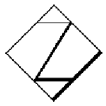

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Master's Thesis

Driving Forces of European Landscape Change

An Analysis of the Wadden Sea Region

Author: Gordon Matt

Tutor: Dr. Miloslav Lapka

České Budějovice, October 2021

UNIVERSITY OF SOUTH BOHEMIA IN ČESKÉ BUDĚJOVICE

Faculty of Economics

Academic year: 2020/2021

ASSIGNMENT OF DIPLOMA THESIS

(project, art work, art performance)

Name and surname:	**Gordon MATT**
Personal number:	**E19051I**
Study programme:	**N6237 Regional and European Project Management**
Field of study:	
Work topic:	**Changes in European landscapes. What are driving forces of the changes in European landscapes?**
Assigning department:	**Department of Regional Management and Law**

Theses guidelines

The North Sea region and its landscape is facing many changes and challenges. Climate change endangers the coastal areas and lowlands and the transition to a greener economy adds renewable energy wind turbines and solar panels to traditional landscapes. The challenges for the North Sea region and its inhabitants have led to a shift in the perception of landscape. Environmental issues have become more important than ever.

Extent of work report:	**50-60 pages**
Extent of graphics content:	**as needed**
Form processing of diploma thesis:	**printed**
Language of elaboration:	**English**

Recommended resources:

Bürgi, M., Bieling, C., Von Hackwitz, K., Kizos, T., Lieskovský, J., Martín, M. G., ... Printsmann, A. (2017).Processes and driving forces in changing cultural landscapes across Europe. Landscape Ecology, 32(11), 2097- 2112. https://doi.org/10.1007/s10980-017-0513-z

Darby, H. (1951). The Changing English Landscape. The Geographical Journal, 117(4), 377-394. doi:10.2307/1790680Fowler, Peter. (2000). Cultural Landscapes of Britain. International Journal of Heritage Studies. 6. 201-212. 10.1080/13527250050148197.

Fowler, Peter. (2000). Cultural Landscapes of Britain. International Journal of Heritage Studies. 6. 201-212. 10.1080/13527250050148197.

Ian Whyte (2006) Upland Britain: cultural processes and landscape changethrough time, The International Journal of Biodiversity Science and Management, 2:3, 138-141, DOI: 10.1080/17451590609618109

Natural England (2004). Countryside quality counts: Tracking Change in the character of the English landscape. Retrieved from http://publications.naturalengland.org.uk/publication/60074

Supervisors of diploma thesis:	**doc. PhDr. Miloslav Lapka, CSc.** Department of Regional Management and Law

Date of assignment of diploma thesis: **April 13, 2021**
Submission deadline of diploma thesis: **August 15, 2021**

JIHOČESKÁ UNIVERZITA
V ČESKÝCH BUDĚJOVICÍCH
EKONOMICKÁ FAKULTA
Studentská 13 (1)
370 05 České Budějovice

doc. Dr. Ing. Dagmar Škodová Parmová
Dean

doc. PhDr. Miloslav Lapka, CSc.
Head of Department

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Abstract

This master's thesis examines driving forces of landscape change in the Wadden Sea region. The region is a UNESCO World Natural Heritage site and encompasses North Sea coasts of Denmark, Germany and the Netherlands. The cultural landscape has faced change for millennials.

The socioeconomic, technological, political and institutional, cultural as well as natural driving forces of these changes were analyzed in this thesis with the help of systematic review. Historical overviews were presented, and new, emerging trends identified.

Keywords: landscape change, driving forces, proximate and underlying drivers, landscape, landscape history, cultural landscape, nature, landscape identity, energy transition, nature conservation

Table of Contents

List of Figures and Tables

List of Abbreviations

CWSS	Common Wadden Sea Secretariat
DPSIR	Drivers-Pressures-State-Impact-Responses
EEA	European Environmental Agency
ELC	European Landscape Convention
LCS	Landscape Change Science

1 Introduction

Landscapes are dynamic and have changed as long as they exist. With new technologies, increasing globalization and the fast-changing needs of society, landscape change has been receiving much attention in the past years leading to grown interest by scholars and therefore continuous an increase in the use of the term landscape in studies related to, for example, land use, environmental change, agriculture, and land management. The basic drivers or causes of landscape changes have been subject of research by many different approaches, which has resulted in a wide range of terminologies (Kizos et al. 2018).

