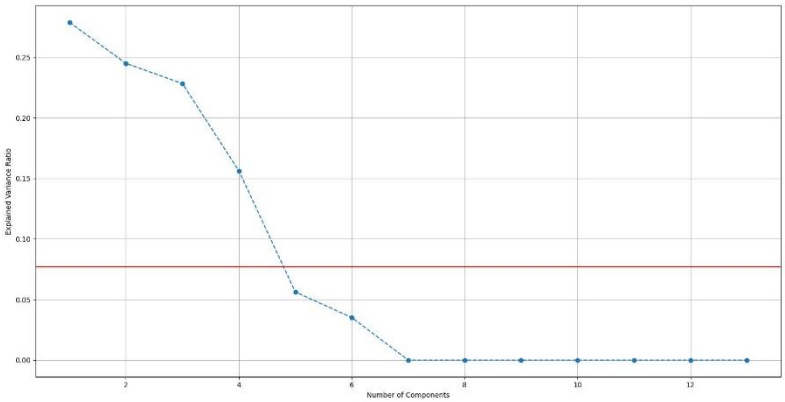
Graph 8

Scree plot and Kaiser criterion for the statements on accessibility



Graph 9

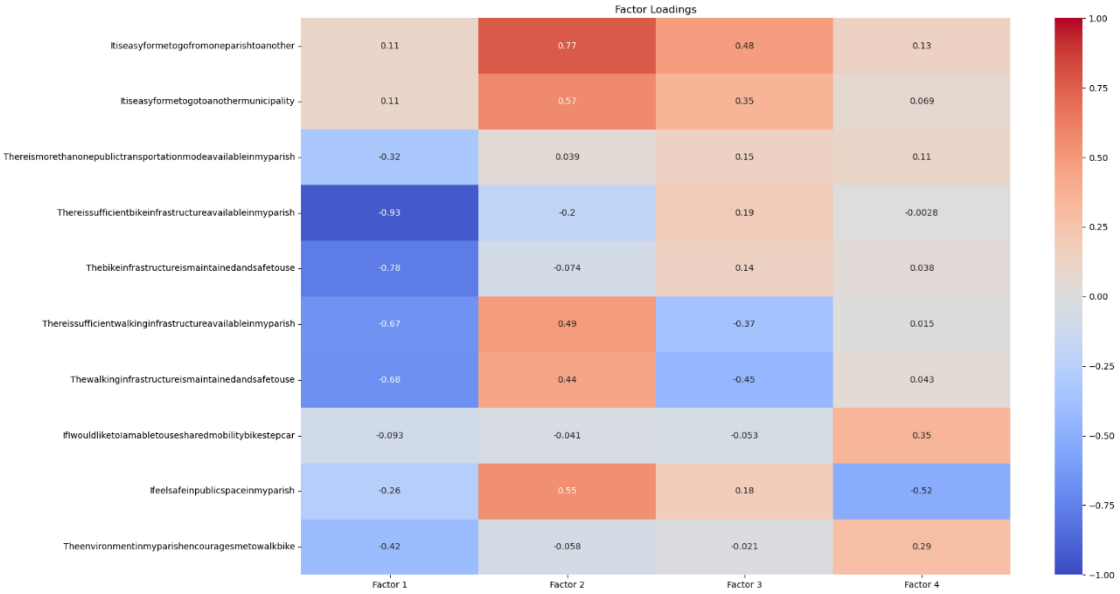
Scree plot and Kaiser criterion for the statements on economy



Statements with a factor loading of 0.4 or higher (negative or positive) were considered for further analysis. As a result, the 10 statements on accessibility were divided into four factors: the lack of cycling and walking infrastructure (Factor 1: statements 4, 5, 6, 7 and 10), good connectivity (Factor 2: statements 1, 2, 6, 7 and 9), neglected walking network (Factor 3: statements 1 and 7), feeling unsafe in public space (Factor 4: statement 9). The 13 statements on the economy were divided into three factors: the lack of services (Factor 1: statements 11 and 12), the lack of recreational activities (Factor 2: statements 8, 9 and 10), and the lack of employment opportunities (Factor 3: statements 1 and 2). Graphs 10 and 11 show respectively the factor loadings of the statements on accessibility and economy.

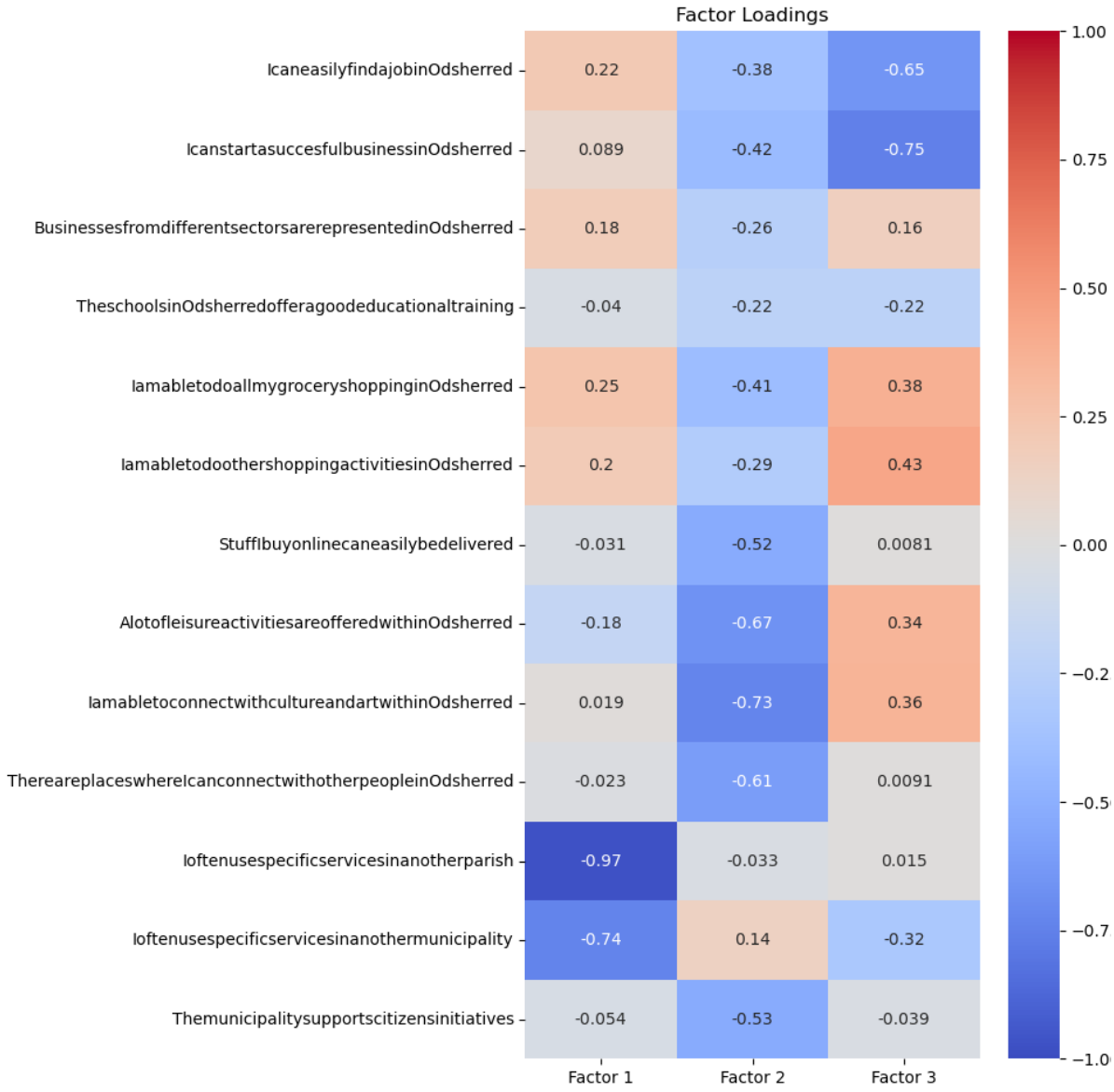
Graph 10

Factor loadings of the statements on accessibility



Graph 11

Factor loadings of the statements on the economy



These newly formed groups were used to find some significant relations between the factor scores and different variables using a Chi-square test. Different variables were used: the origin of people (rural or urban areas or foreign countries), the parishes in Odsherred where the respondents currently live, and the age group to which respondents belong. Unfortunately, none of the results of the Chi-square tests were significant ($p < 0.05$), which means that the null hypothesis is accepted and that there is no significant relationship between the factors on economy and accessibility and the origin, the age group or the parish of residence. This can be due to the small dataset (44 respondents).

5.2.2.2 Relation between expected and preferred scenarios and age groups

To examine the relationship between the expected and preferred scenarios and the different age groups of the respondents, a Chi-square test was performed on the data. With a p-value of 0.075, Graph 12 suggests that there is almost a significant relation between the expected scenario and the age group of the respondents. This indicates that age may influence individuals' perceptions of the future of Odsherred. On the other hand, as indicated by the p-value of 0.502 on Graph 13, the relationship between the preferred scenario and the age group is not significant. The question about the most preferred scenario of people is very personal as it asks about people's hopes and desires. The results illustrate that such personal preferences cannot be explained by the age group of the respondents.

Graph 12

SPSS output of the Chi-square test with the expected scenarios and the age groups as categorical variables

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15,615[a]	9	,075
Likelihood Ratio	18,908	9	,026
Linear-by-Linear Association	1,159	1	,282
N of Valid Cases	44		

a. 15 cells (93,8%) have expected count less than 5. The minimum expected count is ,68.

Graph 13

SPSS output of the Chi-square test with the preferred scenarios and the age groups as categorical variables

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8,318[a]	9	,502
Likelihood Ratio	9,317	9	,409
Linear-by-Linear Association	2,279	1	,131
N of Valid Cases	44		

a. 13 cells (81,3%) have expected count less than 5. The minimum expected count is ,41.

5.3 Points of action for parishes

The literature study and the responses from the survey provided us with a deeper understanding of the parishes and the push and pull factors within the four selected parishes. With this information, we were able to propose some realistic points of action to achieve the most preferred scenario (scenario 1) based to the responses of our survey.

The sense of community in Vallekilde is very strong, but it lacks employment opportunities as it only has one school (which many of our respondents in Vallekilde are connected to). Increasing the number of employment opportunities could attract more younger, working people. However, the introduction of employment opportunities may negatively impact the sense of community, as it is an important driver for coming to Vallekilde.

Nykøbing Sj has a lot of employment opportunities, shops and services, but respondents pointed out that the biking and walking infrastructure needs to be improved. However, most of these respondents previously lived in Copenhagen, which may explain their higher standards for walking and biking infrastructure.

Asnæs is a parish with a lot of internal migration and numerous public services. However, some respondents didn't feel safe in public spaces in Asnæs. This stands out because people from other parishes feel very safe in public spaces. Therefore, safety could be improved in this parish.

The ecovillages in Egebjerg are something unique in Odsherred and have the potential to attract more young adults, particularly from cities such as Copenhagen. This could lead to an increase in population, but Egebjerg might face a shortage of services, as it currently has only one small grocery store. However, the parish does have primary and secondary schools, which would be enough if the population increases.

6. DISCUSSION

6.1 Insights from data analysis

Based on the official migration statistics (statistics Denmark, 2023a) and the results of the survey, we can conclude that there is a net out-migration of young adults in Odsherred. The municipality is aware of this trend

and is already implementing several measures to make Odsherred more attractive to young people. In this study, the survey questions about the perception of out-migration and the motives for this migration were qualitatively analysed. Therefore, the analysis can only give an idea about the motives that respondents chose very often or not at all and can indicate big differences between parishes. Our results suggest that 'education', 'employment' and 'wanting to live in a bigger city' are the most important motives for moving out of Odsherred. These motives are consistent with those identified in the literature on migration from rural areas. However, it is important to note that we interviewed people that are still living in Odsherred, instead of people that have actually moved out for a specific reason. In order to get more direct information about the motives for moving, it would be interesting to interview an expert on migration in the area, but unfortunately, we were not able to get in touch with someone. You could also consider contacting people who have moved, although they may be harder to reach.

To get a better idea of the current situation of the municipality in terms of accessibility and economy, the respondents could score several statements on these two topics. The statements were statistically analysed to test the null hypothesis which states that there is no association between the variables. Since the result of the Chi-square test is insignificant, there is not enough evidence to reject the null hypothesis. This means that we cannot explain the opinion of the respondents about accessibility or economy based on the origin of people (rural or urban areas), the parishes where the respondents currently live or their age group. A possible explanation for this insignificant result is that our sample of respondents was too small. This problem could be prevented by making our survey shorter or by doing fieldwork over a longer period of time.

Furthermore, we could have reached a more diverse group of respondents by doing fieldwork at different times during the day. Because we planned our fieldwork during working hours, it was more difficult to reach people of working age. Although the relationship between the parish where the respondents live and their opinion on the statements was not significant, the answers resulted in interesting findings about possible improvements in terms of accessibility and economy in the different parishes. This is because we guided the people through the survey and stood next to them to answer potential questions. In that way, we got more information, because the people could talk to us or show us something if they wanted. This extra input was used to indicate the action points for the parishes.

6.2 Alternative methods

There are several aspects of the research methodology that could have been done differently. First of all, the mapping of the in-and out-migration can be statistically biased due to the aggregation of the migration numbers into parishes. It would be interesting to know where people move to or from on a more detailed level since parishes are an assemblage of very different living environments. Unfortunately, this statistical data was not available. Furthermore, the migration numbers on the parish level were not available for different age categories, so we could not extract more specific data about the movement of young people within Odsherred. If this data could be acquired, it would be interesting to address this in further research. Furthermore, the interviews revealed that the inhabitants of Odsherred did not think in terms of parishes. They lacked a clear understanding of parish boundaries and instead based their mental map on the various villages.

Secondly, it would be possible to present the four scenarios differently. During the surveys, people needed quite some time to read the different scenarios and sometimes indicated that they did not fully understand everything. Because we stood next to the respondents, we could give them more information or give examples, but this is more time-consuming. Hence, it could be interesting to use images instead of text to describe the scenarios and show Odsherred when there is, for example, a declining economy and thriving accessibility. These images could be collected from the internet or artificial intelligence could be used to create new images about that specific topic. Because the municipality of Odsherred is very diverse with a lot of different landscapes, it would be necessary to select different images for each scenario. Another option for further research would be to focus on a specific region or parish as study area.

Finally, we could have treated summer house tourists as a separate group of respondents. Comparing their answers with those of permanent residents in Odsherred would be insightful, as this group has distinct characteristics and plays a crucial role in the municipality's economy. Additionally, they reside in specific areas and likely have a different perception of Odsherred.

6.3 Future research directions

To end this discussion, we will reflect on some new research questions and hypotheses that emerged from our research project and could be the starting point for future research. Firstly, the trend of accessibility and economy in the municipality can be further analysed in order to investigate which of the four scenarios that we

described and asked people about in the surveys, will be the reality in the future. Will Odsherred in 2035 be characterized by an “accessible oasis” with a high accessibility and a thriving economy, like most of the respondents expect? Or will the municipality listen to the needs and hopes of the residents and evolve into a “remote charm” environment that can be described as a “thriving economy amidst nature's solitude”?

Secondly, the action points proposed at the end of the study can be made more concrete. Additionally, the potential consequences of implementing these actions can be analyzed using quantitative and/or qualitative research methods. To assess the feasibility of the proposals, collaboration with the municipality is advisable. Another possible future research topic is a comparative analysis of different Danish municipalities concerning internal migration and future aspirations. Specifically, the hypothesis that young people are increasingly leaving rural areas can be tested across various peripheral municipalities. This research could also explore and compare potential future scenarios for these municipalities.

Finally, future research can use various channels to reach young people and gather more specific data on their motives for moving. This would include planning interviews specifically targeting this age group. Instead of distributing the survey through online media, as mentioned in paragraph 3.1, it can be distributed on paper in schools and sports associations in Odsherred to improve participation.

7. CONCLUSION

The migration patterns in Odsherred, Denmark, are characterized by a slightly positive net internal migration, with more people moving to Odsherred from other municipalities than leaving. However, this trend reversed in 2023, resulting in negative internal migration. The net migration of young adults (aged 20-29) has been negative for years, and this trend persists, leading to a smaller young adult population and therefor ageing demographic. This can lead to a loss of human and social capital in the rural community, which could result in even more people leaving and eventually a collapsing rural society.

The research delves deeper into the migration of young adults in Odsherred and aims to provide a comprehensive understanding of the underlying causes and potential solutions to mitigate their out-migration. The persistent negative migration trend among young adults in Odsherred is driven primarily by the search for better job opportunities, educational facilities, and enhaced living conditions in urban areas. Conversely, key push factors for moving out of Odsherred include limited job opportunities, inadequate infrastructure, and insufficient public

services. The research focused on four distinct parishes – Nykøbing Sj, Vallekilde, Asnæs, and Egebjerg – each exhibiting unique migration patterns and characteristics.

Through qualitative and quantitative analyses, several key findings were obtained. The study revealed that while there is no significant relationship between the origin of people, the parishes where they currently live, or their age group and their opinions on economic and accessibility-related statements, interesting insights were gained about potential improvements. The findings highlighted the importance of accessibility and economic opportunities in shaping the attractiveness of different parishes within Odsherred. This underscores the necessity for targeted action points to enhance these aspects to retain and attract young residents. Based on the surveys and the characteristics of the parishes, we can propose an increase of employment opportunities in Vallekilde, more walking and biking infrastructure in Nykøbing Sj, increased safety measures in Asnæs and more diverse services in Egebjerg.

A factor analysis and Chi-square tests provided valuable insights into the underlying patterns in the data. However, the results indicated that the sample size and the diversity of respondents could be improved. Future studies should consider conducting fieldwork at different times and extending the survey period to reach a broader and more representative sample.

Several new research questions have emerged from this study. Comparing the results with other Danish municipalities could provide a broader context and highlight unique challenges and opportunities for Odsherred. Investigating the potential evolution of Odsherred towards the most preferred or expected scenarios, and assessing the consequences of implementing the proposed action points, are also promising areas for future research. Additionally, distributing surveys to gather more specific data about the motives for moving among young people and conducting interviews in different parishes could provide deeper insights.

The migration of young adults from rural to urban areas is a complex phenomenon influenced by various socio-economic factors. By understanding these dynamics and implementing targeted strategies, Odsherred can mitigate the out-migration and foster a more vibrant, sustainable rural community. This study can serve as a foundation for the municipality to further develop the pillars of their vision in collaboration with residents. This approach allows for informed decisions on accessibility and the economy that align with the community's preferred future. The municipality should carefully consider the impact of their decisions on tourism, nature, housing prices, and services across the various parishes in Odsherred.

8. REFERENCES

8.1 Internet sources

BC Rural Network & Fraser Basin Council. (2014). *Project comeback: Creating vibrant rural communities by retaining and attracting a young adult population*. https://ceric.ca/fr/2017/10/attracting-young-professionals-to-rural-places/

Climate Adapt. (2023, March 15). *Denmark*. https://climate-adapt.eea.europa.eu/en/countries-regions/countries/denmark

Deichmann, J., Ebel, E., Heineke, K., Heuss, R., Kellner, M., & Steiner, F. (2023, January 6). *The future of autonomous vehicles (AV) | McKinsey*. McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected

ESPON. (2020). *Policy Brief on Shrinking Rural Regions*. https://archive.espon.eu/sites/default/files/attachments/ESPON%20Policy%20Brief%20on%20Shrinking%20Rural%20Regions.pdf

European Network for Rural Development. (2018). *ENRD Social Inclusion Workshop: Making rural areas more attractive for young people.* https://ec.europa.eu/enrd/sites/default/files/w27_rural-youth_meeting-highlights.pdf

Eurostat. (2022). *Urban-rural Europe—Demographic developments in rural regions and areas*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Urban-rural_Europe_-_demographic_developments_in_rural_regions_and_areas

Eurostat. (2024). *Ageing Europe—Statistics on population developments*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Ageing_Europe_-_statistics_on_population_developments

Kahancová, M., & Williams, C. C. (2023). *The Rise of Teleworking: Improvements in Legislation and Challenges for Tackling Undeclared Work*. https://www.ela.europa.eu/sites/default/files/2023-12/output-paper-teleworking-March-2023-Plenary.pdf

Noonan, E., & Rusu, A. (2022). *The future of climate migration*. https://www.europarl.europa.eu/RegData/etudes/ATAG/2022/729334/EPRS_ATA(2022)729334_EN.pdf

Odsherred Kommune. (2023, December 19). *Ny vision for Odsherred Kommune*. https://www.odsherred.dk/da/nyheder/ny-vision-for-odsherred-kommune/

Odsherred Kommune. (n.d.-a). *Det gode arbejdsliv i Odsherred*. https://www.odsherred.dk/da/arbejde-og-uddanne-dig/det-gode-arbejdsliv-i-odsherred/

Odsherred Kommune. (n.d.-b). *Vejen til Odsherred*. https://vejentilodsherred.dk/om-kampagnen/

Robinson, E. (n.d.). Attracting young professionals to rural places. *CERIC*. https://ceric.ca/fr/2017/10/attracting-young-professionals-to-rural-places/

Salto-youth. (n.d.). *Make young people proud of their rural heritage*. https://www.salto-youth.net/rc/inclusion/archive/archive-resources/inclusiongroups/inclusionrural/InclusionRuralPride/

Scottish Government. (2024a, February 16). *Supporting and enabling sustainable communities: Action plan to address depopulation*. https://www.gov.scot/publications/supporting-enabling-sustainable-communities-action-plan-address-depopulation/pages/2/

Scottish Government. (2024b, February 29). *Attracting young people to rural life: Working together to develop the right solutions*. https://www.gov.scot/news/attracting-young-people-to-rural-life/

Serban, A.M., & Braziene, R. (2021). Young people in rural areas: diverse, ignored and unfulfilled. Youth Partnership 2021. Available from: https://pjp-eu.coe.int/documents/42128013/106317733/Rural-youth-study.pdf/1fde9ee6-48ce-a2f7-2985-124b44ae46e7

Statista Research Department. (2024). *E-bikes in Europe*. Statista. https://www.statista.com/topics/10389/e-bikes-in-europe/

Steineke J. M. (n.d.). From recreation to retirement. *Nordregio.* https://archive.nordregio.se/en/Metameny/About-Nordregio/Journal-of-Nordregio/2007/Journal-of-Nordregio-no-3-2007/From-recreation-to-retirement/index.html

Ung i Odsherred. (n.d.). *Ung! Odsherred*. https://ungiodsherred.dk/

Wind, A. (2017). *Outmigration of rural youth. Academics on the outmigration of rural youth in the Western world from 1970 until 2017.* https://edepot.wur.nl/421070

8.2 Articles

Hansen, H. (2020). Peripheral Denmark, population development and labour market dynamics. *Migration-Muuttoliike*, *46*(1), 15-20.

Hofstede, H., Salemink, K., & Haartsen, T. (2022). The appreciation of rural areas and their contribution to young adults' staying expectations. *Journal Of Rural Studies, 95,* 148-159. https://doi.org/10.1016/j.jrurstud.2022.07.018

Llave, O. V., Hutley, J., & Peruffo, E. (2023). The rise in telework: Impact on working conditions and regulations. *Publications Office.* https://doi.org/10.2806/069206

Stockdale, A. (2004). Rural Out-Migration: Community Consequences and Individual Migrant Experciences. *Sociologia Ruralis, 44*(2), 167-194. https://doi.org/10.1111/j.1467-9523.2004.00269.x

Svendsen, G. (2018). Between Belonging and Longing: Why do Young Rural-urban Migrants Leave Their Places of Birth, What Do They Leave Behind, and Do They Consider Moving Back? *Journal of Cultural Analysis and Social Change*, *3*.(1), 02. https://doi.org/10.20897/jcasc/2671

8.3 Statistical data for mapping

Statistics Denmark. (2023a). FLY66: Internal migration between municipalities by sex, age and municipality [Dataset]. Geraadpleegd op 15/06/2024. https://www.statbank.dk/20024

Statistics Denmark. (2023b). KMSTA003: Summary vital statistics by parish and movements [Dataset]. Geraadpleegd op 26/03/2024. https://www.statbank.dk/20024

9. ATTACHMENTS

9.1 Survey

9.1.1 General questions

How old are you?