The Wadden Sea Region is one of Europe's exceptional wetland areas, stretching from Denmark to the Netherlands. Its typical landscape consists of tidal mud flats, small barrier islands and marshlands behind the dykes. The shore is surrounded by high ground villages and towns. As such, it builds a natural environment for the urban precincts. The rich cultural heritage attest centuries of human interaction with nature. The marine landscape was continually shaped and transformed by man and was developed to new environments, characterized by the combination of natural diversity and cultural richness.

In 2009, the German-Dutch Wadden Sea was inscribed on the UNESCO World Heritage List. In 2011 it was extended to include the Hamburg Wadden Sea and in 2014 the Danish part followed together with a seaward extension of the Lower Saxony Wadden Sea. The Wadden Sea has outstanding global significance both in terms of geological and ecological processes and in terms of its importance for biodiversity conservation. The "Outstanding Universal Value" of the Wadden Sea is thus internationally recognized and the achievements of over 40 years of transboundary protection and management are acknowledged. The Wadden Sea is on a par with other world-famous natural wonders such as the Grand Canyon in the USA and the Great Barrier Reef off the coast of Australia.

1.1 Objectives

This master's thesis objective is to examine the landscape changes within the Wadden Sea and its driving forces. shall describe the evolution of the landscape in the North Sea region. The practical part will concentrate on the changes that the landscape in this region has faced over centuries as well as on the underlying forces that drive these changes. Before that, the theoretical part shall enlighten two crucial aspects of this thesis. First, an explanation and definition of the concepts of 'Landscape' itself will be given. This is important in order to determine a common definition of the term in the further course of the thesis, which is consistent with the work assignment. Since there are many different concepts from many different scholars from different disciplines, this is quite important. Concepts and ideas range across multiple fields and disciplines of study and vary by viewer, region, institution, and period.

Second, the phenomenon of landscape change is discussed. Present and predictable trends in Europe herald major changes that will affect biodiversity, cultural heritage, landscapes, environmental quality, and economic values (Klijn 2004). Hence, the focus is set on global driving forces that can be natural as well as human in origin as well as on regional forces that influence the landscape change directly at the local level.

After the theoretical framework has been set, the practical part of the project deals with the question which driving forces determine landscape change in the North Sea region around the trilateral Wadden Sea (Germany, Netherlands, Denmark) and how these have changed since the 20th century. Climate change and the energy transition have a global impact, but especially regional measures have to be taken to tackle these obstacles and to seize opportunities. The question thus is: How does these actions affect the landscape around the Wadden Sea, how are nature and the landscape affected and what role do humans play in this?

1.2 Literature Review

In Europe, landscape research dates back to the nineteenth century, when Alexander von Humboldt (1769–1859) and Carl Ritter (1779–1859) introduced the term "landscape" (Landschaft in German) as a scientific concept (Kirchhoff et al. 2013).

Since then, it has developed as a lively area of study, especially after the beginning of the twenty-first century, when the German geographer Carl Troll (1899–1975) coined

the term "landscape ecology" to examine the reciprocal interactions between social and ecological processes. Since the 1970s, landscape research increasing attention on the political level when the United Nations made environmental sustainability concerns part of their development programs. Eventually, scholars and policymakers realized the need to overcome the shortcomings of single-sector policies and management strategies, which prompted the adoption of the "landscape approach" (Sayer et al. 2013 as cited in García-Martin et al., 2021, 18). A significant milestone inclusion of the landscape approach in the political agenda was the European Landscape Convention, in which landscapes were defined as the result of the interaction of natural and human factors (Council of Europe 2000).

Rapidly changing landscapes, not only in Europe but worldwide, are increasingly causing negative consequences for people and the environment (Anthrop, 2005, 21). In some of these regions, there is therefore a societal demand to limit the rate of landscape change and steer it into more desirable paths. This requires knowledge about the causes of change as well as information about inhibiting and stabilizing factors.

In recent years, land change science has responded by moving from descriptive documentation of land cover and landscape change to an attempt to understand and analyze the forces behind observed changes. The study of the so-called driving forces of landscape change has been encouraged and influenced by several methodological contributions (Geist and Lambin 2002; Bürgi et al. 2004; Plieninger et al. 2016), building on a long tradition in geography and landscape research. A general theory of human-environment relationships, the relationship between the driving forces of human-induced landscape change form a complex interdisciplinary system of interdependencies, interactions, and feedback loops that span multiple temporal and spatial scales. Consequently, it is challenging to analyze and represent them systematically, which contributes to the recent lack of clarity and consistency in the terminology used in land change science (Meyfroidt 201). However, the diversity of spatial and systemic scales at which different studies operate, as well as the lack of a disciplinary base, should not be seen as limitations, but also as an expression of the vibrancy of the field and the many possibilities that arise.