Since when do you live in Odsherred?

- Since I was born
- I moved to Odsherred

In which parish do you currently live?

- Asnæs
- Egebjerg
- Fårevejle
- Grevinge
- Højby
- Hørve
- Lumsås
- Nørre Asmindrup
- Nykøbing Sj
- Odden
- Rørvig
- Vallekilde
- Vig
- Other: …

Do you notice people moving out of Odsherred?

- Yes
- No
- I don't know

Do you notice people moving to Odsherred?

- Yes
- No
- I don't know

9.1.2 Questions for the people who moved to Odsherred

From where did you move to Odsherred?

- Another municipality, please fill in which one: …
- Another country, please fill in which one: …
- Prefer not to say

How old were you when you moved to Odsherred?

What was the reason for moving to Odsherred? (multiple choice)

- Better housing prices
- Proximity to family/friends
- Proximity to nature
- Better sense of community
- More peace and quiet
- Stronger place attachment
- Better employment opportunities
- Opportunity to start a business
- Personal reasons
- Summerhouse
- I don't know
- Other: …

9.1.3 Questions for the people who notice people moving out

What are the motives of people moving out of Odsherred for moving away? (multiple choice)

- Houding prices
- Education
- Employment
- Starting a business
- Proximity to family/friends
- "Nothing ever happens in Odsherred"
- Proximity to services and facilities
- Wanting to live in a city
- Personal reasons
- I don't know
- Other: …

At which stage of life are these people when they move out of Odsherred? (multiple choice)

- Teenagers
- Young adults
- Working adults
- Retired adults
- I don't know

How do you experience the moving out of Odsherred by young people?

- Their migration is relatively low
- Their migration doesn't stand out to me
- Their migration is relatively high
- Haven't really thought about that

9.1.4 Questions for the people who notice people moving in

What are the motives of people moving to Odsherred for moving here? (multiple choice)

- Houding prices
- Education
- Employment
- Starting a business
- Proximity to family/friends
- Strong placement attachment
- Sense of community
- Peace and quiet
- Nature
- Personal reasons
- I don't know
- Other: …

At which stage of life are these people when they move to Odsherred? (multiple choice)

- Teenagers
- Young adults
- Working adults
- Retired adults
- I don't know

Who are these people who move to Odsherred?

- Mostly people who lived in Odsherred before
- Mostly people who didn't live in Odsherred before
- About as many people who did and who didn't live in Odsherred before
- I don't know

9.1.5 Statements on accessibility

Following statements were scored on a Likert scale from 1 (totally disagree) to 5 (totally agree):

- It is easy for me to go from one parish to another.
- It is easy for me to go to another municipality.
- There is more than one public transportation mode available within my parish.
- There is sufficient bike infrastructure available in my parish.
- The bike infrastructure is maintained and safe to use.
- There is sufficient walking infrastructure available in my parish.
- The walking infrastructure is maintained and safe to use.
- If I would like to, I am able to use shared mobility (bike, step, car).
- I feel safe in public space in my parish.
- The environment in my parish encourages me to walk/bike.

9.1.6 Statements on economy

Following statements were scored on a Likert scale from 1 (totally disagree) to 5 (totally agree):

- I can easily find a job in Odsherred.
- I can start a successful business in Odsherred.
- Businesses from different sectors are represented in Odsherred.
- The schools in Odsherred offer a good educational training.
- I am able to do all my grocery shopping in Odsherred.
- I am able to do other shopping activities in Odsherred.
- Stuff I buy online can easily be delivered.
- A lot of leisure activities are offered within Odsherred.
- I am able to connect with culture and art within Odsherred.
- There are places where I can connect with other people in Odsherred.
- I often use specific services in another parish.
- I often use specific services in another municipality.
- The municipality supports citizens' initiatives.

9.1.7 Future scenarios

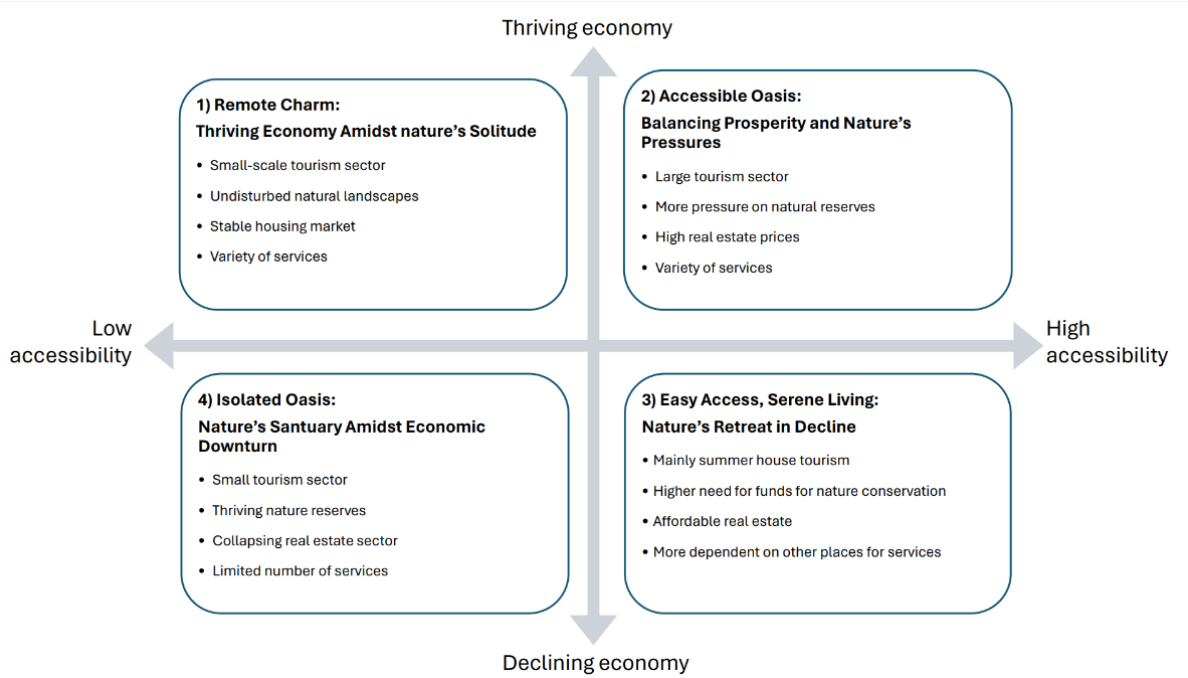
Which scenario is most likely to happen?

1) Remote Charm: Thriving Economy Amidst Nature's Solitude
2) Accessible Oasis: Balancing Prosperity and Nature's Pressures
3) Easy Access, Serene Living: Nature's Retreat in Decline
4) Isolated Oasis: Nature's Sanctuary Amidst Economic Downturn

Which scenario is the most suitable for yourself?

1) Remote Charm: Thriving Economy Amidst Nature's Solitude
2) Accessible Oasis: Balancing Prosperity and Nature's Pressures
3) Easy Access, Serene Living: Nature's Retreat in Decline
4) Isolated Oasis: Nature's Sanctuary Amidst Economic Downturn

Figure 1: Diagram of the four plausible future scenarios, with the two axes of economy and accessibility, and the most important points of each scenario.



9.2 Python code for data analysis of the statements on accessibility and economy

```python
# -*- coding: utf-8 -*-
"""
Created on Thu May 16 11:57:19 2024

@author: Lars
"""

import pandas as pd
import matplotlib.pyplot as plt
from sklearn.preprocessing import StandardScaler
import seaborn as sns
from sklearn.decomposition import FactorAnalysis
from sklearn.preprocessing import OrdinalEncoder
import numpy as np

# Pad van .csv file definiëren
path = r"C:\Users\Lars\OneDrive - UGent\02_Education\GIP\Accessibility_groep3.csv"

# Dataframe maken
df = pd.read_csv(path, sep=';')
df = df.drop(['Thereismorethanonepublictransportationmodeavailablewithinmyparis'],axis=1)

# Ordinale variabelen definiëren
ordinal_columns = df.columns[4:]
ordinal_categories = [
    ["Strongly disagree", "Disagree", "Neutral", "Agree", "Strongly agree"]
] * len(ordinal_columns)

# Vervang lege waarden door "Neutral"
df[ordinal_columns] = df[ordinal_columns].replace(' ', 'Neutral')

# OrdinalEncoder gebruiken voor de ordinale kolommen
ordinal_encoder = OrdinalEncoder(categories=ordinal_categories)
df[ordinal_columns] = ordinal_encoder.fit_transform(df[ordinal_columns])

# Schalen van de data
features = df.columns[4:]
x = df.loc[:, features].values
x = StandardScaler().fit_transform(x)

# Variantie per component berekenen
n_components = len(features)
fa = FactorAnalysis(n_components=n_components)
fa.fit(x)
explained_variance = np.var(fa.transform(x), axis=0)
explained_variance_ratio = explained_variance / np.sum(explained_variance)
eigenvalues = explained_variance * (x.shape[0] - 1) / x.shape[0]

# Kaiser-criterium toepassen (eigenwaarden > 1)
kaiser_criterion = np.sum(eigenvalues > 1)

# Scree plot maken met Kaiser-criterium
plt.figure(figsize=(10, 6))
plt.plot(range(1, n_components + 1), explained_variance_ratio, marker='o', linestyle='--')
plt.xlabel('Number of Components')
plt.ylabel('Explained Variance Ratio')
plt.grid(True)
plt.axhline(y=1/len(features), color='r', linestyle='-')
plt.show()

# Factoranalyse uitvoeren
fa = FactorAnalysis(n_components=4)
fa.fit(x)
fa_components = fa.transform(x)

# Factorladingen toevoegen in de DataFrame
factor_loadings = pd.DataFrame(fa.components_.T, index=features, columns=['Factor 1', 'Factor 2', 'Factor 3','Factor 4'])

# Heatmap visualisatie van de factorladingen
plt.figure(figsize=(10, 6))
sns.heatmap(factor_loadings, annot=True, cmap='coolwarm',vmin=-1,vmax=1)
plt.title('Factor Loadings')
plt.show()

# Voeg de factoren toe als nieuwe kolommen in de oorspronkelijke dataframe
for i in range(fa_components.shape[1]):
    df[f'Factor_{i+1}'] = fa_components[:, i]

# Exporteren als .csv
export_path = r"C:\Users\Lars\OneDrive - UGent\02_Education\GIP\migration\accessibility\df_accessibility.csv"
df.to_csv(export_path)
```

9.3 Detailed explanation of the four future scenarios

9.3.1 Scenario 1: low accessibility & thriving economic situation

- Tourism

In this scenario, Odshered could have a small-scale, but thriving tourism sector. The low accessibility can invoke a feeling of exclusivity, which can be attractive to tourists or summer house owners who like to avoid mass tourism. Since the accessibility is low, the municipality will have many places with (untouched) nature that few people visit, which would be the perfect vacation spot for people looking to escape their busy lives and unwind in nature. The authenticity of the municipality might also be preserved, which can be an attractive factor. Furthermore, if the local economy is thriving, the municipality might have the funds to cater to the specific needs of the tourists.
Of course, there is also another side to this. The low accessibility might be attractive to some, but it will be a deterrent for others. So, while the municipality might have the means to see to bigger groups of people, in reality, there will be smaller groups.

- Nature

Because of the low accessibility, the biodiversity and natural habitats will be left undisturbed by human activity. In addition with the thriving economy, it will be easier to preserve the natural environment, inside and outside of the Geopark, because of the surplus of funds that can be reserved for this purpose. Since tourism will be rather small-scale, there will be less pressure on natural resources and the tourism industry can be accommodated in a sustainable and environmentally-friendly way.
It will however make it harder to do more drastic interventions in the area because of the low accessibility. In the case of emergencies due to climate change such as flooding or other extreme weather events, it will be harder to save people and/or preserve nature in the area.

- Housing prices

The low accessibility could have a rather reducing impact on local housing prices. While a longer commute would be less of a problem for people who telework, or people who have a job close by due to the thriving local

economy, other people might need easier access to education, family or other employment opportunities and cannot afford to be on the road for a long time every day.
On the other hand, the thriving economy could have an increasing effect on local housing prices. The economy could increase the demand and the amount of real estate investment. They keep each other in a balance that would cause a stable, affordable real estate market in the municipality.
The price of summer houses might increase though, since the municipality will be attractive for a certain kind of tourists.

- Services

The thriving local economy makes it possible to invest in services from different categories. Not only the "necessary" ones, like education, healthcare, working and living, but also the category entertainment can be represented in the municipality, which makes Odsherred a more pleasant place to live in for people that like to do activities in their free time. The tourists will also benefit from this supply of recreational activities, since the municipality will feel like a more vibrant place. More services also mean that Odsherred will be less dependent on neighbouring municipalities, because the inhabitants don't need to go elsewhere to do their shopping for example. This might create a positive feedback loop and can strengthen the local economy even further. However, since the accessibility of Odsherred is low, the access to different services all over the municipality will still be quite limited. This can lower the survival chances of the different facilities, if not enough people can be reached.

- Residents

In this first scenario, the municipality is not very accessible, but has a thriving local economy. This leads to a small-scale tourism sector, undisturbed natural landscapes and habitats, a rather stable housing market and different services that focus on the needs of the inhabitants. Odsherred will be a very authentic and independent part of Denmark, and these are also the characteristics of the people that the municipality will attract. Living in a remote region with few connections to other places and other communities is possible for people who have a job and social network within Odsherred, but it is not the ideal place for people who commute, travel a lot or need specific services from a bigger city, such as Copenhagen.

In this scenario, Odsherred will offer opportunities for young people since there is affordable housing and a thriving local economy with job opportunities. Young people who want to avoid the hectic city life, can find a calm living environment in Odsherred and enjoy nature and its landscapes. Additionally, Odsherred might be a suitable living place for elderly people who need good access to shops and health care, but don't need good accessibility to other places. The challenge will be to combine the needs of these different age groups in order to create a municipality for all.

9.3.2 Scenario 2: high accessibility & thriving economic situation

- Tourism

In this scenario, tourism will have increased in large numbers, and depending on how the municipality responds to that, this might evolve into mass tourism. A lot of people will be able to easily access Odsherred with its temperate climate and moderate temperatures. Because of the thriving economic situation, the municipality and its inhabitants will be able to provide tourists with a diverse range of services, such as accommodation, restaurants and recreational activities. With high accessibility, it will be easy for tourists to arrive at the municipality but also move between parishes to take part in activities all over the area. This has the potential to turn into a system with positive feedback: the thriving economic situation will stimulate the tourism sector, which in turn will stimulate the economic situation.

- Nature

Due to the increase in accessibility and economic activity, the nature in the area will be disturbed by more human activity than in the past. More tourism and more pressure on natural resources will make it harder to preserve the biodiversity and environment in the area. However, due to the local thriving economy, the municipality will have the resources to intervene when necessary, for example when the preservation of nature becomes endangered. As they not only rely on tourism for their income, they will be able to put a temporary stop to the influx of tourists in the case of mass tourism. They will also have the resources to ensure that tourism proceeds in a sustainable and environmentally-friendly manner.

- Housing prices

Due to an increase in tourism and economic activity, the demand for real estate will increase in a major way. When living here, people can enjoy the quiet nature in the area, while having easy access to a job in the municipality or in the neighbouring areas. It will also be an interesting area for investors. This makes the area very attractive to all kinds of people, which will increase the demand, and in consequence the price of real estate. This might impact the inequality in the municipality, and people with a higher income will be favoured by this real estate market. Unless the municipality also invests in social housing, people with a lower income might be forced to move out of the municipality.

– Services

With a thriving economy and high accessibility, Odsherred will be a good location for services in all categories. There will be a positive feedback loop between the economic situation and the availability of services. The high accessibility will also make it possible for people to reach different services during different times of the day and week and this might even attract people from other places in Denmark to this peninsula. Another effect of the growing activity in Odsherred might be that the municipality loses its authenticity and local character which can change the place attachment of the inhabitants or the kind of people that call Odsherred their home.

– Residents

In this scenario, there will be a large tourism sector, more pressure on natural reserves, high real estate prices and different services of all categories. The municipality will gain a more urbanised and less remote character. Young families that want to settle in a more rural area, but have a job or family elsewhere, will find everything they need in Odsherred. However, because of the higher housing prices, it will be more difficult for young adults to settle in the area, although there are a lot of job opportunities and recreational activities available. These developments might feel very positive for certain groups of people that encourage change but might push away others that had a strong place attachment to a calmer and less connected Odsherred.

9.3.3 Scenario 3: high accessibility & declining economic situation

- Tourism

In this scenario, tourists will probably be people who own a summer house in the neighbourhood and go there during the summer to enjoy the nature of the Geopark. Since the economic situation is declining, enterprises will have to lower their prices to keep competitors at bay, which could be appealing to potential new tourists. However, there will be few things to do except enjoy the peace and quiet provided by nature because the municipality will not have the resources to provide many services or activities. This might deter new potential tourists from coming here, despite the low prices, temperate climate and easy access.
Despite the high accessibility, since the municipality is located on a peninsula, it will also not be a place where travellers could stop for a day or two on their journey to a different place. However, the high accessibility makes it a possibility, which might be very attractive to some nature lovers who really want to visit the Geopark. The Geopark will keep being appealing to a lot of people despite the economic situation of the municipality. Even if there are fewer funds to handle the upkeep of the park, it will remain an important geological and ecological site. Because of the high accessibility, tourists who want to visit the park but don't want to stay in Odsherred itself because of a lack of services and accommodation, will be able to stay at neighbouring municipalities since the park will be only a short drive away.

- Nature

Due to the high accessibility, the Geopark and the surrounding nature will be popular visiting spots. Even people who might be hesitating whether it would be worth the visit since there is not much else to do in the area, might be persuaded due to the easy accessibility. This increase in human activity will create a higher need for conservation. Since there will be fewer funds in the area to facilitate the environmental needs, the municipality will have to find more creative solutions to protect the area from human and environmental dangers.

- Housing prices

Since the accessibility is high, but the area itself is not interesting in terms of economic and employment opportunities, this area might be a popular area to live while commuting to work in a further area or working from home. This increase in demand might increase housing prices. On the other hand, the declining local

economy might result in lower housing prices, so as not to chase everyone away into moving to a more economically thriving area, which would result in the economy declining even further. The combination of these factors might result in a rather stable housing market, with affordable real estate prices.

- Services

The number of available services will be low due to the declining economic situation, but the need for the different services might also be smaller, since there is high accessibility within the municipality which can increase the connection between Odsherred and the neighbouring municipalities. This makes it easier for people to travel elsewhere to go to work or school, to do their shopping and to participate in all kinds of activities. In this way, the inhabitants of Odsherred will be dependent on other places to meet their daily needs. In case of emergencies or pandemics like COVID-19 where people are not allowed to travel far from home, this kind of development might have negative consequences for the inhabitants. However, the combination of evolving technology and high accessibility can open new doors in terms of access to services. The inhabitants can rely heavily on delivery services or telework, for example, to meet their daily needs while the municipality will not have to invest in more local services.

- Residents

In this scenario, Odsherred will have mainly tourists in the summer who like to visit the Geopark, affordable real estate prices and a lack of different services. This situation will support a calmer lifestyle for people who prefer to live in an area rich in nature with fewer economic activities and recreation opportunities. Due to the high accessibility, Odsherred might be a good living place for people who commute to work or don't need different services close to home. The low housing prices will make the area attractive for young people, but the combination with a lack of services and a declining economy might reduce the opportunities for this age group in the municipality.

9.3.4 Scenario 4: low accessibility & declining economic situation

- Tourism

In this scenario, the tourism sector will be declining just like the economic situation. The only tourists that Odsherred will receive are people who own a summer house and have been coming there for quite some time. There will be few services and facilities that cater to tourists, and because of the situation, the ones that are left might also be closing. Due to a lack of resources, the little infrastructure that the municipality has might also deteriorate even further, which will in turn hurt the accessibility.

- Nature

A lack of tourism and other human activity will give the fauna and flora more space and fewer disturbances, which can have a positive effect on the preservation of the biodiversity and vulnerable ecosystems. There will be less pressure on natural resources in the area and the biodiversity will be easier to maintain. There might be less funds for bigger interventions for example in case of extreme weather events, but since there is less danger of human and unnatural disturbances, the municipality can let nature take its course where possible. They could employ less invasive and more natural forms of nature preservation.

- Housing prices

Due to low accessibility and a declining local economy, the municipality will become less attractive to live in outside the tourist season. Low prices and a lack of demand might result in a lot of vacancy and decay of housing. However, the buyers that remain will have more power in deciding where to live and what price to pay.
The summer houses will be less impacted since they are located in more attractive locations, which will probably still see some investment. The residential parts of the municipality might face some abandonment and decline.

- Services

The declining economic situation will make it difficult for the municipality to provide a variety of services and activities to its inhabitants, since there will be less funds for new investments or development projects. The services that are already present in the municipality will reach only a selected number of inhabitants due to the

low accessibility in Odsherred. However, these small-scale, basic services might still be sufficient for the communities of the different parishes. In this way, there can be very personal interactions instead of big crowds or events. The organisation of leisure activities or the provision of daily needs can start with the community members, who don't need big economic investments to make the neighbourhood a pleasant place to live.

- Residents

In this last scenario, Odsherred is characterised by low accessibility and a declining economic situation. The tourist sector will be very small, the fauna and flora will thrive, the real estate sector will collapse, and the services will be very limited. The residents of Odsherred will be part of small, self-sustaining communities. The rural area will only be suitable for people who have a job in Odsherred and only need basic services. Likely, young people will not see a future for themselves in this area due to a lack of activities and job opportunities. Odsherred might also not be attractive for people from outside the municipality since the connection with other places is very poor.

FACULTY OF SCIENCES

MASTER OF SCIENCE IN GEOGRAPHY AND GEOMATICS

ALL ABOARD? A JOURNEY TO INCLUSIVITY IN ODSHERRED'S PUBLIC TRANSPORT

EXAMINING THE ACCESSIBILITY OF THE PUBLIC TRANSPORT SYSTEM IN ODSHERRED, DENMARK

Word count: 8930

Frauke Van Kerckhove, Helena Van Parys, Bas Ponnet and Tom Verheyden
Student number: 02108883, 02010336, 02009389 and 02003611

Responsible lecturer: Prof. dr. Veerle Van Eetvelde, department of Geography and Geomatics
Assistant: Dr. Maite Dewinter, MSc. Seppe De Wit, MSc. Lars De Sloover and Msc. Kiara Haegeman

A dissertation submitted to Ghent University in partial fulfilment of the requirements for the degree of Master of Science in Geography and Geomatics

Academic year: 2023 - 2024

GHENT UNIVERSITY

TABLE OF CONTENTS

1. INTRODUCTION

For people with physical disabilities, using public transport can sometimes give restrictions on their ability to travel. Being able to use public transport is an important part of someone's life, because it gives you lots of opportunities. It is needed to be able to take part in society, it is your right to be able to take the public transport by law and it gives you freedom in general to go wherever you want.