2 Nature, Landscape and Cultural Landscape – Theoretical Background

The region "Wadden Sea" that will be investigated later in this paper, has ever since been closely interrelated between human activity and nature. In 2009, the region has been declared as a Natural World Heritage Site by the UNESCO. Before we start with the analysis of the driving forces of landscape change in the case study region, it is vital for this work's purpose, to identify the relation between nature and landscape as well as the concept of cultural landscapes. This chapter thus serves as an introduction to the field of cultural landscapes and landscape studies by explanation of important concepts as 'nature', 'landscape' and 'cultural landscape'. This step is essential for later classifying the North Sea region 'Wadden Sea' and its development. By doing this, important driving forces can be adapted.

2.1 Historical Background

The traditional cultural landscapes are disappearing whereas new landscape types arise, leading to international concern and has become a recurring topic in science. Causing loss of (bio)diversity, coherence and identity of existing landscapes, landscape changes are seen as a threat and a negative development. The fear, that new structures and elements introduced look alike everywhere is rising. However, landscapes are constantly changing as they reflect the dynamic interrelation between natural and cultural (human) forces.

Cultural landscapes are the result of consecutive reorganizations of the land in order to adapt its use and spatial structure better to changing societal demands. Many successive and even devastating landscape changes have been recorded in history, leaving hardly any remains today. Initiatives for adapted land-use policies and rules for landscape management and protection were used in all the important periods of landscape showing for example important land reclamations and deforestation initiatives during the Middle Ages that were systematically planned and many being subject to explicit laws and regulations. In those times, measures to preserve and protect certain qualities and values such as the protection of forests and the creation of landscape parks for the hunt, were the responsibility of landlords. Water resource and forest management are perfect examples for the importance of considering sustainable control of natural resources (Antrop, 2005,22).

However, the concern on natural 'ordinary' landscapes declined with the era of the Renaissance. Therefore, 'cultural' landscapes were planned and constructed for wealthy people and their properties. Until the 19th century, landscape architecture and landscaping gained importance leading to the art of garden architecture. Generally spoken, a rational, geometrical order in urban planning and land organization emerged. During the late 19th and early 20th century the changes caused by the Industrial revolution were considered as devastating and threatening for nature as well as for landscapes. At the same time, naturalist scientists shared their revolutionary views upon nature and landscape and their evolution. Based on these concerns, first legislations on nature and landscape conservation emerged. Besides the protection of sites and natural 'monuments', the visual and functional aspects for visitors were always considered (Bundesamt für Naturschutz, 2007)

With the second half of the 20th century, integrated management changed, adding a more and more ecological point of view. When landscape ecology faced a revival in the 1980s, landscape science became finally transdisciplinary with a more holistic approach, i.e., the integration of underlying and practical research as well as policy implementation. With the new millennium, concern about landscapes as cultural heritage aroused again. Rapidly advancing globalization and the accompanying danger of losing regional identity and diversity drove scholars, institutions and scientists to rethink landscape research and policymaking (Antrop, 2005, 22).

In 1991, the Dobříš Assessment on Europe's environment by the European Environmental Agency made landscape important again as policy makers became aware of the growing challenges and obstacles of preserving values of traditional landscape (ibid.). Researchers thus increased their research and the Council of Europe worked on the formulation of a European Landscape Convention that was then opened for signature in 2000. The important distinction to older regulations on landscape protection was that all landscapes were involved and not just very special valuable sites, such as natural protection sites. Article 2 describes the scale of the Convention, which "covers natural, rural, urban and peri-urban areas. It includes land, inland water and marine areas. It concerns landscapes that might be considered outstanding as well as everyday or degraded landscapes" (Council of Europe, 2000). Landscapes are seen as "part of Europe's common heritage, which deserve protection and management" (art. 30) implying the importance of aesthetics, of scenery and not just economic and ecological functions and utility. The objectives of the landscape Convention are the promotion of "landscape protection,

management and planning", as well as the organization of "European co-operation on landscape issues" (art. 3). The European Landscape Convention essentially aims to bridge the past with future landscapes, but it remains unspecific on how to tackle these challenges.

2.2 Concepts of Nature and Landscape

The brief introduction to the latest landscape history brings us to the next chapter. Here, we will now focus on the different concepts of landscape, the difference between nature and landscape and the special case of cultural landscapes. For the disciplines of sciences dealing with space and landscape in research and planning and landscape, it is constitutive what exactly is understood by landscape.