From this point of view, this integrated international project work wants to research whether the public transport network in Odsherred is inclusive to people with physical disabilities. The importance of this research lies in earlier research that was done in the same region last year. These students examined the general appreciation towards the public transport network to see which improvements could be made. Their conclusion was that the biggest problems were focused on the buses, because they don't drive late at night and most people said bus stops were not close enough to their homes. This research wants to take it a step further by focusing on the minority of physically disabled people to see which problems they might experience while taking public transport or why they don't use it at all. The main goal of this research is to see how inclusive the public transport network is, whilst the problems they experience is a sub question to answer the main goal. Another subgoal that is investigated is what efforts the companies already make for improving the accessibility of their transport modes. The last subgoal consists of trying to recommend future improvements, based on the current efforts and experienced problems or barriers.

This research is done first of all via observations whilst taking the public transport network. Secondly, people in Odsherred were interviewed with three short questions about their experiences, and when possible, the interview got more in-depth. Lastly and most importantly, the train stations and bus stops in the region were evaluated on their inclusiveness based on earlier research, via a checklist. This evaluation is shown as a result in two comprehensive maps. This evaluation is then matched to the perception of people to see which aspects were of lesser or bigger importance, depending on their physical disability. This perception is based on other research as well. This report follows with a discussion about the difficulties that were experienced throughout the research, the overall experience and

references for future research. At the end, the report closes with a compilation of conclusions based on the evaluation via the maps and the interviews.

2. RESEARCH GOALS AND QUESTIONS

This research wants to evaluate the inclusiveness of the public transport network in Odsherred for people with physical disabilities. Physical disability indicates any physical limitations or disabilities that inhibit the physical function of one or more limbs of a certain person (Konczal, 2020). It is important to emphasize that this includes both visual and hearing impairments as well. A crucial subgoal is to see what the current frustrations of the physically disabled people are and what difficulties they experience, which is researched through a short interview consisting of three questions, with the people in Odsherred. This offers the opportunity to provide tentative proposals to improve the public transport network in its inclusiveness.

Further on, another subgoal is to see whether the companies responsible for the public transport in the region already make efforts to make the network more accessible. This grants a comprehensive overview of the current situation in Odsherred.

To accomplish these research objectives, the primary research question was formulated as follows:

How inclusive is the public transport system in Odsherred for people with physical disabilities?

The following three sub questions have been formulated to support the main question. Each question answers a research aim on its own, but also contributes to the comprehensive overview of this study.

- *What are the current frustrations/difficulties of people with physical disabilities using public transport in Odsherred?*
- *What are the current and recent efforts made by transport companies to make the transport modes more accessible?*

- *What future improvements can be recommended to make the public transport network in Odsherred more inclusive?*

3. THEORETICAL FRAMEWORK

3.1 Inclusive public transport

As the name suggests, inclusive public transport is public transport where the infrastructure and services have been adapted so that everyone is able to make use of the public transport. People with disabilities are often victims of inadequate infrastructure and services, forcing these people to use alternative, mostly private, modes of transport. In many cases the car is used. These restrictions can be of different nature. In order to have a better understanding of the concept of disabilities, a distinction is made between physical disabilities and social disabilities. Since this study focusses on the inclusivity of public transport for people with physical disabilities, social inclusion will not be discussed.

The transition to using public transport requires a seamless and easy-to-navigate interface for everyone between the point of departure, the public transport network and the destination. It is therefore crucial for people with physical disabilities that the details of this interface are worked out down to the last detail in order to ensure a smooth and pleasant journey. However, this necessary level of detail is not taken into account in regular transport planning. (Maynard, 2009)

The social model of disability states that limitations arise from the barriers in the physical, sensory and social environment. According to this model, disability is defined as the inability to participate in regular activities caused by the limitations that these activities themselves impose. Society does not sufficiently take into account the needs of people with disabilities such as hearing, visual or mobility impairments which prevent these people from participating in activities. A disability is therefore not determined by the disability itself, but by the inaccessible environment. An illustrative example of the social model of disability is a wheelchair user who cannot participate in an activity. This inability is not caused by the use of the wheelchair, but by the location of the activity in a building without an elevator, located on

the top floor. So it is the inaccessibility of the environment that creates the disability, not the physical limitation of the person. This model emphasizes society's responsibility to make environments and activities accessible to everyone, regardless of their limitations. It requires a fundamental overhaul of policymaking and design practices to ensure inclusion and eliminate barriers. This model can be applied to public transport infrastructure. A further distinction is made between barriers in the physical environment and barriers in the social environment. The barriers in the physical environment refer to poor layout of buildings and streets and therefore pose an additional difficulty for people with learning disabilities who need a clear environment to navigate. The absence of colour contrasts means that people with reduced vision are unable to read the information signs. The barriers in the social environment include organizational barriers. These are the aspects of organizational culture and the systems and processes that reduce access for disabled people. For example, a person who would like to request assistance in Belgium must make a reservation 24 hours in advance via the app/site. This ensures that this person cannot make last minutes train rides. (Maynard, 2009)

According to the UITP (2022), 15% of the global population suffers from some sort of disability and 750 million people have difficulty reading or writing. In order to participate in society on an equal basis with other, it is obligatory to make transport accessible to people with disabilities. Since 15% of the global population suffers from some sort of disability and 80% of these people are willing to work, yet do not succeed in finding work due to inaccessibility. Being inclusive allows disabled users to experience mobility more easily and should therefore be adapted to people with diverse abilities, be easy to understand for any user, provide clear and effective communication understandable for every user (UITP, 2022).

3.2 Current situation in Belgium

Belgium's mobility landscape is characterized by a complex interplay of regional and federal authorities, each responsible for different aspects of transportation infrastructure and services. This intricate arrangement reflects the country's federal structure, with distinct responsibilities allocated to the Flemish, Walloon, and Brussels-Capital regions, as well as the federal government. At the federal level, the Belgian Federal Ministry of Mobility and

Transport oversees nationwide transportation policies. However, regional authorities implement these policies, reflecting Belgium's decentralization. In Flanders and Wallonia, regional ministries manage mobility policies: the Flemish Ministry of Mobility and Public Works and the Walloon Ministry of Mobility and Infrastructure handle public transportation in their areas. The Belgian National Railway Company (NMBS/SNCB), a federal entity, operates the national rail network with regional divisions reflecting linguistic and administrative differences. Regarding infrastructure for less mobile people, Infrabel plays a critical role in managing and maintaining Belgium's railway infrastructure. As a federal public entity, Infrabel is responsible for the construction, maintenance, and safety of the railway infrastructure, including tracks, signalling systems, and stations. While Infrabel collaborates closely with NMBS/SNCB to ensure the smooth operation of train services, its primary focus lies in the management of the physical railway infrastructure rather than passenger services (Husson *et al.,* 2017).

Belgium has made significant strides in ensuring accessibility and inclusivity within its transport system for individuals with visual, physical, and auditory impairments. Beginning in the early 2000s, the country embarked on a journey to enhance accessibility across all modes of transportation, recognizing the fundamental right of every citizen to move freely and independently. One important development in Belgium's policy was the implementation of tactile paving systems across major train stations and bus stops. These tactile indicators provide crucial guidance for individuals with visual impairments, enabling them to navigate safely. Major transportation hubs and busy stations in urban centres are more likely to be equipped with tactile paving systems. These stations often serve as priority locations for accessibility upgrades due to their higher passenger volumes and greater visibility. However, smaller or less frequently used stations may not have tactile paving systems installed yet. In some cases, accessibility improvements may be planned or in progress, reflecting ongoing efforts by authorities to enhance inclusivity across the entire transport network. When it comes to initiatives like tactile paving systems, which enhance accessibility within railway stations, the responsibility may be shared between different stakeholders. In many cases, the implementation of tactile paving systems falls under the jurisdiction of regional authorities, such as the Flemish Ministry of Mobility or the Walloon Ministry of Mobility and Infrastructure, particularly for stations located within their respective regions. However,

collaboration between regional authorities, federal entities like Infrabel, and NMBS/SNCB is often necessary to ensure comprehensive accessibility measures across the entire railway network (Manuela *et al.*, 2021).

3.3 Current efforts made by companies in Denmark

After examining the efforts made in Belgium, it is also important to consider the measures taken in Denmark to support individuals with disabilities in using public transport. The first efforts that need to be shown are the efforts following the official website of 'Your Public Transport', or in Danish 'Din Offentlige Transport' (Personer Med Handicap, n.d.). They state that people with a disability can travel at half the price of a normal adult, and so does their companion. One can bring their wheelchair, walker, guide dog or service dog free of charge on the bus, train and metro. But, you have to be careful where you can sit when you bring your guide dog. On all modes of transportation there are different rules to follow and places to sit. To see whether you can bring your wheelchair, walker, electric scooter, or special-needs bicycle on the bus, train, or metro, you can call them. Additionally, you can check on the website *rejseplanen.dk* to see whether the train has level access and if the elevators at the stations where you need to get on and off are operational. Lastly, at several stations, assistance is available for boarding and descending from the train. You can also receive help with carrying your luggage (Personer Med handicap, n.d.).

Further on, The European Blind Union state on their website that the regulations for guide dogs are rather simple: they are allowed on all public transportation, backed up by law. The only mode of transport that can restrict guide dogs is taxis, but only when the driver can prove via a certification that they are allergic to dogs (Denmark | European Blind Union, n.d.).

Beecroft *et al.* (2019) state that Denmark has no ministry specifically for rural areas. The Ministry of Environment and Food appears to have the most responsibility for rural policy areas, and there's no explicit reference to accessibility, mobility or the role of transport in relation to this Ministry on its website (Beecroft *et al.*, 2019).

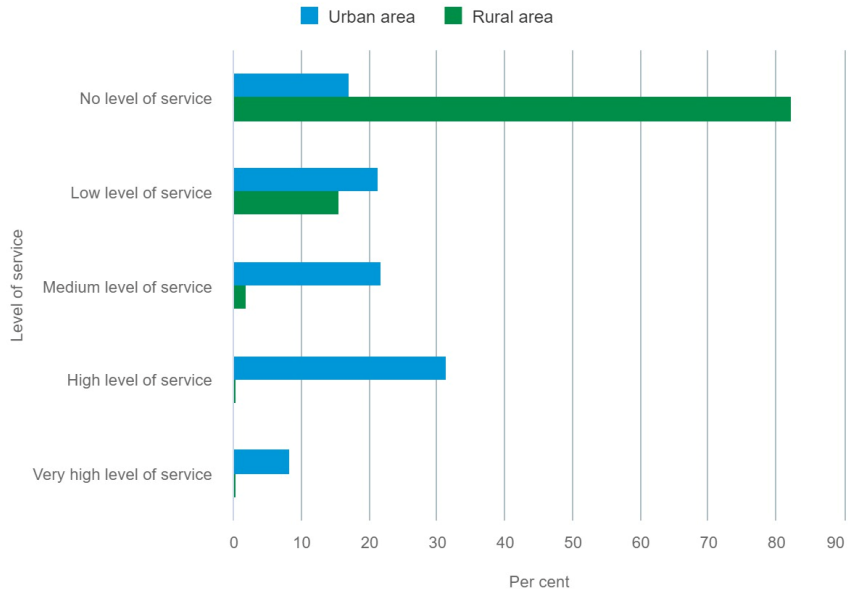
Lastly, Figure 1 shows an indicator that sheds light on the extent to which the population benefits from access to public transport within 500 meters of their residences. It is made up by Statistics Denmark (2023) as a follow-up of the sustainable development goals. The sustainable development goals were further divided into subgoals, with the complete subgoal for this indicator written as follows:

> *By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons (Access to public transport, 2023).*

The indicator is calculated using public transportation stop data from Rejseplanen (the Danish travel planner for public transport), road data from the Danish Map Supply, and population data from CPR and Statistics Denmark's Urban Census.

Figure 1

Proportion of population that has convenient access to public transport, sorted by urban and rural living areas. (Statistics Denmark, 2023)



The accessibility is categorized into five levels:

1. Very high: More than 10 departures per hour on average, with access to both buses and trains/metro.
2. High: More than 10 departures per hour on average.
3. Medium: 4-10 departures per hour on average.
4. Low: Fewer than 4 departures per hour on average.
5. No service: No departures between 6:00 and 20:00 on a working day (Statistics Denmark, 2023).

3.3.1 Flextrafik

Flextrafik is a service throughout Denmark that guarantees flexible transport for people who are less mobile. The service includes four types: Flexroute for those unable to use public transport, Flexpatient for hospital visits, Flexkommune for health and school transport via municipalities, and Flexhandicap under legal guidelines for severely disabled citizens. There is no fixed schedule; a flex tour can be ordered up to 2 hours before departure and up to 14 days in advance, with deadlines of 8 PM the day before or 8 AM on the same day. Operating hours vary by day and region: generally they are operating between 6 AM and 11 PM, with adjustments around Christmas and New Year. For Flexhandicap, the hours are for Monday to Friday from 7:00 AM to 6:00 PM, and weekends and holidays from 8:00 AM to 6:00 PM. Routes are adjusted for shared rides (Handelsbetingelser, n.d.).

The Flextrafik service can be accessed via the Flextrafik app or website, available throughout Denmark (in Odsherred it operates as Movia). Drivers assist around the car but do not provide door-to-door service. There can be up to 3 fellow travellers/ passengers (2 for Flexhandicap at 50% fare), one aid object per person, and small pets, guide dogs, or strollers are allowed. You board the vehicle at your mailbox, with a maximum 20-minute wait window (5 minutes before and 15 after scheduled time). A fee needs to be paid for cancellations less than 2 hours in advance. The cost variables for Flexhandicap trips, starting at DKK 30 for the first 5 km and adjusting thereafter. To register, you have to be minimum fifteen years old. Required to register are a Danish civil registration address, MitID or NemID account creation, and a valid bank card. The service has minor altercations in Copenhagen for the requirements. You must be 18 or older, you must live in the City of Copenhagen and your disability must be sufficiently

severe that you are unable to use public transport. The service can be compared to the Belgian service called 'Hendriks'. Hendriks aims to improve mobility in Flanders, Brussels, and Wallonia for people with a disability, wheelchair users, and everyone with mobility impairments by collaborating with public services, groups, and individuals (Handelsbetingelser, n.d.).

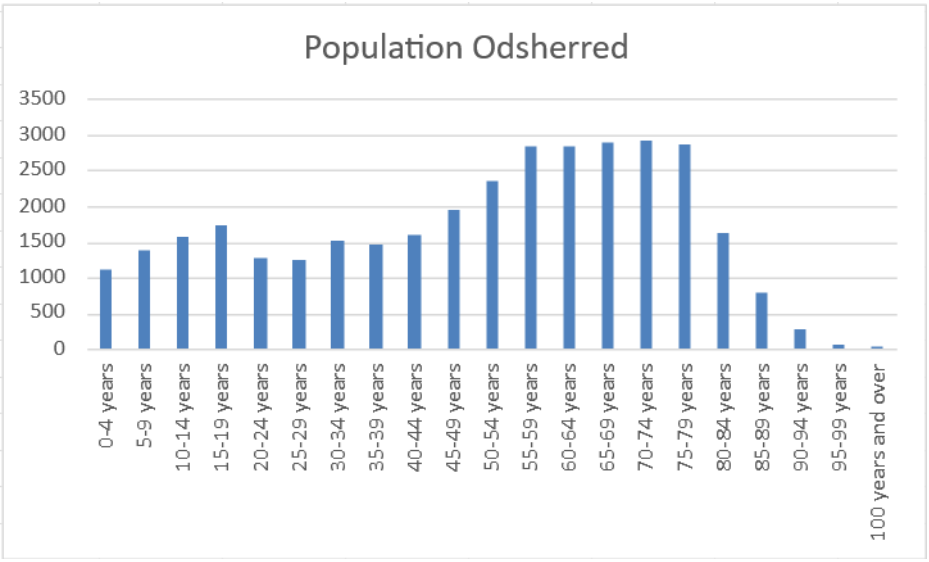
3.4 Research area: Odsherred

The research area for this project is the municipality Odsherred in the Danish region Zealand (Sjaelland). Odsherred has an area of 355.3 km² and a total population of 34 233 (January 2024). The region that is located on a peninsula is characterized by its unique landscape, formed during the Weichsel glaciation period (vejen til odsherred, n.d.). Today, the landscape mostly consists of hills, beaches, moorlands and cliffs with a few smaller villages and lots of summer houses build on (Wayback Machine, 2007). Odsherred can therefore be described as a rural, tourist region. The biggest urban areas in the region are Nykøbing, Asnæs and Hørve.

Figure 2 shows the population of Odsherred for age groups of 5 years. The figure shows that the biggest age group in the region is 55 to 79, it is thus a quit old population.

Figure 2

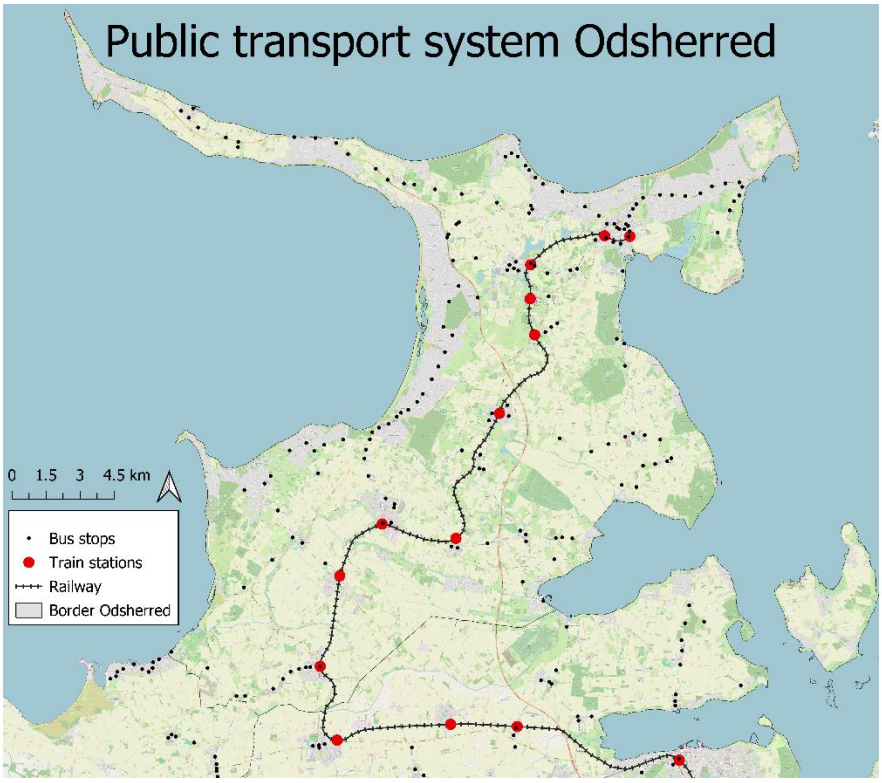
Population Odsherred 2024 (Statistikbanken, n.d.)



Odsherred is served by three types of public transport: train, bus and ferry. The 510R Odsherredsbanen train track runs through Odsherred with a total of 14 stops between Nykøbing Sjaelland and Holbæk (9 stops in Odsherred). A train passes every station twice an hour. From Holbæk, two trains an hour ride to Copenhagen, which is a 45 minute or 1 hour drive. In addition, twelve bus lines cross the Odsherred region with a total of 188 bus stops. There are two ferry terminals, one in the eastern most point of the peninsula (Sjællands Odde) which connects Odsherred with Åarhus, and one in the western most point of the peninsula (Rørvig) which connects Odsherred with Hundested (Odsherred Commune, n.d.). Figure 3 is a map of Odsherred with the train stops, train track and bus stops presented.

Figure 3

Public transport in Odsherred, Denmark (bus and train)



3.5 Perception

When researching people with physical disabilities and their surroundings, it is important to note that this is not one and the same group. People with physical disabilities are a diverse group, and to give a limited division, this research focused on people with visual impairments,

auditive impairments and people who are less mobile. The latter includes people who use a wheelchair or any other object to help them transport (both in time limited and not in time limited, for example, someone who broke their leg is also less mobile). People who can walk by themselves but are limited in how far and/ or how long they can walk also belong to this group. Thus, a very diverse group. This means that not every person with a physical disability has the same needs and/ or preferences when it comes to an adjusted surrounding. This is what Nybacka and Osvalder (2018) researched in Sweden.

For visual impairments, the most important source is spoken information. The issues concern that during traffic disturbances, there are too many announcements. The quality of the announcements in general is perceived as poor and background noise is too loud. The most used source for people with hearing impairments are visual information screens and mobile phones. Here the issues were that there are too few information screens available and mobile phone applications are updated too slowly (Nybacka and Osvalder, 2018).

For people who are less mobile, other concerns are important. The state of the footpaths and the urban environment surrounding a transport node (or train station/ bus stop) for example. People who are less mobile perceive poor pavements, protruding tree roots, uneven surfaces, cobbles and undulations as difficult. Next to that are hills, steep and dangerous curb or curb cuts, steep gradients, poor intersections and cross buttons that cannot be reached. Lack of tactiles is another variable that plays a role. Another umbrella of variables is the parking at terminals, which can be a frustration when this is not accessible enough. Other frustrations and poor perceived variables are lack of shelters, steep gradient ramps, lack of lifts, inadequate access to toilets and/ or inadequate numbers of toilets, gaps between the platform and the train and inadequate number of tag-off zones at train stations (Park & Chowdhury, 2018).

4. METHODOLOGY AND SOURCES

4.1 Before fieldwork

4.1.1 Literature study

In a first phase of this research, a literature study was conducted. The literature study was focused on three main parts: “inclusive public transport in general”, “inclusive public transport in Denmark” and “Odsherred”, our research area. The first part examined what exactly is inclusive public transport, why it is needed, how it can be implemented, which policies exist etc. The second part examined how the public transport system in Denmark works, what its current policy around inclusivity is and which improvements were made over the past few years. The last part examined the demographics of Odsherred where it was investigated how many people in the region need extra support for using public transport. In addition, Odsherred’s public transport system was also examined, where it was investigated, which different modes exist, which lines exist in the area and what the frequency of the lines is. A few studies that already examined the accessibility of a public transport system in other regions were reviewed. Based on these studies it was decided to distinguish three target groups of physical disabilities that will be used in this study: mobile disability, hearing disability and visibility disability.

4.1.2 Research area

A few things were extracted from this literature study. Firstly, the specific research area and study objects were demarcated. It was decided to leave the ferry lines out of the study as there were only 2 in the area which were quite far apart and there were only a few boats operating, so it would take too much time to investigate them. The 12 bus lines with all the bus stops were however all included in the study. The Holbæk-Nykøbing train line was also completely included, with all 15 stations. The study area therefore includes not only Odsherred, but also a part of the municipality Holbæk.

4.1.3 Facility checklist

Subsequently, a checklist was drawn up based on the literature with 21 points that should be present or may not be present in a train station to be accessible to people with a physical disability. This checklist can be found in the appendix. For each target group (mobility, hearing, visibility) all checkpoints were given a positive or negative score. This score represents how an item is, in a positive or negative sense, for the specific target group. The scores had a value between -3 (very important that it is not present) to +3 (very important that it is present). Score 0 means that for this target group, it does not matter whether it is present or not. These scores can also be found in the appendix.

4.1.4 Bus stops

Then the bus stops in the region were examined and given a score of 0 to 5 based on the state of the bus stop and the present facilities. For this, all bus stops were visited on Google Street View. From 0 to 5, the different scores mean only a pole in the grass, a pole on the sidewalk, a pole on a sloped sidewalk, pole and bus shelter on sidewalk, pole and bus shelter on sidewalk and bus terminal. This last one is an extensive location with multiple bus stops, bus shelters and sloped sidewalks.

4.2 During Fieldwork

After the desktop work, a fieldwork study was conducted. The fieldwork was carried out between the 12th and 16th of May 2024. During this week there was railway maintenance along the route. Therefore, a replacement bus ran between Nykøbing and Hørve stations, stopping at all intermediate stations.

4.2.1 Train station evaluations

The first part of the fieldwork included an evaluation of the different train stations with the facility checklist. All train stations in the study area were visited in one day. The 31 points of the checklist were reviewed, and it was checked whether or not each item was present in the

station. This was filled out on a paper version of the checklist. If an item was present, it was given a score of 1, otherwise it was given a score of 0.

4.2.2 Bus and train observations

Following this, a second part of the fieldwork included a bus and a train trip where an unstructured non-participatory observation was carried out (Scriptium, 2023). During these observations, attention was paid to adjustments that were made to make the transport mode more accessible. This included, among others, ramps, open space for wheelchair, indications in braille, spoken announcements. Firstly, the replacement bus from Nykøbing to Hørve was taken. There, a transfer was made to the train heading to Holbæk. In Holbæk the bus on line 560 was taken back to Nykøbing.

4.2.3 Interviews

The last part of the fieldwork included semi-structured interviews (Dingemanse, 2015; Merkus, 2021) that were carried out in different places in Odsherred, like retirement homes, rehabilitation centres, train stations, on the train and bus and in the city centre of Nykøbing. Mainly people with a visible physical disability, usually a mobile disability, were approached for this, but others without a (visible) physical disability were also interviewed. Three main questions were used for the interviews: “Do you use public transport?”, “Why do/don’t you use public transport?” and “What are good or bad points about public transport?”.

Additionally semi-structured interviews with train and bus drivers were conducted. The questions used for these interviews were: “How is your bus/train adapted for people with physical disabilities?”, “Do you think you bus/train is accessible for people with physical disabilities?”, “Which extra adaptations should be made to make your bus/train more accessible?” and “How many people with physical disabilities use your bus/train?”.

These interviews will serve as an addition of the perception of residents and visitors of Odsherred to the objective evaluation of public transport.

4.3 After fieldwork: data analysis

With the data collected through the desktop analysis and the fieldwork, facility-index maps for both the bus stops and train stations were created. For the bus stop facility-index map, all bus stops were presented on a map and given a colour based on their score (0 to 5). A darker colour represents a higher score, thus a more accessible bus stop.

To create the facility-index map of the train stations, an index was calculated for each of the stations. This index represents the sum of all scores (0 or 1) the train stations have got for all items on the facility checklist. The facility-indices were then normalized within a scale 0 - 100. A higher score means that there were more facilities present in the station. This index was then depicted on the map by means of colour: a darker colour represents a higher percentage of inclusiveness.

A general facilities map has been created showing six categories of facilities. Of the 31 facilities on the checklist, 29 were divided into six categories: other mobility, visual, wheelchair friendly, comfort, spoken information and general information. Because notifications and applications via mobile phones can be present or absent in a station, these two facilities are not included in the facilities map. If, per class, half of the facilities were available at a station, the corresponding icon was displayed on the map. If the icon of a class is displayed on the map, this shows that sufficient interventions have been taken to make the station inclusive. The other mobility category contains the following characteristics: accessible parking lot, kiss & ride zone, parking lot, bicycle shed and nearby public transport nodes. The visual category includes the presence of tactile. The wheelchair-friendly features are: the presence of sidewalks, the condition of the sidewalks, whether or not there are ramps, the presence of steep and dangerous curbs, the absence of steep ramps at terminals and stations, whether there is a gap between the platform and the train, whether there is a lift at the stations if necessary, the presence or absence of stairs and the presence of normal doors, sliding doors or revolving doors. The last category, general information, includes the visual information screens, information boards, information desks/hosts at the station and the possibility of assistance services. The spoken information category includes spoken information via

loudspeakers, talking machines and background noise. The comfort category includes the presence of shelters, access to toilets, number of toilets and waiting chairs.

5. OBSERVATIONS

In this part our personal observations, using both the train and the bus, are discussed. During these, features that could serve either as obstacles or as aids for people with disabilities or reduced mobility were monitored.

5.1 Bus

Two routes were studied. The replacement bus between Nykøbing Sj St. and Hørve departed from the station in Nykøbing Sj at 10:05. The replacement bus was operated by the company Ditobus. The bus had 3 entrances, with the middle one equipped with a manually extendable ramp. This entrance can be seen in Figure 3. The designated area for wheelchairs was located near this entrance. In that area, the seats were folded up to provide extra space not only for wheelchairs but also for strollers, bicycles, or large pieces of luggage. Additionally, several seats were reserved for the elderly or pregnant women, indicated by a sign symbolizing these groups seen in Figure 4. This thoughtful arrangement ensured that those who needed additional support or space had easy access to it. There was however a sign indicating that only two units (wheelchair, bike, stroller) are allowed in the open space.

Figure 3

Bus entrance with manually extendable ramp, open location for wheelchair users (Tom Verheyden, May 14th 2024)

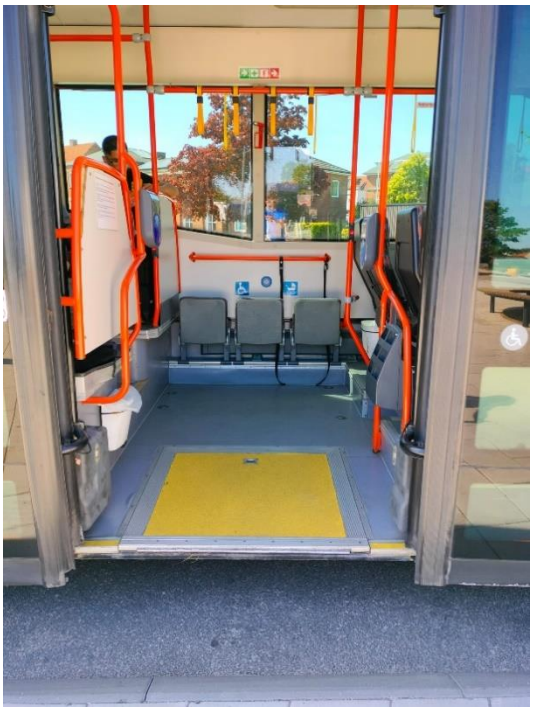


Figure 4

Sign indication reserved seats for people with mobile disability or pregnant women on the bus (Tom Verheyden, May 14th 2024)

For people with visual impairments, there were few provisions on the buses themselves. The speakers were present but not in use, which could have provided auditory information about upcoming stops. Inside the bus, there was no tactile paving system to guide visually impaired passengers to their seats or the exits. However, the bus always stopped with the door aligned to the area where tactile paving systems were present at larger bus stops. This was done intentionally, and the bus drivers made efforts to do this as precisely as possible. The aim was to ensure that blind individuals did not need to relocate to board immediately, minimizing any inconvenience and enhancing their independence while traveling. All buttons on the bus were also provided with morse writing.

Regarding provisions for people with hearing impairments, there was little available. However, it should be noted that there were no significant disadvantages either. The bus did not use an auditory announcement system, which might have been challenging for hearing-impaired passengers, but the absence of such a system also meant there was no critical information missed by these passengers. Additionally, there were screens on the bus that primarily displayed current events and could potentially be used to show route information, stops, and other relevant data. This visual information could be beneficial for passengers with hearing impairments, as it provided a way to stay informed during the journey.

The second bus route that was taken was from Holbæk station back to Nykøbing Sj station. This bus was also operated by the company Ditobus, and the interior of this bus looked the same as the previous one. The consistency in bus design and accessibility features is notable. From this, we can conclude that the buses used to replace the train during this period of maintenance are identical to regular buses in terms of accessibility for people with disabilities or reduced mobility. This uniformity is important as it ensures that passengers with specific needs can expect the same level of service and accessibility on all routes, reducing uncertainty and making public transportation a more reliable option for everyone.

5.2 Train

Various trains were boarded during the observation study, of which only one was actually in motion. This moving train provided a connection to the replacement bus, which terminated

its route in Hørve. From there, the journey was continued by train to the final station in Holbæk. It is worth noting that for wheelchair users, boarding the train can be quite challenging. To address this, there is a button by each door that passengers can press to call for additional assistance. Additionally, there is a special entrance designated for wheelchair users, conveniently located near the reserved wheelchair spaces.

Figure 5

Train entrance designated for wheelchair users, with button (Tom Verheyden, May 14th 2024)

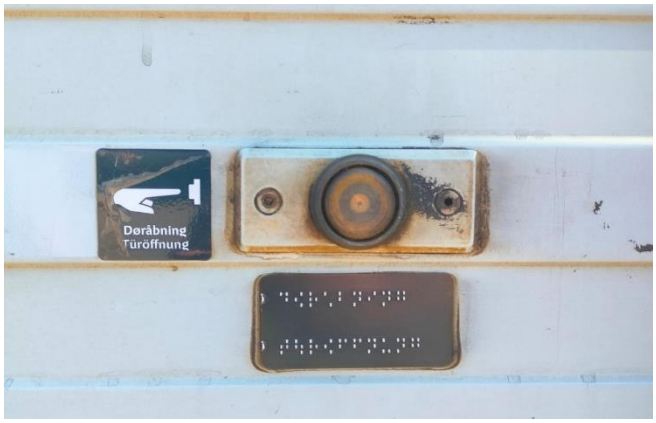
The amenities on this train were as follows: in one particular carriage, space was allocated for passengers traveling by bikes, in another carriage space was allocated for wheelchair users. This arrangement ensures that bicycles do not interfere with passengers with physical disabilities, a common issue on buses. Once again, there were designated spaces for wheelchair users. This allocated area also doubles as a parking spot for strollers. A button is installed next to these spaces, providing the option to request additional assistance onboard. Specific seats were also reserved for elderly passengers or people with less mobility. These seats, along with those for wheelchair users and passengers with strollers, were clearly marked with symbols on the wall.

Furthermore, there was a toilet located next to the wheelchair spaces. This toilet was specially adapted for wheelchair users. The entrance to the toilet was only slightly elevated, making it more accessible. The button for opening the door was positioned lower on the wall, within easy reach. Inside the toilet, ample space was provided, and grab bars were installed along the wall from the toilet to the sink to offer additional support and stability.

When examining the facilities specifically designed for people with visual impairments, we observed notable differences. Within the train, there were no tactile paving systems to guide visually impaired passengers. However, the next stop was consistently announced through a public address system, providing essential auditory information. The presence of steps when moving between carriages also presented an obstacle for visually impaired passengers. Most trains did not feature Braille inscriptions, making it challenging for visually impaired passengers to navigate. However, when we explored several other trains in Holbæk, we noticed a significant variation. Some trains were equipped with Braille subtitles on every possible sign, symbol, and text, greatly enhancing accessibility for visually impaired passengers.

Figure 6

Button to open train doors with extra morse writing (Tom Verheyden, May 14th 2024)



Provisions for the deaf community were also present. Each carriage was equipped with several screens, specifically one in each carriage, displaying upcoming stops. This visual information is crucial for passengers with hearing impairments. However, it was notable that both on the

train and at the platforms, several screens were experiencing mechanical issues. For example, the screen located behind the toilet was non-functional, displaying only a black screen and providing no readable information. This lack of functional screens could lead to confusion and inconvenience for all passengers, especially those with hearing impairments.

6. RESULTS

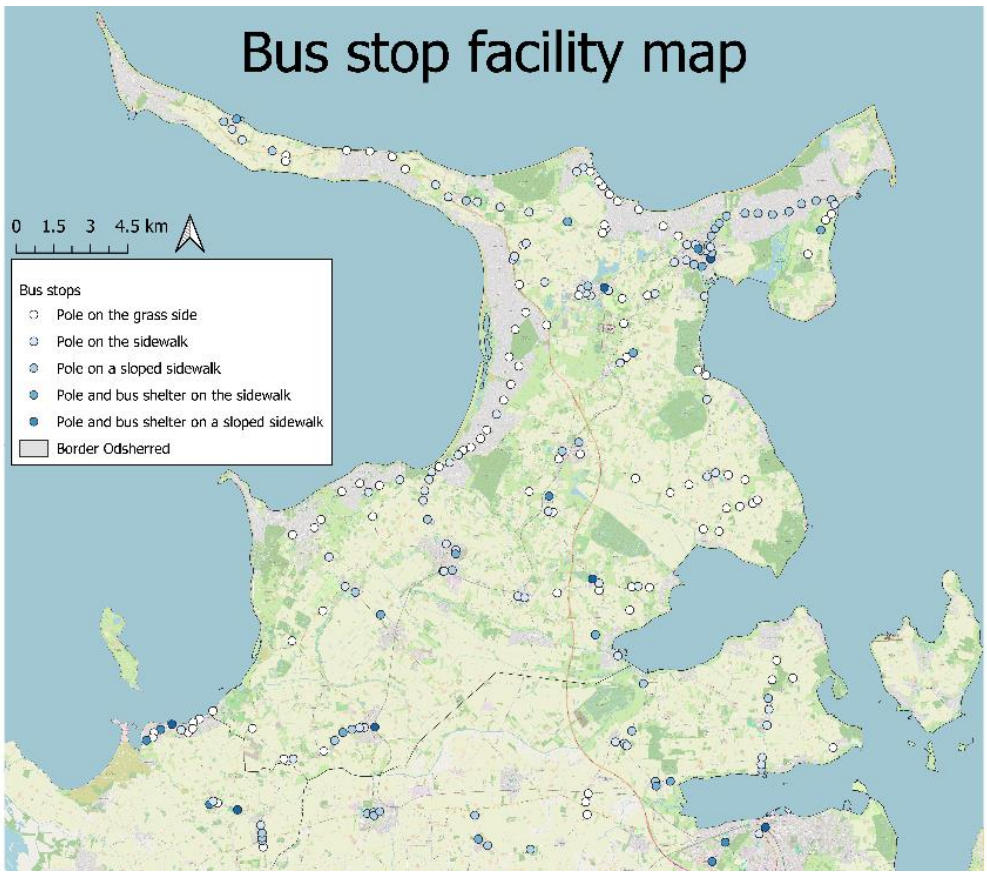
6.1 Facility maps

6.1.1 Bus stops

As mentioned in section 4.3, a bus stop facility map has been made (Figure 7). Five classes are distinguished depending on the existing infrastructure of the bus stops. 90 out of 188 observed bus stops consist of a pole with travel information on the grass side of the road. In these 90 cases, there are no facilities to support less mobile people when getting on and off the bus. The only aid is the ramp, present on the bus itself, but this may be too steep as there is no raised platform. There is also no aid for hearing-impaired travellers provided. A second class are bus stops consisting of a pole on a paved sidewalk. This class contains 61 out 188 observed bus stops. The sidewalk is not flattened, which means that a wheelchair user may not be able to easily get on and off the sidewalk. Here too, no auditory information or braille for the hearing- and visual-impaired people is provided. A third class consists of bus stops as in class 2, yet on a sloped sidewalk. This makes it easier for less mobile people to get on- and off the sidewalk to get to the bus stop or on-and of the bus. This class holds 16 bus stops. A fourth class are bus stops on a non-sloped sidewalk with a pole and shelter. This shelter provides protection against rain and a bench to rest on. Nine similar shelters were observed in Odsherred. The last class consists of a shelter on a sloped sidewalk. Twelve of these shelters were observed. It is noted that as bus stops become more inclusive, fewer instances are observed.

Figure 7

Bus stop facility map (Bas Ponnet, June 22nd 2024)



6.1.2 Train stations

Figure 8 shows the accessibility index for each train station. This map gives an overview of how inclusive a train station's infrastructure is according to a checklist made of 31 facilities. The train station with the highest percentage is the one in Svinnige with a percentage of 65%. Four train stations fail to achieve 50%. The stations in question are the ones from Grevinge, Ny Hagested, Nyled and Sommerland Sjaelland with 48%, 48%, 32% and 23% respectively. Sommerland is located in an amusement park, which is a possible explanation for the low score. There are no nearby car parks or bike parks, a lot of cobbled pathways and no infrastructure for audible impaired people or visible impaired people are provided. The other train stations achieve a score between 52% and 58%. However, this map does not indicate in which areas additional efforts can be made to achieve a higher index.

Figure 7

Train station index map (Bas Ponnet, June 22nd 2024)

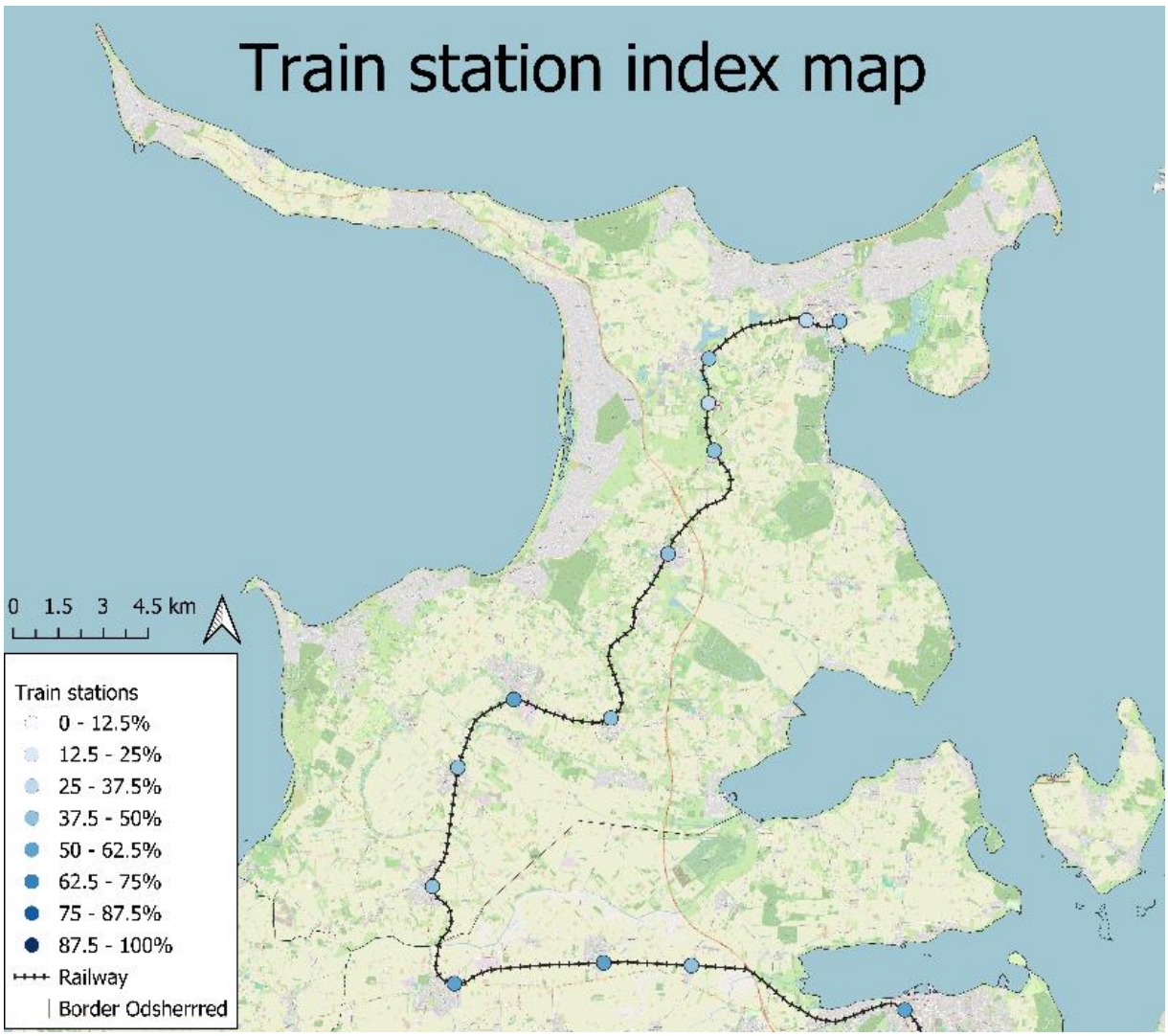
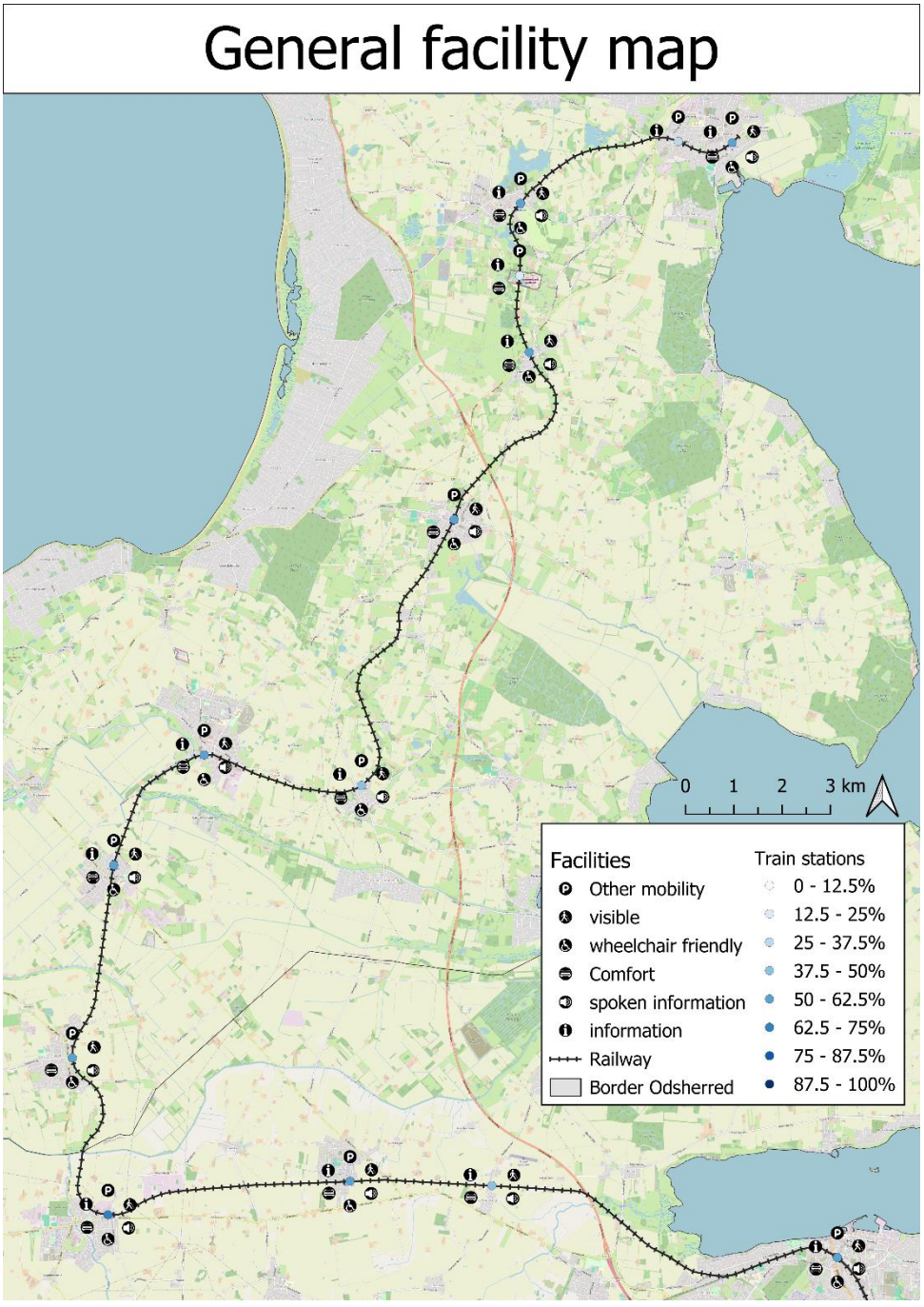


Figure 8 shows the facility map for the six classes of facilities for the less mobile people, the hearing impaired and the visually impaired. Train stations that are located in a village or city centre contain sufficient infrastructure for most of the six classes. An exception to the rule is the northernmost station, the one in Nyled. This station is located in a small village centre relatively close to a bigger city, Nykøbing. This could explain why fewer investments have been made in the train station in Nyled, since the majority of travellers get on the train in Nykøbing. Another train station that is not performing well in general is Sommerland. In this train station only investments in general information sources such as information screens and comfort such as the placement of benches and a lot of shelters have been made. Other forms of inclusive infrastructure such as tactiles, no gap between the train and platform and a pavement without

obstructions are not present. This means that only the classes other mobility, comfort and information are met.

Figure 8

General facility map (Bas Ponnet, June 23th 2024)



To provide an overview of the facilities for people with reduced mobility and people with visual and auditory impairments, three separate facility maps were created. Figure 9 shows the facilities that were considered important for hearing-impaired people according to the perception table (Table 2) in appendix. These are facilities that improve comfort, visually support people as well as a higher accessibility by other mobility options.

Figure 9

Facility map: visual aids (Bas Ponnet, June 23th 2024)

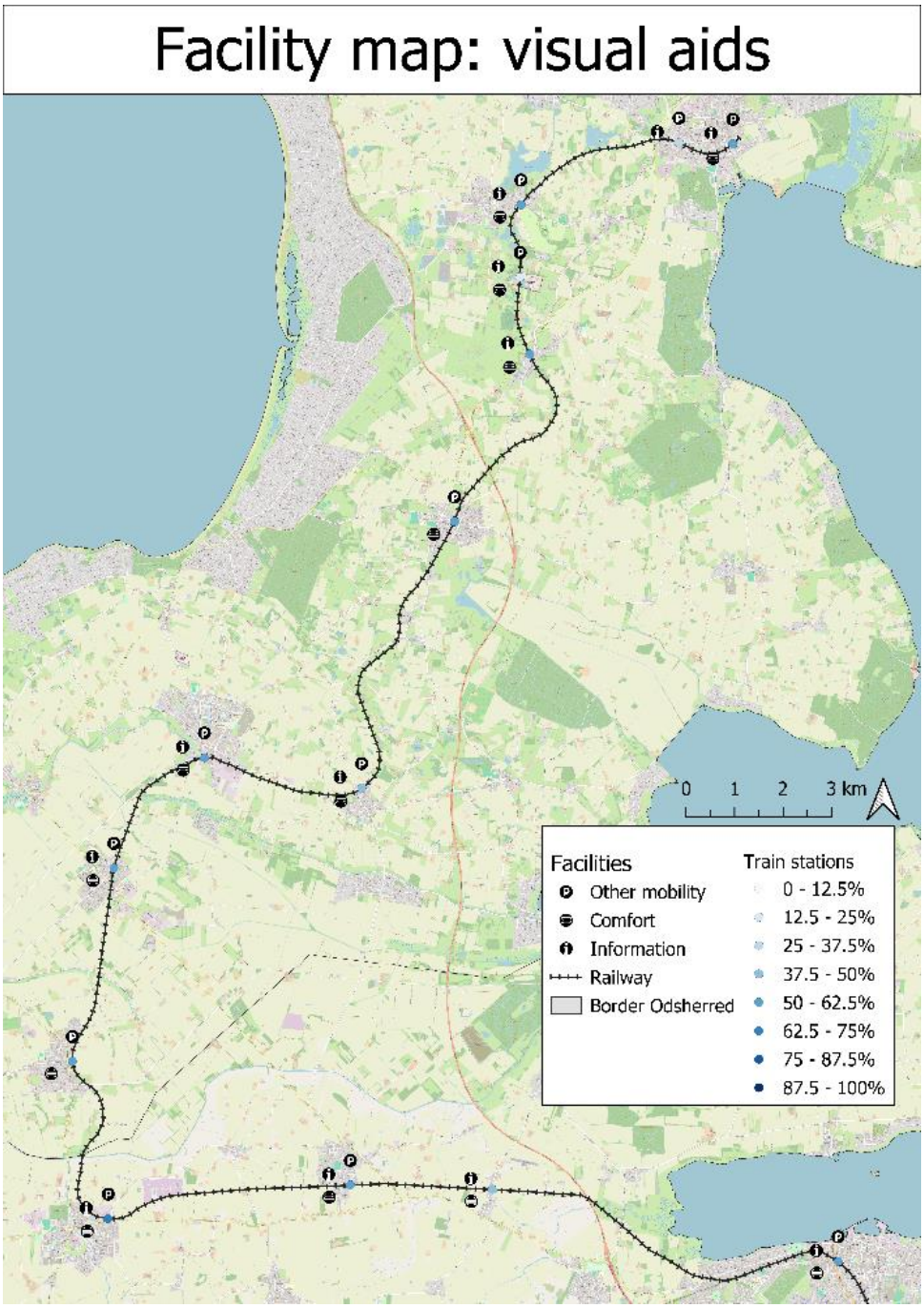


Figure 10 shows the facilities available that were considered important for people with reduced mobility according to the perception table (Table 2) in appendix. These are facilities that make the train station more comfortable, more wheelchair friendly, provide easier access to information and a higher accessibility by other mobility options.

Figure 10

Facility map: mobility (Bas Ponnet, June 23th 2024)

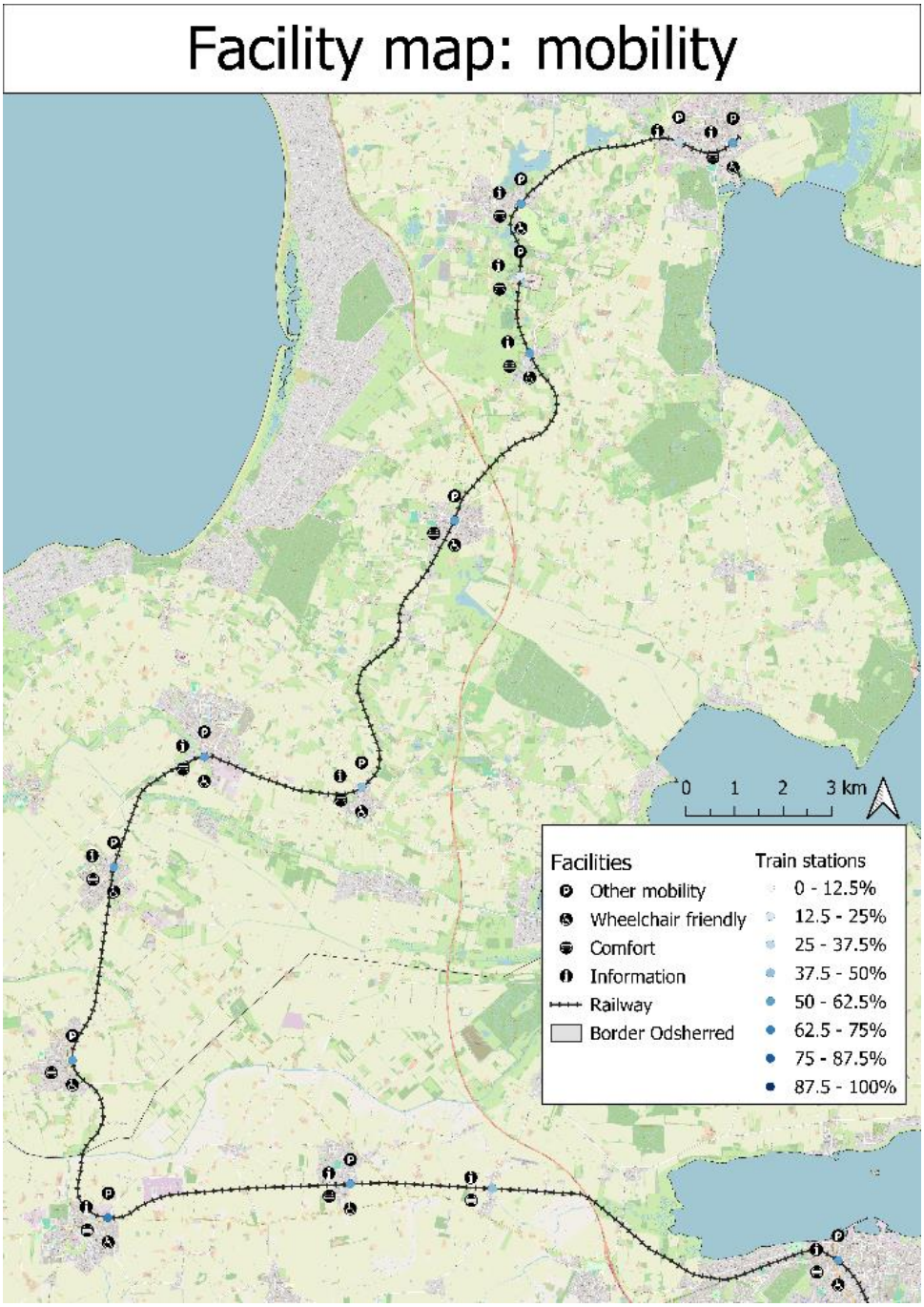
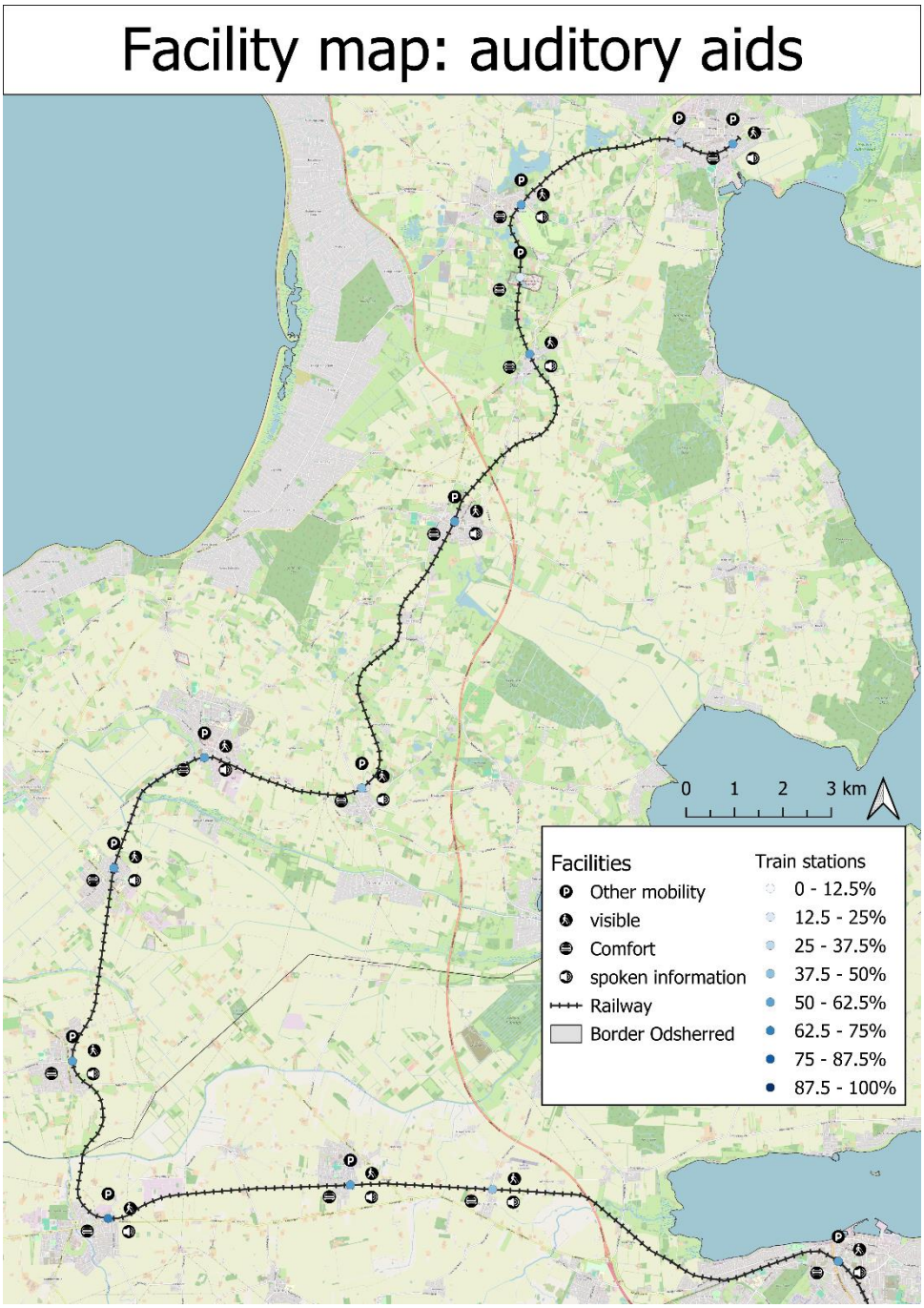


Figure 11 provides information about the present facilities that were considered important for visually impaired people according to the perception table (Table 2) in appendix. These facilities support the visually impaired people by providing spoken information via speakers as well as tactiles near the platform. Other facilities are slopes instead of stairs and a same height for the train step up and platform.

Figure 11

Facility map: auditory aids (Bas Ponnet, June 23th 2024)



6.2 Interviews

The interviewed people could be divided into three groups: people with a physical disability, people without a physical disability and train or bus drivers. In total, we managed to interview 42 respondents.

6.2.1 People with a physical disability

Twenty people with a physical disability were interviewed, thirteen women and seven men. Of this, fourteen persons were 70 years old or older. Five people belonged to the aged group 30-50 and one person to the age group 20-30. All these people had a physical disability ranging from wheelchair users to those simply less mobile. Most of these people used a car as their main mode of transportation, but also a few used Flextrafik. Only three persons mentioned they use public transport (train and bus) as their main way of traveling.

Positive points that these people mentioned about public transport are the good connections that the bus and train have in the region and to Holbæk from where you can get easily to Copenhagen. Another positive point that was mentioned is that it is pleasant that one can sit down and socialise in a bus or train. Negative points the interviewees mentioned were the big gaps between the platform and the vehicle, a shortage of seats to sit down and the timetable. Someone also mentioned that it is difficult to find the different routes and departure times. People who use Flextrafik say it is a very good and easy service, but people sometimes have to wait quite some time.

6.2.2 People without a physical disability

In total 26 persons without a physical disability were interviewed in Odsherred, of which sixteen women and ten men. Of these 26 persons, only one person mentioned that she takes the public transport (in combination with a bike) as her main mode of transport. All 25 other use the car more often. Reasons for this were that a car is easier and faster according to them and that it is easier to get your suitcases to a summer house with a car. In addition, it was

often mentioned that bus stops and train stations are too far from their homes and that there are too few rides.

6.2.3 Train and bus drivers

Lastly five bus drivers and two train drivers were interviewed. They mention that there have been made some adjustments to their vehicles to make them more accessible. The train drivers mention the button next to the train doors which calls them, so they can help wheelchair users get on and of the vehicle. The bus drivers mention the tactile pavements, the ramp and their mirror to keep an eye out to people needing help. However, they also mention some negative points. The biggest obstacle is that people with limited mobility have to rely on bystanders to help them open the ramp so they can safely board the bus. However, this is a very difficult task that requires know-how and strength. It is prohibited for the bus driver to leave their seat during the route, including when the bus is stationary. Most drivers are aware of this problem but feel powerless in the situation. When asked if they see many customers with limited mobility, the response was unanimous: very few. There was, however, disagreement about the exact number. Some mentioned a maximum of one per week, while others mentioned a maximum of one per month.

7. DISCUSSION

7.1 Accessibility in Odsherred public transport

In analysing the accessibility of public transportation in Odsherred, various crucial factors that influence the study's reliability were identified. One significant aspect is the demographic representation within the study. The research primarily targeted individuals with physical disabilities, including mobility, hearing, and visual impairments, but it might not have fully encompassed the diverse range of disabilities and needs present in the population. This could lead to a partial understanding of the challenges faced by different groups. Moreover, the decision to exclude ferry lines due to their limited number and geographic spread might also affect the comprehensiveness of the study. While the focus on bus lines and train stations was

thorough, this exclusion means that insights into the accessibility in general in the region are incomplete.

Furthermore, the methodology of using Google Street View for evaluating bus stops, has its limitations. It may not capture all real-time changes or current conditions, leading to potential inaccuracies in the assessment of accessibility. In addition, the interviews conducted with both passengers and transport staff provided valuable qualitative data, but the sample size and diversity of interviewees might not be sufficient to generalize findings across the entire population. Additionally, the focus on visible physical disabilities in interviews might have overlooked the experiences of those with less apparent or non-physical disabilities.

Lastly, the reliance on personal observations and subjective scoring systems for facilities introduces a degree of subjectivity that could influence the study's outcomes. Ensuring a more objective and standardized approach in future studies could enhance the reliability of the study.

7.2 Faced difficulties

We faced several challenges during this research. Our initial plan was to take the train with a person from our target group to observe and document their experiences firsthand. We reached out to all nursing homes in the region via email to find a participant who could join us for this fieldwork, aiming to identify and highlight the obstacles they encounter. Such a trip would have been highly educational for us as well. However, in the absence of a participant, we conducted the fieldwork ourselves, identifying as many potential obstacles and aids within different transport modes as possible. We meticulously documented everything we observed, resulting in extremely detailed descriptions of all compartments of the vehicles. But of course, crucial information is missed as a result, which could have provided additional insights.

Another significant issue we encountered was maintenance work on the train tracks. As a result, no trains ran between Nykøbing Sj and Hørve during our entire stay. This maintenance affected nearly the entire line that crosses Odsherred from north to south. Consequently, we had limited opportunities to travel by train, and most of the trips we managed to take were

outside the administrative boundaries of the municipality. This problem also complicated our efforts to find a participant, as the travel route was quite far from their residences, making it impractical for them to join us.

Additionally, we initially planned to use surveys in both Belgium and Denmark. Despite sending dozens of emails to various organizations, posting on social media, and leveraging personal contacts, the response rate in Belgium was disappointing, with only 37 responses. This low response rate made it challenging to process the answers quantitatively as we had intended. This was particularly frustrating given the significant time and effort we invested in creating the survey and distributing it.

In Denmark, reaching our target group was also challenging due to a language barrier. Many older individuals were not proficient in English, and our survey contained specialized jargon about limited mobility and other disabilities. Furthermore, we created posters to hang at the stations to increase awareness of our survey. However, since no trains were running, these posters were likely less visible to potential respondents, resulting in fewer survey completions.

Given these challenges and the limited time frame, we had to quickly adapt. We switched to semi-structured interviews to gather the necessary data. While this resolved the issues of low survey response and language barriers, it introduced new challenges: we had to rapidly prepare the interview questions, determine how to process the responses, and figure out how to compare these qualitative data with the survey data from Belgium. Despite these hurdles, the interviews provided valuable insights, helping us to understand the issues faced by our target group more deeply.

7.3 Comparison between Denmark and Belgium

If we compare the results of the interviews from Denmark with the survey results from Belgium, we can cautiously draw the following conclusions. It is important to note that the target audience in Denmark was mainly older people with limited mobility, whereas in Belgium, the focus was specifically on people with a physical disability.

- In Belgium, we see that 22 out of 24 people use public transportation since acquiring their disability. In Denmark, we noticed that the majority tried to avoid public transportation, with alternatives like Flextrafik being more popular.
- In both countries, the train is the most commonly used mode of public transportation. It is preferred over the bus, tram, metro, and ferry. In Belgium, it is even the only mode used daily by one person, with four respondents using the train weekly and only one respondent using the bus weekly.
- A similarity between the two countries is that bus drivers are not allowed to help with boarding and alighting. This was evident from interviews with five bus drivers in Denmark and was also mentioned by three respondents in the Belgian survey.
- From the interviews, it appeared that satisfaction was higher for trains than for buses in Denmark. This trend is also visible in Belgium: 20% (2 out of 10) of all the respondents rated bus accessibility as 'very poor'. No respondent selected this option for the train service. The average score for the train (2,92/5) was also higher than the bus (2,70/5).
- The biggest difficulty for both buses and trains in both Denmark and Belgium is getting on and off the vehicle. Eight out of fourteen people (57%) cited this as the main reason for the poor accessibility of trains. For buses, this was mentioned by four out of six respondents (66%).
- The service offered was relatively unknown in Denmark. Few people seemed to be aware of it but expressed a willingness to use it. In Belgium, this was clearly different: sixteen out of eighteen respondents were aware of the service. Twelve respondents rated the assistance: four respondents (33%) found it poor, three respondents (25%) found it neutral, four respondents (33%) found it good, and one person (9%) considered it very good.

7.4 Policy recommendations

7.4.1 Policy recommendations specifically for Denmark

It may be beneficial to launch awareness campaigns to ensure that the services are more widely known. To reach all different target groups, this can be done through three different

channels. Use social media to reach young people and adults regarding the available assistance services. In public spaces, such as stations, informative posters and/or information can be displayed on digital screens. To reach the older population, it may be helpful to collaborate with care institutions, such as hospitals, nursing homes, and rehabilitation centres. Organizing information sessions, for example, can subsequently spread through word of mouth within this target group.

7.4.2 Policy recommendations specifically for Belgium

Since we were able to gather some more specific data on the satisfaction with the assistance services in Belgium, we can immediately identify some strengths and weaknesses of the system. The biggest problem appears to be that this service is only available in the larger Belgian stations. When customers request assistance for a smaller station, they are told that this is not possible. Expanding this system could improve user experiences on the one hand, and on the other hand, it could increase the target audience that would consider using public transportation.

7.4.3 General policy recommendations

In both countries, there was a clear problem with the accessibility of vehicles, resulting in difficulties with boarding and alighting from, for example, buses. Additionally, in both countries, the bus driver is not allowed to provide assistance and is required to remain seated. A policy solution could be to focus more on support for boarding and alighting. Ensure automatic and/or personnel assistance for boarding and alighting from both buses and trains. This can include foldable ramps, lifts, as well as automation of current systems. Additionally, trained personnel can offer extra help and services. Moreover, it seems relevant to us to change the regulations regarding the prohibition of assistance from the driver. Implementing a program to train drivers in providing assistance when boarding the vehicle can be a quick, inexpensive, and accessible solution to the current problem.

8. CONCLUSION

After thorough research into the accessibility of public transport for people with physical disabilities in Odsherred, clear challenges and promising initiatives have emerged. The study revealed significant obstacles such as large gaps between platforms and vehicles, limited 'seating', and other issues with accessibility. Concurrently, transportation companies have taken steps to enhance accessibility, including installing tactile markings at bus stops, providing ramps and dedicated wheelchair spaces on buses, and implementing both auditory and visual information systems on trains and buses. Recommendations for future improvements to make public transport in Odsherred more inclusive have been proposed. These include infrastructure enhancements to reduce platform gaps and increase seating capacity, improving information provision through clear signage and digital displays, and training staff to effectively assist passengers with disabilities. Revising policies to integrate universal design principles across all aspects of public transport is also encouraged. By embracing these recommendations, Odsherred can move towards a public transport network that meets the diverse needs of all its residents and visitors. This approach not only promotes accessibility but also enhances inclusivity and equality within the transport system, thereby improving overall mobility and independence for people with physical disabilities.

9. REFERENCES

Beecroft, M., Nelson, J. & Mounce, R.. (2019). *Insight Paper - DENMARK.* https://ruralsharedmobility.eu/wp-content/uploads/2019/08/SMARTA-IP-Denmark-2.pdf

Denmark | *European Blind Union.* (n.d.). https://www.euroblind.org/convention/article-9/denmark

Dingemanse, K. (2021, November 12). *Soorten interviews: voor- en nadelen*. Scribbr. https://www.scribbr.nl/onderzoeksmethoden/soorten-interviews/

Handelsbetingelser. (n.d.). Mysupport Trafik. https://movia.flextrafik.dk/handelsbetingelser/

Husson, JF., Mahieu, C., Sägesser, C. (2017). Federalism and Decentralisation in Belgium. In: Ruano, J., Profiroiu, M. (eds) The Palgrave Handbook of Decentralisation in Europe. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-32437-1_3

Konczal, E. F. (2020, February 20). *Physical disabilities.* Rutgers University:: Department of Kinesiology and Health. https://kines.rutgers.edu/dshw/disabilities/physical/1060-physical-disabilities

Maynard, A. (2009). Can measuring the benefits of accessible transport enable a seamless journey? https://www.jstor.org/stable/26201629

Manuela, P. R., De Mello Germana, S., & Morato, S. (2021). Tactile paving surfaces at bus stops: The need of homogeneous technical solutions for accessible tourism. *upcommons.upc.edu*. https://doi.org/10.17411/jacces.v11i2.313

Nybacka, M., & Osvalder, A. (2018). Inclusive Design strategies to enhance inclusivity for all in public transportation - a case study on a railway station. In *Advances in intelligent*

systems and computing (pp. 1689–1698). https://doi.org/10.1007/978-3-319-96071-5_173

Offentlig transport - Odsherred Kommune. (n.d.). Odsherred Kommune. https://www.odsherred.dk/da/bo-og-leve/trafik-i-hverdagen/trafik/offentlig-transport/

Over Hendriks NV. (n.d.). Hendriks. https://www.hendriks.be/klantportal-organisatie-prs/hnv-over-hendriks-nv

Park, J., & Chowdhury, S. (2018). Investigating the barriers in a typical journey by public transport users with disabilities. *Journal of Transport & Health, 10*, 361–368. https://doi.org/10.1016/j.jth.2018.05.008

Personer med handicap. (n.d.). *Din Offentlige Transport.* https://dinoffentligetransport.dk/saadan-rejser-du/personer-med-handicap

Rejseplanen. (n.d.). https://rejseplanen.dk/webapp/#!P|TP!histId|0!histKey|H578627

Scriptium, M. (2023, December 22). *Observationeel onderzoek en observatietechnieken*. Scriptium.nl. https://www.scriptium.nl/observationeel-onderzoek-en-observatietechnieken/

Statistics Denmark. (2023). *Access to public transport.* https://www.dst.dk/en/Statistik/temaer/SDG/globale-verdensmaal/11-baeredygtige-byer-og-lokalsamfund/delmaal-02/indikator-1

The Importance of Public Transport Accessibility and Social Inclusion | UITP. (n.d.). UITP. https://www.uitp.org/news/the-importance-of-public-transport-accessibility-and-social-inclusion/

10. APPENDIX

Table 1: Checklist for accessibility train stations.

Item	Present?
Footpaths (obstructions, undulating, lack of)	
Hills	
Steep gradient ramps at terminals/ stations	
Gap between platform and train	
Platform is same height as train step up	
Stairs	
Information desk/ hosts at station	
State of pavements + obstructions	
Lack of lifts at stations	
Steep and dangerous curbs	
Assistance service	
Applications via mobile phone	
Lack of shelters	
Tactiles	
Accessible car park	
Inadequate access to toilets at stations	
Inadequate number of toilets at stations	
Sliding doors	
Waiting chairs	
Car park	
Spoken information	
Notifications via mobile phone	
Speaking machines	
Advertiser machines	
Visual information screens / tv screens (small print)	
Background noise	
Kiss and ride / tag off zone	
Normal doors	
Revolving doors	
Information bords	
Other public transport node close by	
Bike park	

Table 2: Perception table.

X	Visual	Auditive	Less mobile
Footpaths (obstructions, undulating, lack of)	+	-	+++
Hills	+-	-	+++
Steep gradient ramps at terminals/ stations	+-	-	+++
Gap between platform and train	+	-	+++
Platform is same height as train step up	++	-	+++
Stairs	+++	-	+++
Information desk/ hosts at station	++	+-	++
State of pavements + obstructions	+	-	++
Lack of lifts at stations	-	-	++
Steep and dangerous curbs	+	-	+
Assistance service	++	+-	+
Applications via mobile phone	+	++	+-
Lack of shelters	+-	-	+-
Tactiles	+	-	+-
Accessible car park	+-	+-	+-
Inadequate access to toilets at stations	-	+-	+-
Inadequate number of toilets at stations	-	+-	+-
Sliding doors	-	-	+-
Waiting chairs	+	+-	+-
Car park	-	+-	+-
Spoken information	+++	-	-
Notifications via mobile phone	+-	++	-
Speaking machines	--	--	-
Advertiser machines	--	--	-
Visual information screens / tv screens (small print)	---	+++	-
Background noise			-
Kiss and ride / tag off zone	++	+-	-
Normal doors	+-	-	-
Revolving doors	+-	-	-
Information bords	+++	+++	-
Other public transport node close by	+-	+-	-
Bike park	-	+-	---

FACULTEIT WETENSCHAPPEN

DIGGING OUT THE SPATIAL DISTRIBUTION AND CHARACTERISTICS OF BURIAL MOUNDS IN ODSHERRED

Names: Wannes Vandenhaute, Dries Keppens, Nikolas Dobbelaere, Floris Vanden Broucke

Student numbers: 02011793, 02010747, 02011342, 02009722,

Responsible teacher: Prof. dr. Veerle Van Eetvelde

Oriënted international projectwork

Academiejaar: 2023 – 2024

UNIVERSITEIT GENT

Introduction

This study of burial mounds offers a unique window into the past, providing insights into the social, cultural, and environmental aspects of ancient societies, especially during the Bronze and Stone Ages. Odsherred, a town in Denmark known for its rich archaeological heritage, is dotted with these intriguing prehistoric structures. They form an important aspect of their cultural landscape. In the early 20th century, Danish legislation paid less attention to the preservation of these landmarks. It was not until 1987 that the Museum Act entered into force in Denmark, incorporating the protection of cultural assets into the legislation. Other Nordic countries did this much earlier, such as Sweden in 1927. With the Museum Act, the Danish government has become more aware of the cultural significance of burial mounds (Kulturværdierdiudvalget, n.d.) This study seeks to explore the spatial distribution of burial mounds in Odsherred, guided by three pivotal research questions: What factors determine the spatial distribution of burial mounds? What are the characteristics of burial mounds in Odsherred? What holds the future for the burial mounds?

Understanding the factors that influence the spatial distribution of burial mounds is crucial for interpreting the socio-cultural and environmental dynamics of the communities that constructed them. We focused on the work of Jeroen the Reu: 'Land of the Dead', who identified important factors that determine the spatial distribution of burial mounds in Flanders. We applied these same factors in our study.

The second research question focuses on the specific characteristics of burial mounds in Odsherred. This involves a detailed examination of their physical attributes and any variations in style or structure. We created clusters based on similar characteristics and proximity to each other, performing a so-called cold and hotspot analysis. This method allowed us to identify several clusters of burial mounds that shared similarities.

Lastly, the investigation will address the future of these ancient monuments. This involves assessing the current state of preservation, the measures in place for their protection and conservation, and what could be improved. Understanding these factors is vital for developing strategies to ensure that these valuable cultural heritage sites are preserved for future generations.

1. THEORETHICAL FRAMEWORK

1.1 Historical situation

Denmark's history regarding burial mounds can be divided into three main periods: the Stone Age, Bronze Age and Iron Age, spanning a period of about 15,000 years. Although no written records have survived from the Stone Age, archaeological excavations and finds give us insight into how and when humans slowly developed in Denmark (Danske Fortidsminder, n.d.).

Around 4000 BC, a transition to agriculture and animal husbandry began in Denmark. This is the period when burial mounds and dolmens were built, not only as individual burial places, but also as symbols of communal ideologies and territorial boundaries of groups. The idea of visible burials most likely arose as part of this changing lifestyle. The construction of these monuments became more sophisticated with time and testifies to a remarkable building ability in the Neolithic period. The emergence of settled communities resulted in the construction of permanent and larger houses instead of the traditional, easily movable huts of the Mesolithic (Danske Fortidsminder, n.d.). During the Bronze Age, which extended from 1700 to 500 BC, Denmark experienced a boom in agriculture and animal husbandry, resulting in open landscapes due to deforestation for agricultural purposes and prominent burial mounds. These mounds testify to a communal effort and unity in society, and also symbolise a deep religious commitment to the landscape. Each individual grave or group of graves became a sacred place where people regularly returned to honour their dead and feel connected to their ancestors and community. The deceased were often buried in oak coffins, with carefully chosen grave goods to accompany them to the afterlife (Danske Fortidsminder, n.d.).

In the Stone Age, burial mounds were formed by stone structures that were hollow on the inside, allowing them to be entered. The burial mound was the place to lay the deceased in along with some possessions. The stones were covered with packs of earth and a top layer of grass. An opening at the side kept the burial mounds accessible to all. Burial culture underwent several developments during the Bronze Age, with a shift towards cremation as a common practice. Archaeological excavations and finds have documented these changes. In the Bronze Age, large stones were no longer used; instead, the deceased were cremated and buried in urns in a massive burial mound made of earth, preventing access to the interior (Danske Fortidsminder, n.d.).

Besides honouring the deceased, these early cemeteries also represented a shared ideology. The burial mounds also had an important navigational component as physical markers of a territory. They were placed in highly visible places such as on the crest of a hill or along roads with a lot of passage, allowing passing groups to orient themselves in the landscape and using them as beacons. They testify to a common European network of trade and exchange in which the burial mounds fulfilled their function by guiding traders through the landscape (Danske Fortidsminder, n.d.). Although thousands of burial mound groups once graced the landscape, many have disappeared over time due to intensive agriculture and modern developments. Nevertheless, they remain impressive monuments of the past to this day. They bear witness to the rich and complex cultural and religious heritage of the Danish people and are deeply rooted in the identity of the Danish people (Danske Fortidsminder, n.d.).

1.2 Legislation and protection of burial mounds

The legislation regarding the protection and preservation of burial mounds in Denmark falls under the Museum Act (No. 1505), that entered into force in 1987. This act, along with other regulatory measures, contains specific guidelines for the protection and preservation of ancient burial monuments and archaeological sites, including burial mounds. The primary goal of the Danish legislation is to ensure the preservation of burial mounds as significant archaeological and historical sites. These mounds are legally protected, and activities that might damage or disturb them are strictly regulated. The act prohibits excavation, construction, or any form of alteration without prior authorization from the relevant authorities. This ensures that any interventions are conducted with great care and respect for the historical integrity of these sites (Kulturstyrelsen, n.d.).

Burial mounds are generally considered public property and are managed by state or local museums. Under the Museum Act, these institutions are tasked with the stewardship of burial mounds, which includes their documentation, preservation, and, where appropriate, public accessibility. Museums are responsible for conducting necessary archaeological research to uncover and preserve artifacts and knowledge associated with these sites (National Museum of Denmark, n.d.). Archaeological research is a significant component of the Danish legislation, encouraging and regulating excavations to contribute to the broader understanding of Denmark's history and prehistory. Excavations require proper authorization and must be conducted by qualified professionals, with findings documented comprehensively and reported to the appropriate authorities. This ensures that data gathered contributes to the

national heritage record and is accessible for future research and educational purposes (National Museum of Denmark, n.d.).

The Danish Museum Act also emphasizes public engagement and education, encouraging museums and cultural institutions to facilitate public access to burial mounds and related exhibits. This promotes awareness and appreciation of Denmark's archaeological heritage through educational programs, guided tours, and informational materials (Kulturstyrelsen, n.d.). Additionally, the legislation incorporates stringent legal and ethical guidelines to ensure the respectful treatment of burial mounds, including regulations against the illicit trade of artifacts, unauthorized excavations, and vandalism. It aligns with international conventions on heritage preservation, reflecting Denmark's commitment to global standards in cultural heritage management (UNESCO, 1972).

Despite the robust framework provided by the Danish legislation, challenges remain, such as ensuring adequate funding for museums, balancing public access with site preservation, and addressing environmental impacts on burial mounds. The legislation continues to evolve, adapting to new archaeological findings, technological advancements, and changing societal values regarding heritage preservation.

The Danish legislation regarding burial mounds, particularly through the Museum Act, serves as a vital instrument in preserving these significant historical sites. By establishing clear guidelines for their protection, management, and research, the legislation ensures that burial mounds are preserved and respected. Through this comprehensive approach, it not only safeguards Denmark's cultural heritage but also promotes public awareness and appreciation of the rich archaeological history embedded within these mounds. This legislation plays a crucial role in maintaining the continuity of Denmark's historical narrative and its transmission to future generations.

1.3 Location of burial mounds

In the context of studying the relationship between archaeological sites and their surrounding landscape, topographic position and local topography are often considered crucial parameters determining the location of specific site types (such as settlements, ritual and burial sites, military or defensive structures, etc.) within the landscape (De Reu, 2012).

Research by Fisher et al. (1997) and Lageras (2002) revealed that Bronze Age monuments were deliberately placed with a view of the sea on the Scottish island of Mull and in Scania, Sweden (De Reu, 2012). Other studies highlight the mutual visibility between burial mounds, suggesting that traders and travelers could use these mounds as beacons to navigate through the landscape by moving from one beacon to the next (Wheatley, 1995; Woodman, 2000). Woodman (2000) links locations with better visibility to prominent spots in the landscape by using the concept of viewshed completeness. Other commonly used analysis parameters related to topography include slope, aspect, and curvature (Bevan et al., 2003; Kvamme, 1992). Moreover, it has been demonstrated that distinct and evolving topographic patterns of sites over time are evident, underscoring the importance of local topography in archaeological landscape research (De Reu, 2012).

2. METHODOLOGY

Given the abundance of burial mounds in Denmark, we aim to gain a clearer understanding and create subdivisions specifically for Odsherred. The literature review on burial mounds in Flanders by Jeroen De Reu inspired us to conduct a spatial analysis in GIS based on five factors: viewshed, distance to the sea, absolute height, relative height, and slope. This resulted in a map highlighting hot/cold spots and non-significant areas of burial mounds with similar attributes. Telling us something more about the spatial distribution of the burial mounds.

Next, we visited and assessed several burial mounds within each cluster using an evaluation form with descriptive characteristics. These characteristics were analyzed and compared to identify new typologies for each cluster. Using these techniques, we aim to summarize the thousands of burial mounds in Odsherred into a few distinct clusters.

The insights gained from this study will help define various types of burial mounds for the Odsherred municipality and provide recommendations for their future management and maintenance.

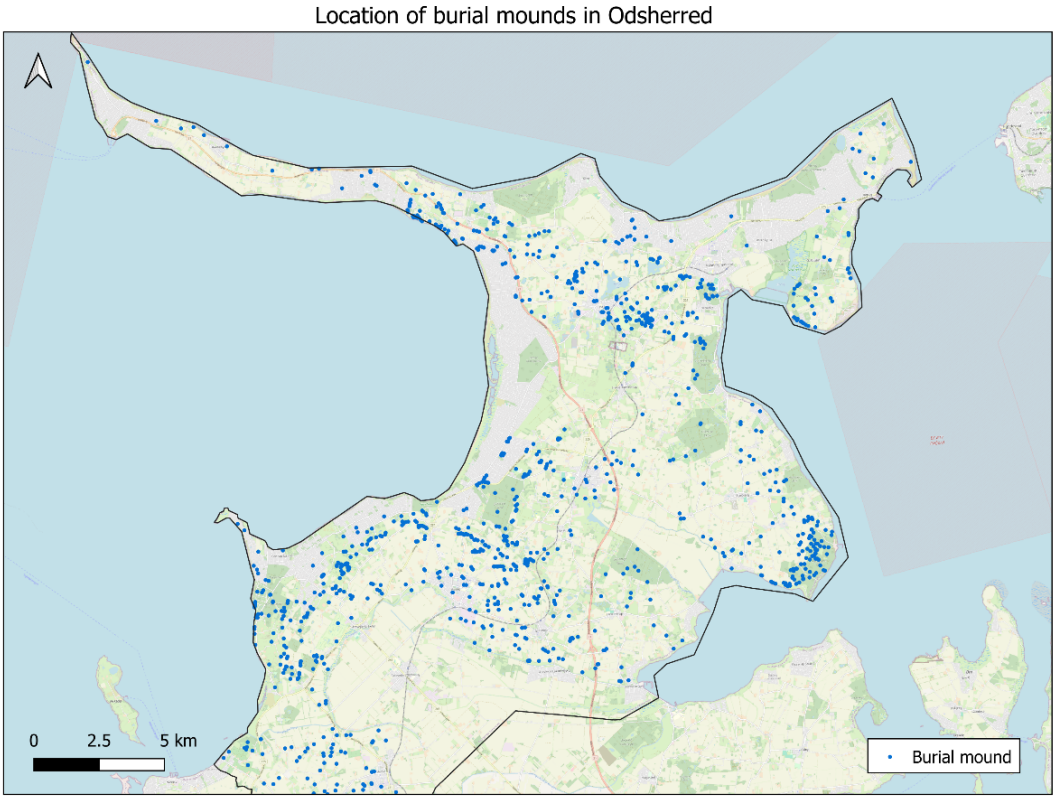
2.1 Study area

The study area is the municipality of Odsherred. To better explain the location of burial mounds in Odsherred, a brief description of the physical environment is provided. The topography of Odsherred is highly varied, with areas ranging

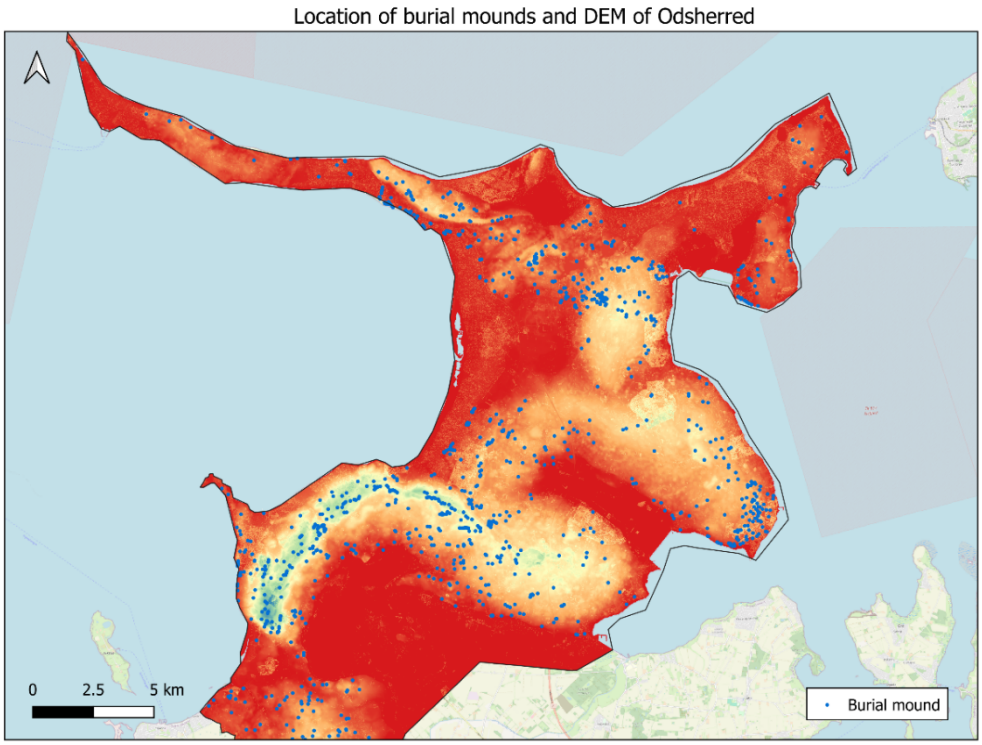
from 5 meters below sea level to peaks reaching 111 meters. The characteristic landscape is defined by the Odsherredbuerne, a series of three arc-shaped ridges formed during the last part of the last Ice Age.

In the southern part of Odsherred lies the Vejrhøj Ridge, with notable peaks such as the 88-meter-high Esterhøj near Høve and Vejrhøj, which at 120 meters is the highest point in the municipality, located north of Dragsholm. Further northeast are the more modest hills of Hønsingebuen and Højbybuen. North of Stenstrup Lyng, another part of the hilly landscape rises between Lumsås and Ebbeløkke. This distinctive hill stretches for 7 kilometers, forming the base of Sjællands Odde, ending in Gniben, a prominent peninsula jutting out towards the sea (Kruger, 2021). Many burial mounds are found along these ridges.

Map 1 presents a map of the study area, the municipality of Odsherred, highlighting all the burial mounds in the region (Kulturarvstyrelsen, n.d.). Additionally, map 2 overlays these burial mounds on an elevation map of the study area, clearly illustrating that most of the burial mounds are located in the more elevated, mountainous regions.



Map 1: The location of the burial mounds in Odsherred. (Source: Kulturministeriet, n.d.)



Map 2: The location of the burial mounds overlayed on a digital elevation model. (Source: Kulturministeriet, n.d.)

2.2 Creating clusters

To provide a concrete answer to the question of what characteristics burial mounds in Odsherred have, a preliminary data analysis is conducted to facilitate targeted fieldwork. Literature studies have shown that the location and distribution of burial mounds are not random but depend on certain factors such as local topography. Since it is not possible to visit all 1000 burial mounds, the data analysis aims to create clusters of burial mounds that are not only spatially close to each other but also share similar characteristics. This way, each of these clusters can be visited in the field. A hotspot/coldspot analysis is performed to determine the degree of local clustering. By investigating the influence of physical factors on the distribution of burial mounds using GIS, a strong empirical and quantitative approach to the data is achieved.

Hot and cold spots are zones where all burial mounds have respectively high or low values for a particular attribute, such as height, and are also in close proximity to each other. The burial mounds in these groups should therefore be approximately similar for that specific attribute. These findings are supported by the first law of geography, which

states that near things are more related than distant things. This means that locations with similar characteristics, such as nearby elevations or the distance to the sea, tend to exhibit similar patterns of burial mounds.

The hotspot analysis is conducted using the Getis-Ord Index (GI*), which measures the degree of local clustering of high and low values of a feature. The advantage of this method is that it not only examines the spatial distribution of burial mounds, as in location-based spatial autocorrelation, but also considers how high and low attribute values spatially cluster (Environmental Systems Research Institute, n.d.). For a feature to be a statistically significant hotspot, it must have a high value and be surrounded by other burial mounds with similarly high values. For the calculation of cold and hotspots, the starting point was the dataset with burial mounds. This dataset was gradually enriched with the attributes distance to the sea, absolute and relative height, slope, and visibility. The absolute height and slope were obtained using the DEM. The relative height represents the height of each burial mound relative to its surroundings. In this research, the surroundings of a burial mound are defined by a 35-meter buffer around the mound, as this is the radius of the largest burial mound in Odsherred, Maglehøj (Maglehøj (Odsherred), 2022). The relative height is then calculated using the following formula:

$$relative\ height = \ absolute\ height - minimum\ height\ in\ buffer\ 35\ m$$

The visibility is quantitatively determined through a viewshed analysis. This viewshed represents the area that an observer can see from a specific location. For this purpose, first we have to create our viewpoints using the 'Create viewpoints' module in QGIS. This function requires the layer with burial mounds and the DEM as input layers. When calculating the viewshed, land use is not taken into account, which in reality could be a limiting factor for visibility. The observer height, which indicates the height of the observer above the ground and thus affects the line of sight, is set to 1,6 m. The maximum view radius is set to 5000 m. Next, the visibility is calculated using the 'Viewshed' function. The result of this function produces a raster layer with the attribute 'Sample1', which gives an indication of the viewshed for each pixel. The higher the value, the higher the viewshed and thus the visibility. The various functions used to enrich the dataset are shown in the cartographic model in the Appendix (image 15).

After enriching the dataset with quantitative data, a hotspot analysis is performed in ArcGIS Pro to determine hotspots by calculating the GI*. This analysis is conducted for each parameter, so five times in total. For each attribute, it is

indicated whether a burial mound, based on the GI*, is considered a hotspot, coldspot, or not statistically significant, with confidence levels of 99%, 95%, and 90%.

For the fieldwork, we focus on two specific types of areas. On one hand, we are interested in areas that exhibit hotspots or coldspots, indicated by a high GI* value that is statistically significant (at least 90% confidence). These are the burial mounds that closely resemble each other and are spatially clustered. On the other hand, we are interested in areas where burial mounds differ significantly in appearance and have many different characteristics. These are the areas where the GI* is not statistically significant.

2.3 Field work

The fieldwork consisted of visiting the five identified clusters to analyze and determine the characteristics of the burial mounds. Our goal was to visit all the burial mounds within these clusters to gain a comprehensive understanding of the types of burial mounds and their surrounding environment, which were also analyzed in detail. We approached the clusters and burial mounds primarily by car, then continued on foot or used a drone to get as close as possible. Extensive photographs were taken with a cell phone camera and drones were used to capture aerial images, especially at burial mounds that were not directly accessible or when an overview of the landscape was needed.

Over the course of three days, we visited and analyzed the burial mounds: Cluster 1 was visited on the first day, Cluster 2 and 4 on the second day, and Cluster 3 and 5 on the third day. Upon arrival at each site, we filled out a checklist that was prepared and printed in advance (Table 1). The checklist contained key elements that characterize burial mounds. Each element was described and scored on a scale from 0 to 6, with 0 representing the lowest grade and 6 the highest. Here, the focus is on the physical condition, maintenance of the burial mound and its surroundings, as well as factors related to tourism (e.g., accessibility). Additionally, the five factors used in the hotspot analysis (visibility, relative/absolute height, slope, and distance to the sea) are also included, making it possible to verify the results of the data analyses on terrain. The different elements used are shown in Table 1.

Cluster: Burial mound:	Score 1-6 (Low-high)
Accessibility (public access, paths)	
Context (surrounding land use)	/
Degree of tourism (information boards, signage)	
Type of tomb (open or closed)	/
Size (small, medium, large)	/
Shape (round, elongated, flat)	/
Degree of maintenance	
Condition of the mound (overgrowth, erosion)	
Presence of megalithic stones	/
Visibility from the road	
Visibility from the burial mound	/
Relative height	/
Absolute height	/
Slope	/
Distance to the sea	/

Table 1: Burial mound checklist

Several linkages between the elements in the checklist can be observed. For example, mounds that have undergone minimal erosion often have a more rounded or spherical shape, indicating a better state of preservation. These less eroded mounds tend to have steeper sides and are generally higher, making them more noticeable in the landscape. This is in contrast to heavily eroded burial mounds, which tend to be flatter and less conspicuous. Moreover, closed burial mounds usually date from the Bronze Age and are more recent than open burial mounds from the Stone Age.

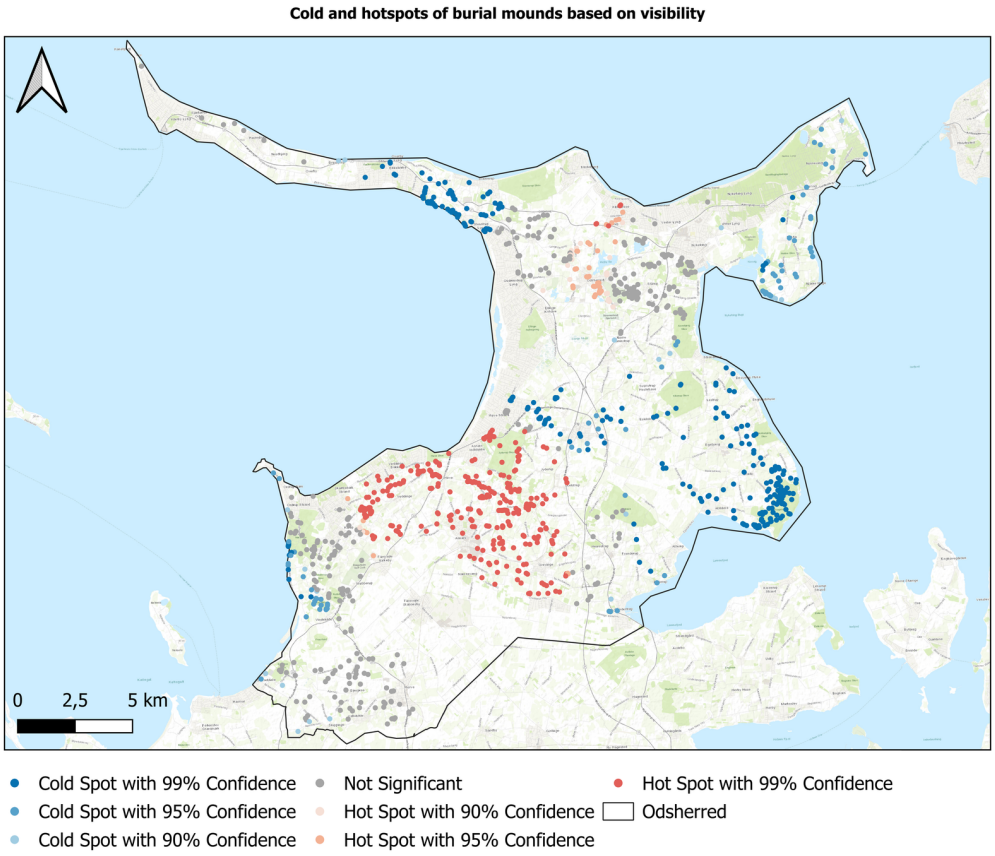
The Stone Age mounds are older and have often undergone more erosion and weathering over time, resulting in a more flattened appearance and smaller height.

Because not every team member could join the field trips every time and discussion with all team members was not possible, it was agreed that the checklist would be filled out by the same person each time. This way, we aimed to work as systematically as possible and avoid subjective data. Often small concentrations of burial mounds were found close together. These burial mounds were usually of the same size and type, so they were noted together on one checklist. After visiting each cluster, the checklist forms and photographs taken were reviewed to develop a descriptive profile for each type of burial mound. This systematic approach ensured that we captured detailed and accurate information about each burial mound, providing a robust dataset for further analysis and understanding of the burial mounds at Odsherred.

3. RESULTS

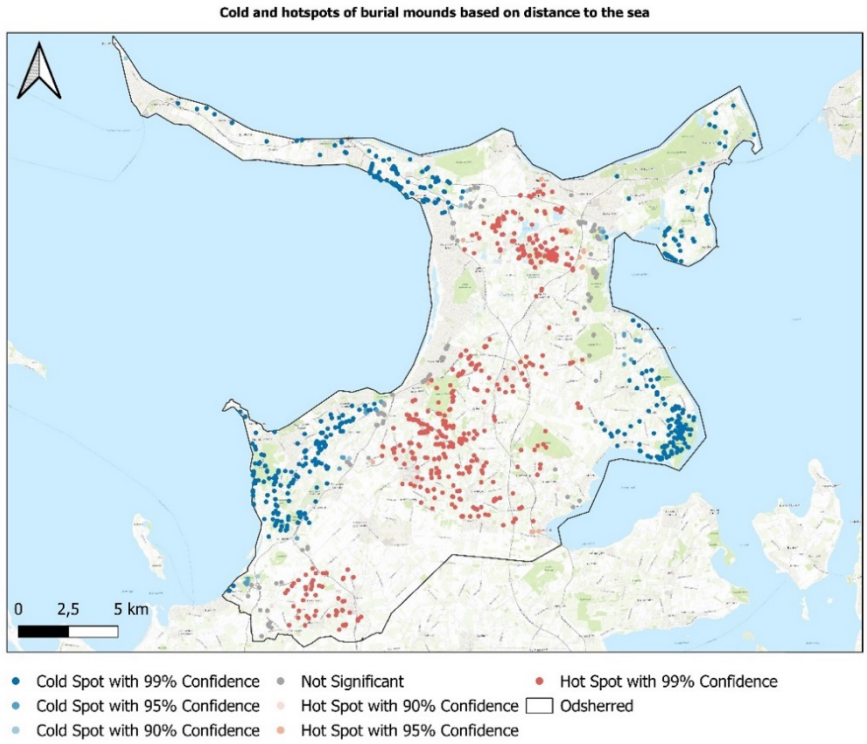
3.1 Defining final clusters

As previously explained, a hotspot analysis was performed on the dataset of burial mounds by enriching it with five attributes: distance to the sea, absolute/relative height, slope, and visibility. In ArcGIS Pro, the GI* was calculated to determine whether a burial mound is a hotspot, coldspot, or non-significant area. for a particular attribute, with a certain confidence level. Map 3 shows the cold and hotspots of burial mounds based on visibility. Burial mounds with high visibility (hotspots) cluster mostly on the centrally located ridge. The Maglehøj situated here has the highest visibility of all burial mounds with an attribute value of 114 for the attribute Sample1. Coldspots are primarily located in the eastern part of Odsherred, in the Kongsøre Forest. These are the burial mounds that spatially cluster and have a low attribute value (= low visibility). In this forest, there is a lot of microrelief, and burial mounds are usually situated slightly lower than the surrounding area, which explains the lower visibility. In other parts of the study area, there are also coldspots present, but with less distinct clustering, as visible in map 3. Finally, there are burial mounds that score non-significant on the GI* based on visibility. A large area of non-significant burial mounds is located south of Nykøbing, as well as in the southernmost part of the study area near Hørve. Here, there is spatial clustering, but the clustering is not extended to the attribute level.

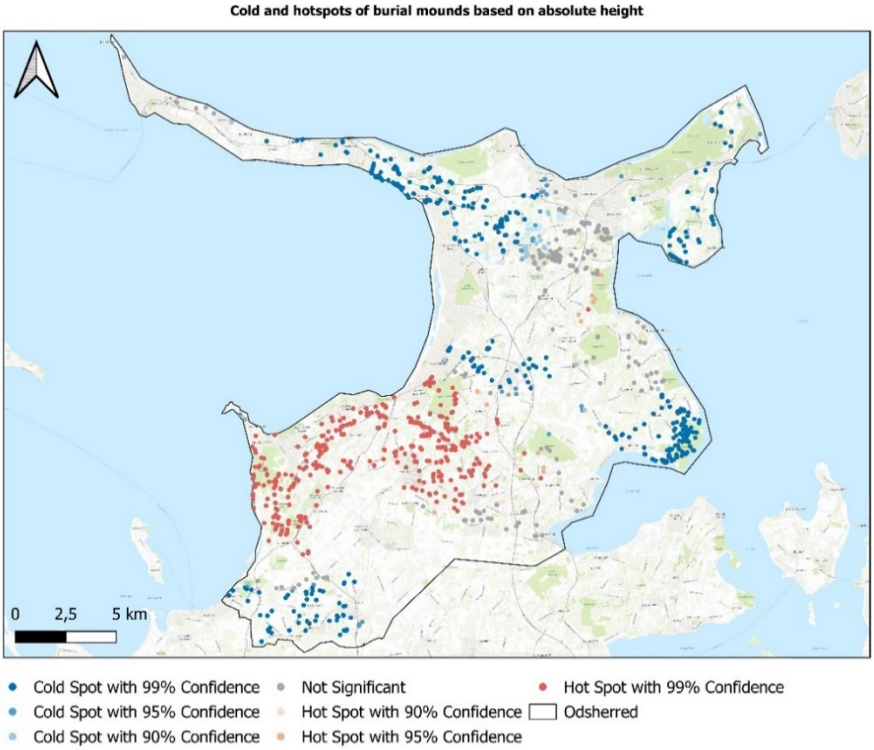


Map 3: Cold and hotspots analysis based on viewshed

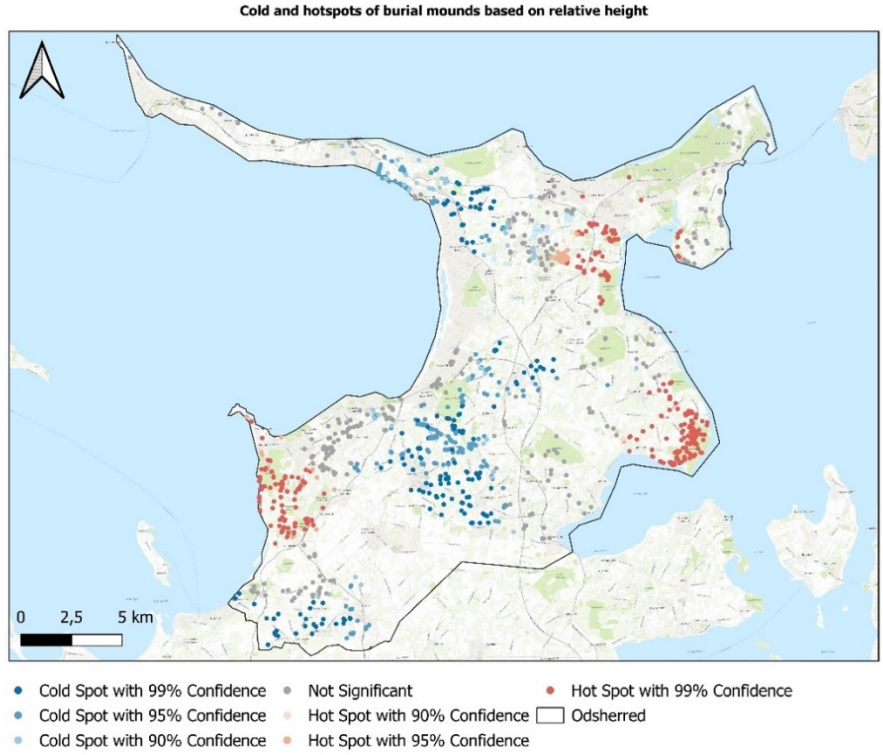
Similar to the visibility map, a map was created for the other four attributes: absolute/relative height, slope, and distance to the sea, showing hotspots, coldspots, and non-significant areas. These data are displayed on map 4-7.



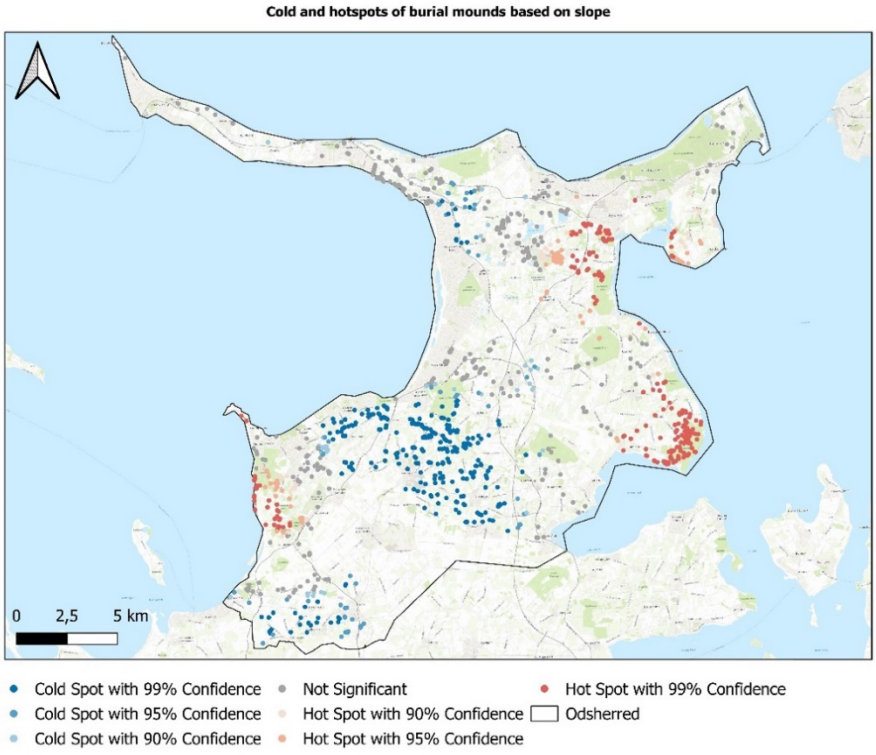
Map 4: Cold and hotspots analysis based on distance to the sea



Map 5: Cold and hotspots analysis based on absolute height

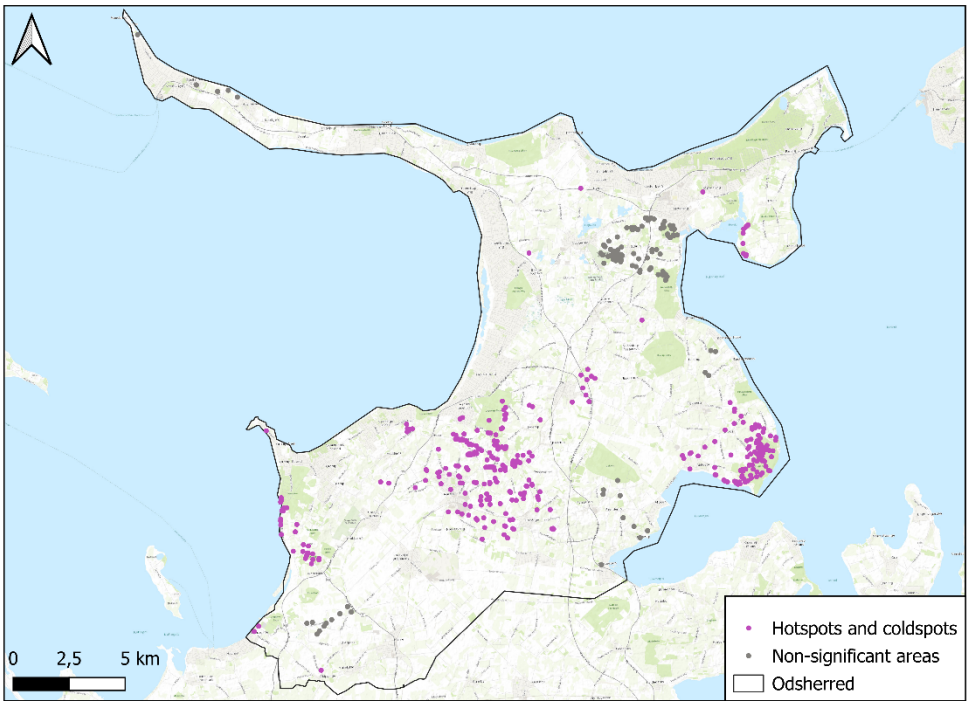


Map 6: Cold and hotspots analysis based on relative height



Map 7: Cold and hotspots analysis based on slope

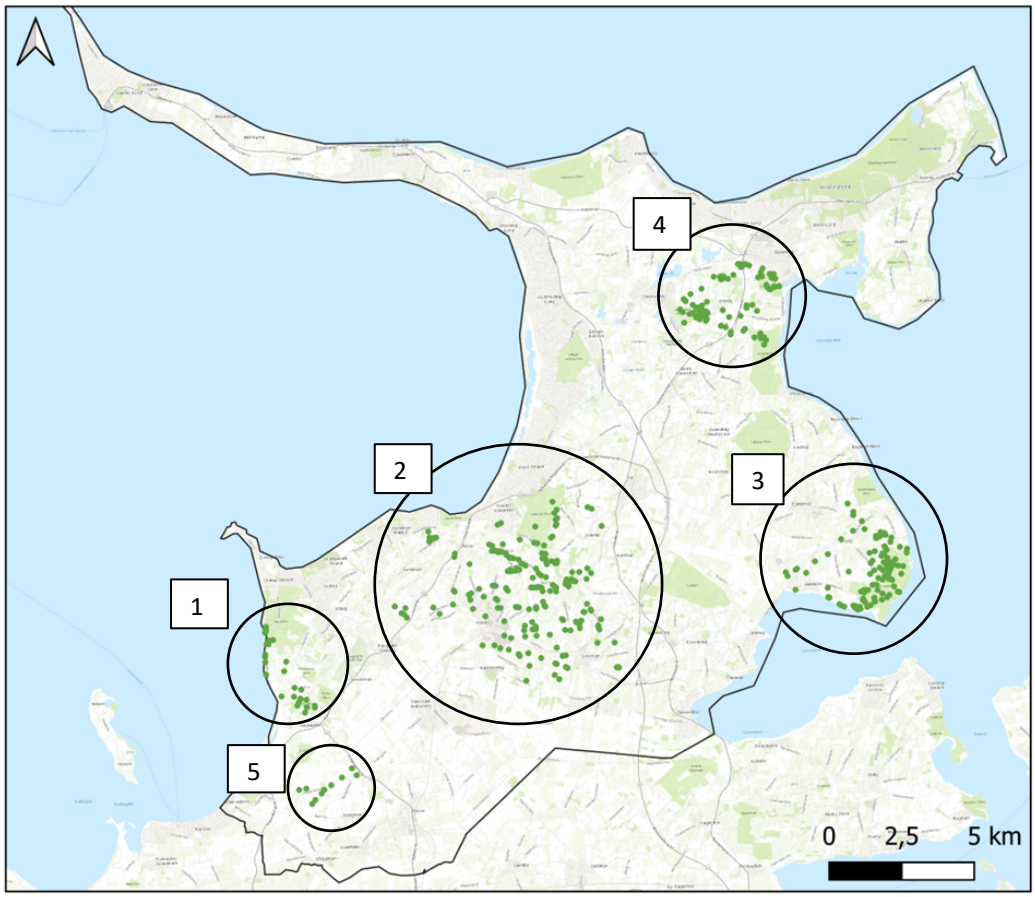
After creating the five separate maps, the maps are then compared to delineate two types of areas that will be used for fieldwork later in this study. On one hand, there are the *hotspots and coldspots*, burial mounds belong to this category if they are non-significant for none of the attributes, in other words, if they are either a hotspot or coldspot for each attribute. This was achieved by applying the union function in QGIS to the five attributes. On the other hand, there are the *non-significant areas*, which include burial mounds that are non-significant for at least two attributes. These two types of areas are shown on map 8.



Map 8: Final map of clusters bases on different attributes

3.2 Description of each cluster and their characteristics

The burial mounds from map 8 were then divided into five clusters. Clusters were delineated visually, not based on any analysis. Clusters 1-3 are significant clusters consisting exclusively of burial mounds from the *hotspots and coldspots* category, while clusters 4-5 are non-significant clusters. The division into these clusters is shown on map 9.



Map 9: Division of the clusters

3.2.1 Cluster 1

The first cluster is located in the west of the study area near the sea, but on the ridge, so at a high absolute height. The burial mounds in the first cluster are all quite small and located in the forest, next to the sea, so visibility is quite low and the burial mounds blend into the landscape (image 1). Several burial mounds are located on the property of summer houses, making them inaccessible. The local population's awareness of the presence and significance of burial mounds is low. We spoke with an English couple who own a summer house, but they knew hardly anything about the burial mounds, even though there are several in the immediate vicinity of their house. Many other burial mounds are situated right by the roadside. These are mostly small paths used only by the locals, resulting in minimal tourism in these areas. An exception to these characteristics is Vejrhøj, which dates back to the Bronze Age and, at 121 meters, is the highest point in the study area and in Zealand (Image 2). This burial mound is more geared towards tourism, as illustrated by the many walking paths leading to it and the large parking area at the base of the hill.

Image 2: Typical burial mound cluster 1: close to the sea/summerhouses, low visibility

Image 2: Vejrhøj, Fårevejle Kirkeby (Source: (OpdagDenmark, n.d.))

3.2.2 Cluster 2

Cluster 2 is located in the inland area of Odsherred and is the largest cluster in the area. This cluster is characterized by its high distance to the sea, high absolute height and high visibility. The area primarily consists of open fields and meadows. These open landscapes allow the burial mounds to be easily seen from the road, making them prominent landmarks that dominate the surroundings. The burial mounds here are also typically larger than those found in other regions. They are usually well-preserved and look like the classic image of a burial mound (image 3-6).

Some of these mounds are equipped with visitor facilities, including parking areas, benches, and information boards. This reflects an effort to make these historic sites accessible to the public and promote their educational value. The presence of such facilities indicates that the mounds are not only of archaeological importance, but also serve as important cultural and recreational sites for visitors. There is also a hiking trail called Højderygstien, or "The Ridge Path," which passes by some of the most impressive burial mounds, including Esterhøj, Maglehøj, and Dutterhøje. Along with Vejrhøj from Cluster 1, it is believed that these mounds were part of ancient routes from the Bronze Age, serving as important landmarks to help people navigate the landscape (Miljøministeriet et al., z.d.).

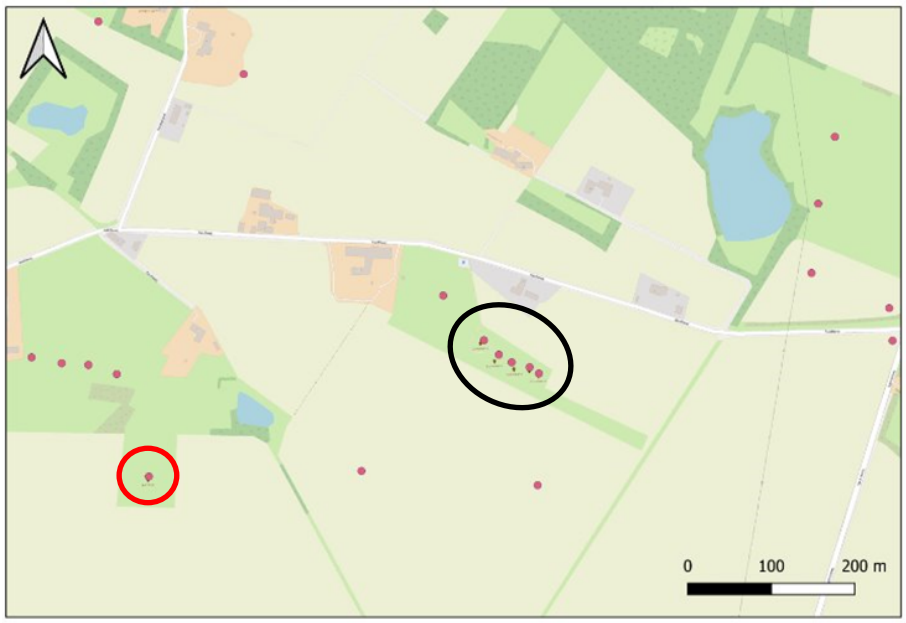
Image 3: Rishøj, Grevinge

Image 4: Dutterhøje, Asnæs

Image 5: Snoghøje, Grevinge

Image 6: Maglehøj, Asnæs (Source: Visit Odsherred, n.d.-b)

Over the years, many burial mounds have disappeared with the expansion of farmland and other changes in land use. For instance, Dutterhøje, a collection of five prominent mounds in a row, remains a notable landmark. However, historical records show that there used to be at least seven other mounds in this area (map 10). Today, only Dutterhøje and a solitary mound called Barnehøj are still visible in the distance (image 7).



Map 10, Dutterhøje (black) and Barnehøj (red)

Image 7, Dutterhøje and solitary burial mound (red)

3.2.3 Cluster 3

Cluster 3 is located on the east coast of Odsherred and is notable for the high density of burial mounds. This cluster is characterized by its proximity to the sea, low absolute height and limited visibility. The area is mostly covered by dense forests, where the burial mounds are generally small, overgrown and poorly maintained (Image 8). Despite the presence of about 80 burial mounds in the Kongsøre Forest, it is difficult to locate them due to their hidden nature

and dense forestation (Kongsøre Skov - Odswiki, n.d.). Access to these burial mounds is limited, with only a few narrow paths crossing the forest, making it difficult for visitors to find them. Many burial mounds have been lost over time, and exploring them often requires deviating from the established paths, without clear indications of their presence. The forest was originally cultivated during the Neolithic period, but has changed to a beech forest since the 18th century (Kongsøre Skov - Odswiki, n.d.). The burial mounds in Cluster 3 are located near ancient settlements, indicating an important archaeological heritage. However, tourism in the area remains minimal, in part due to the forest's use as a military base, which limits opportunities for tourism development.

Most of the burial mounds in Cluster 3 date to the Stone Age, which explains their smaller size. A notable exception is the King Ore grave, which is larger and better preserved (Image 9). This elongated mound is surrounded by numerous stones and has an information board for tourists. Its proximity to the road contrasts with the difficult forest trails. The development of the Kongsøre Forest and its partial use as a military base probably contributed to the neglect of these hills, so they are now overgrown and largely hidden in the landscape.

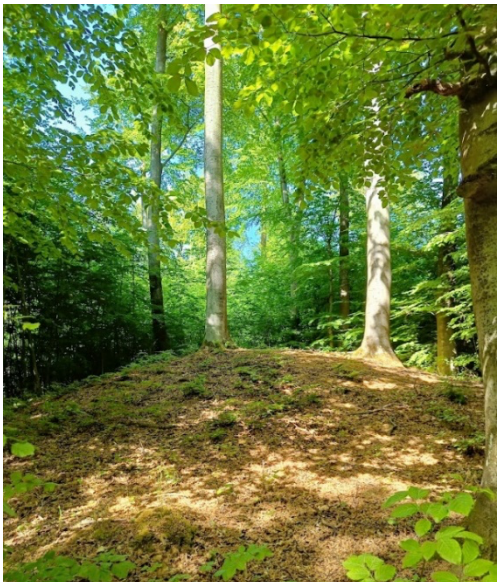


Image 8: Unknown, Kongsøre Forest

Image 9: Kong Øres Grav, Kongsøre Forest

3.2.4 Cluster 4

In addition to three significant clusters, there are two non-significant clusters, indicating that the burial mounds within them do not share similarities on at least two attributes. Cluster 4 is located in the northern part of the study area south of Nykøbing. This cluster shows a wide range of differences between the hills, particularly in terms of absolute height and visibility: the two attributes that are non-significant in the cluster.

Some burial mounds in this cluster were located in a forest, were small in size and not easily visible (Image 10). Further down the cluster there is a high concentration of burial mounds, now located within a golf course and a large meadow, but these were no longer individually observable in the landscape. In addition, there were well-preserved burial mounds of different sizes within the cluster. Prominent in the landscape are the Syvhøje, located southeast of Nykøbing. Syvhøje consists of six burial mounds dating from the Early Bronze Age (Image 11) (Visit Odsherred, n.d.-a). These burial mounds and their surroundings are well-preserved, situated along a walking trail, and feature a tourist information board and a small parking area. Another prominent solitary burial mound, in good condition, is located near a junction (Image 12). Cluster 4 has a diverse range of burial mounds, from small and hidden in woods to larger, more prominent burial mounds in clearings.

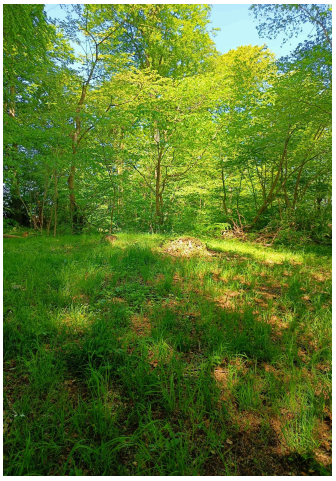


Image 10: Burial mounds in the forest south of Nykøbing

Image 11: Syvhøje, Nykøbing

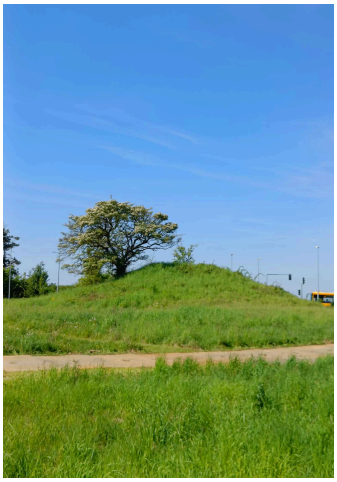


Image 12: Solitary burial mound

3.2.5 Cluster 5

The last cluster is a non-significant cluster, located in the south-west of Odsherred. This is the smallest cluster and beforehand we wanted to visit seven burial mounds. Unfortunately, we only managed to find two in the landscape. The two we found were located in the middle of a farmers field. This can indicate that the other burial mounds were possibly destroyed in the past due to the conversion to arable land. Another explanation could be that the burial mounds were not that visible as we were not able to cross the private property of the farmers. Due to the lack of data in this cluster it is very hard to draw conclusions. (Image 13) shows the two burial mounds that we found in Cluster 5. They are both surrounded by farmland and are preserved by the owner of the land.

Image 13: Small burial mound in Cluster 5, poorly accessible and barely visible in the landscape

4. FUTURE PERSPECTIVES

At this moment the important burial mounds are well maintained, and we feel that the system that is in place now is a good one. However, the people in charge of those burial mounds should not get a false sense of security and should follow the evolution of degradation. So, when certain parts of the burial mound are degrading, they should step in. By maybe installing stairs, those stairs have two functions. First, they protect the burial mound from degradation, secondly, they provide a safer way for people to climb on the burial mound. The burial mounds on private property can keep the same function they have at this moment. That it is an iconic feature of the landscape and because people cannot visit those burial mounds degradation is less of an issue. The only thing that the private owners should look out for is that those burial mounds are visible in the surrounding area and are not grown over by vegetation.

There is also some room for more tourism regarding the burial mounds. Some ideas come to mind like creating cycling and walking trails that connect multiple burial mounds. This should go along with a story that gets told at each burial mound. Hopefully more tourists will get to know the history of the municipality and how the landscape shows some remnants of the past. Other burial mounds not used for tourism can potentially be utilized for renewable energy. For example, it can be investigated whether solar panels can be placed on the slopes of the burial mounds.

All burial mounds are protected in legislation and should be preserved and can be an interesting attraction for tourism. It is not possible to maintain all burial mounds for the purpose of tourism.

Image 14, Maglehøj (At least more than 5 years ago) vs Maglehøj (May, 2024). Source first image: Visit Odsherred, n.d.-b

Maglehøj, the largest burial mound in Odsherred and located in Cluster 3, has been maintained through different methods over the years. The photograph on the left, taken more than five years ago, shows the mound being managed through grazing by sheep, which has proven to be a highly effective technique. In contrast, the image on the right, taken in May 2024, depicts the current maintenance practice of trimming the vegetation with machines. However, this more recent method has also resulted in visible trampling damage. To mitigate such damage, the installation of a stairway could be considered. Continuous monitoring of these changes is crucial to assess the impact of various maintenance practices and to determine the most effective strategies for the preservation of burial mounds.

5. DISCUSSION

In the analysis of Bronze Age archaeological sites, there was a significant oversight in not considering the historical shorelines. The coastal landscape during the Bronze Age was markedly different from today's, affecting settlement patterns, resource availability, and transportation routes. Integrating historical shoreline data into GIS models is crucial to accurately reflect past environments and understand human activity during that period. This omission may lead to incomplete or misleading interpretations of archaeological data.

While performing hotspot analysis, the dataset primarily contained quantitative data. However, integrating qualitative data, such as soil composition and land use patterns, presents a challenge. These qualitative factors are essential for a holistic understanding of archaeological contexts but are often difficult to quantify and incorporate into statistical models. Developing methods to merge qualitative and quantitative data could enhance the robustness and depth of hotspot analyses, providing more nuanced insights into past human activities.

The presence of numerous burial mounds in the landscape and their continued representation on maps introduce a bias in archaeological surveys. These visible features have historically attracted more research attention, potentially skewing our understanding of past human activity. This bias is especially pronounced for the more prominent burial mounds, which are easier to locate and study. To mitigate this bias, a more systematic survey approach is necessary, ensuring that less visible but equally significant sites are also explored and documented.

In our analysis, Stone Age and Bronze Age data were combined, but this approach overlooks the significant differences between these periods. Each era is characterized by distinct cultural, technological, and environmental factors as mentioned before. Lumping them together can obscure these differences and lead to inaccurate conclusions. Future analyses should treat these periods separately to respect their unique characteristics and provide more precise historical interpretations.

There appears to be a disproportionate focus on the Bronze and Stone Ages in archaeological studies, potentially neglecting other significant periods of antiquity. This narrow focus can lead to a skewed understanding of human history and overlooks the contributions and developments of other eras. Expanding the scope of research to include a wider range of historical periods would provide a more comprehensive view of human development over time.

The analysis did not adequately address the cultural value of archaeological sites to local populations. Understanding how these sites are perceived and valued by contemporary communities is crucial for heritage conservation and management. Engaging with local populations and incorporating their perspectives can enhance the relevance and sustainability of archaeological research, fostering a sense of ownership and pride in local heritage.

A Digital Elevation Model (DEM) was used in the analysis instead of a Surface Model, which could impact the accuracy of the results. While DEMs provide valuable elevation data, Surface Models offer a more detailed representation of the terrain, including vegetation and built structures. Utilizing Surface Models could improve the precision of archaeological analyses, particularly in understanding site visibility, accessibility, and landscape use in the past.

The strength of this research lies in its combination of an efficient and accurate implementation of a literature study and a comprehensive data analysis. The study by De Reu (2012) has particularly provided deeper insights into the factors determining the location and distribution of burial mounds. By incorporating a variety of analytical methods, including hotspot analysis, this research has introduced a novel approach to the study of burial mounds. The use of hotspot analysis, which had not been previously applied in similar research on burial mounds, has proven to be a robust method that delivers accurate and meaningful results. This study can be used as a baseline reference in other studies around the world that examine the distribution and characteristics of burial mounds and, more broadly, all point features in the landscape. Addressing these points in future research will improve the accuracy, inclusivity, and relevance of archaeological analyses. Incorporating historical shorelines, better integrating qualitative data, correcting survey biases, distinguishing between different historical periods, broadening the focus of study, considering the cultural value to local populations, and using more detailed surface models will collectively enhance our understanding of ancient human activities and their legacy today.

6. CONCLUSION

The burial mounds in Odsherred are prominent and shape the landscape significantly. It was very interesting to investigate further into this typical feature, given its historical and cultural importance. The main conclusion that can be drawn from this research is that burial mounds located close to each other show more similarities, both in terms of their physical characteristics and their spatial distribution. This observation aligns with the expectations formed during the implementation of GIS analysis and has been further confirmed by extensive fieldwork.

In this study, the characteristics of more than 1000 burial mounds in Odsherred were compared with each other, ultimately resulting in the identification of five distinct clusters. These clusters were delineated by considering both the spatial location and the specific characteristics of the burial mounds. For instance, Cluster 1 consists of burial mounds with poor visibility, which blend seamlessly into the landscape, making them less noticeable. In contrast, Cluster 2 contains burial mounds that are highly visible and generally larger than those in Cluster 1, standing out prominently in the landscape.

Cluster 3 comprises small, overgrown burial mounds that are often surrounded by forest, making access to these mounds more challenging. Clusters 4 and 5, while less significant, exhibit a wide variety of burial mound types, showcasing the diversity in their construction and location. This diversity highlights the complex social and environmental factors influencing burial mound placement.

Overall, the combination of literature review, GIS analysis, and fieldwork has provided a comprehensive understanding of the burial mounds in Odsherred. The identification of these clusters not only enhances our knowledge of the spatial distribution and characteristics of the mounds but also underscores the effectiveness of using innovative analytical methods in archaeological research. This study sets a precedent for future research, demonstrating the value of integrating various data sources and analytical techniques to uncover patterns in archaeological landscapes.

REFERENCES

Internet sources

Environmental Systems Research Institute. (n.d.). How Hot Spot Analysis (Getis-Ord Gi*) works. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/h-how-hot-spot-analysis-getis-ord-gi-spatial-stati.htm

Danske Fortidsminder. (z.d.). Baggrundshistorie - De synlige fortidsminder. https://fortidsmindeguide.dk/baggrundshistorie/

Kulturværdierdiudvalget. (n.d.). Legislation of importance for the Commission on Export of Cultural Assets. https://kulturvaerdier.kb.dk/en/legislation/

Kongsøre skov - odswiki. (n.d.). https://bibod.dk/odswiki/index.php?title=Kongs%C3%B8re_skov

Maglehøj (Odsherred). (2022, 27 January). In Wikipedia. https://de.wikipedia.org/wiki/Magleh%C3%B8j_(Odsherred)

Odsherred UNESCO Global Geopark. (n.d.). The Ridge Path - Footpath with magnificent views. https://www.visitodsherred.dk/api/drupal/sites/visitodsherred.com/files/2019-09/hoejderygstien_folder.pdf

OpdagDanmark. (n.d.). Vejrhøj. https://www.opdagdanmark.dk/en/oplevelser/vejrhoej/

United Nations Educational Scientific and Cultural Organization. (1972). Convention concerning the Protection of the World Cultural and Natural Heritage. In UNESCO World Heritage Convention. https://whc.unesco.org/en/conventiontext/Vejrhøj

Visit Odsherred. (n.d.-a). Syvhøje. https://www.visitodsherred.com/tourist/explore/syvhoje-gdk618689

Visit Odsherred. (n.d.-b). Maglehøj Gravhøj, Odsherred. https://www.visitodsherred.dk/turist/planlaeg-din-tur/maglehoej-gravhoej-odsherred-gdk618878

Articles

Bevan, A., Frederick, C., & Krahtopoulou, A. (2003). A digital Mediterranean countryside: GIS approaches to the spatial structure of the post-medieval landscape on Kythera (Greece). http://eprints.bice.rm.cnr.it/823/

De Reu, J. (2012). Land of the dead. A comprehensive study of the Bronze Age burial landscape in north-western Belgium. http://hdl.handle.net/1854/LU-4337096

Fisher, P., Farrelly, C., Maddocks, A., & Ruggles, C. (1997). Spatial Analysis of Visible Areas from the Bronze Age Cairns of Mull. Journal Of Archaeological Science, 24(7), 581–592. https://doi.org/10.1006/jasc.1996.0142

Kvamme, K.L. (1992). Terrain Form Analysis of Archaeological Location through Geographic Information Systems. https://proceedings.caaconference.org/paper/16_kvamme_caa_1991/

Wheatley, D. (1995). Cumulative viewshed analysis: a GIS-based method for investigating intervisibility, and its archaeological application. https://www.academia.edu/705833/Cumulative_viewshed_analysis_a_GIS_based_method_for_investigating_intervisibility_and_its_archaeological_application

Woodman, P.E. (2000). Beyond significant patterning, towards past intentions: The location of Orcadian chambered tombs. https://archaeologicalcomputing.lincei.it/woodman-pe-beyond-significant-patterns-towards-past-intention

Books

Lagerås, K. E. (2002). Viewshed Analysis of Bronze Age Burial Mounds in Western Scania, Sweden. In E. Scarre (Ed.), Monuments and Landscapes in Atlantic Europe (pp. 132-148). Routledge. https://doi.org/10.4324/9780203994054-15

Kruger, J. (2021). Odsherred Kommunes landskaber. https://trap.lex.dk/Odsherred_Kommunes_landskaber

Datasets

Kulturministeriet. (z.d.). Slots- og Kulturstyrelsen. https://www.kulturarv.dk/fundogfortidsminder/Sog/?fbclid=IwZXhObgNhZWOCMTAAAR3GWDKae7Z5JgWOmwCekd2-spYwV88AVHHenEN6tPP66alVCq8fOUKugag_aem_DvD4Ogj5dOJX_bOHZ978BA

APPENDIX

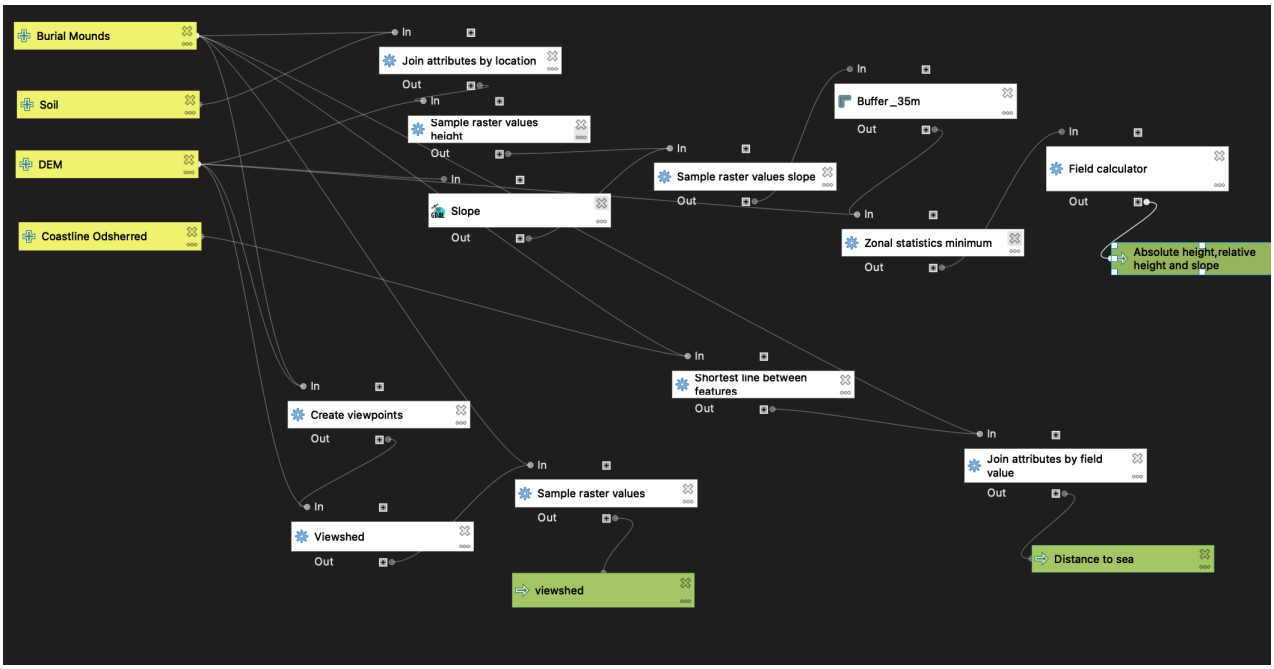


Image 15: cartographic model of enriching the dataset

fid	systemnr	stednavn	anlaegsbet	datering
1	103136	Øllehøj	Rundhøj	Oldtid
2	103138	Asnæs	Rundhøj	Oldtid
3	103139	Rennebjerg	Rundhøj	Oldtid
4	103140	Asnæs	Rundhøj	Oldtid
5	103141	Bobjerg Banke	Rundhøj	Oldtid
6	103142	Ølstenshøje	Rundhøj	Oldtid
7	103146	Asnæs	Rundhøj	Oldtid
8	103148	Grønnehøv	Rundhøj	Oldtid
9	103149	Asnæs	Rundhøj	Stenalder
10	103150	Asnæs	Rundhøj	Oldtid
11	103151	Ølstenshøje	Rundhøj	Oldtid
12	103152	Ølstenshøje	Rundhøj	Oldtid
13	103153	Asnæs	Rundhøj	Oldtid
14	103154	Skrædderholmen	Rundhøj	Oldtid
15	103155	Asnæs	Rundhøj	Oldtid
16	103156	Træhøv	Rundhøj	Oldtid
17	103157	Asnæs	Rundhøj	Oldtid
18	103158	Asnæs	Rundhøj	Oldtid
19	103159	Grønnehøv	Rundhøj	Oldtid
20	103160	Maglehøj	Rundhøj	Oldtid
21	103161	Asnæs	Rundhøj	Oldtid
22	103162	Asnæs	Rundhøj	Oldtid
23	103164	Englodderne	Rundhøj	Stenalder

Image 16: Attribute table of the original dataset with burial mounds (The last column 'datering' indicates the period of the burial mound (Antiquity, Bronze Age, or Stone Age), but we did not use this data because it is likely incorrect.)