Clarity about the content of the landscape concept is also an essential prerequisite for the functioning of communication within the professional community, with those affected by planning, and generally in social discourse. Especially since it has gained greater weight in political programs as well, there are indications that its content might change. The scope of the chosen definition qualifies the respective landscape concept as more or less connectable to political-programmatic documents or to discourse among laypersons, and in both cases decisively shapes the scientific and political profile of a discipline (Hakema, 2013, 10)

Being a central concept in various disciplines, from social to geographical and ecological sciences, 'landscape' has reached a renowned status in interdisciplinary research and literature. Due to this interdisciplinarity, the term evokes a number of different associations, such as natural landscape, cultural landscape, political landscape, economic landscape, landscape view, landscaping, or landscape painting. Originally, landscapes were assumed to be generally embedded as functional units within the broader social, economic, and environmental realms and to have a sufficient degree of homogeneity to be studied as units. During the last decades, the scientific concept of landscape has changed significantly, changing from a narrow geographical area bound concept to a more general notion that also includes non-tangible elements such as values, identity and subjective human perception (Keisteri 1990, 32ff.). As elaborated before, the relationship between landscape and society has been shaped and evolved for centuries. Initially, landscape was practically identical with 'region' and its management and managing

organizations. This territorial meaning of landscape is still maintained in the names of some regional organizations, for example the 'Ostfriesische Landschaft', as well as in definitions of landscapes used by landscape ecologists. During the Renaissance, another meaning of the word landscape was established when painters started to name their interpretations of rural scenes 'landscapes'. From this, the visual meaning of the word landscape developed. Definitions of landscape differ by region. In Germany, for example, the original regional meaning is still very much alive, whereas in the UK the word landscape, which had disappeared during the Middle Ages, was reintroduced by painters from the Low Countries and therefore has a strongly visual meaning (Renes, 2018, 46). The concept thus is rather challenging that is often used differently in different settings and contexts (cf. Table 1).

	Landscape	Nature
Etymology	Region Scenery	Character (human) That which develops without human intervention
Meaning in landscape ecology	Regional system	Regional system
Meaning among general public	Scenery	Scenery ('nature' presented as 'landscape')
Meaning in politics and governance	Scenery, 'visual environmental quality'	Area with designation 'nature'

Table 1 Concepts of Landscape and Nature (Renes, 2018)

The Council of Europe defines landscape in the European Landscape Convention 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 2000, p. 2). By this meaning, landscapes are of public interest and play an important role, especially in cultural, ecological, environmental as well as social regards. They provide resources for economic activity and contribute to the formation of local cultures and identity. Further, landscapes are key elements of natural and cultural heritage, with which they contribute to human well-being. In addition, the protection, management and planning create job opportunities and entail rights and responsibilities for everyone.

> "[Landscape] is an important part of the quality of life for people everywhere: in urban areas and in the countryside, in degraded areas as well as

> in areas of high quality, in areas recognised as being of outstanding beauty as well as everyday areas"
>
> (Council of Europe 2000: Preamble of the European Landscape Convention)

According to this definition, 'landscape' can be understood as a product of society (Berger and Luckmann, 1966). Symbolic worlds of meaning such as 'landscape' are closely connected to history and usually tend to have a large semantic court (Kühne 2015). Berger et al. (2017) describe the term landscape as a term that consists of many contents and subject of various sciences, and which is connected to a range of concepts. Furthermore, it presents high discursive accessibility as it is open to interpretation and among people generally positively related.

Scheller (2020) again defines landscape as a construct of "interacting social, ecological and abiotic processes". Social, i.e., human processes reflect the people, their institutions and their culture (e.g. demographic trends, technological development, networks, etc.). The natural factors are not directly controlled by human and emerge from the biological elements of a landscape as its biodiversity and the competition among flora and fauna. The non-living components of a landscape (abiotic processes) constrain the social and ecological processes (climate change, topography, etc.). Altogether, these processes shape the human behavior and human culture. In addition to previous definitions, Berr and Kühne (2020) have found three components that make landscape a constitutive entity: the individual, the social, and the physical: "Without the individual, social agreements about landscape could not be actualized; without society, the individual could not conceive of landscape; without the physical, the individual and society lacked the incentive to assemble objects into landscape." (ibid.)

The scientific comprehension of the world in general and landscape in particular takes place along the three-dimensional intersection of the individual, society, and physical. All components are not immutable but are subject to change; they can be described as "threefold landscape change." Theoretical approaches dealing with landscape change integrate these components in different ways and with different importance and emphasis, sometimes even ignoring one or the other component.

Both nature and landscape are comprehensive, holistic concepts. Only in politics nature and landscape are completely decoupled. Nature is regionalized, as it is often used

to refer to protected areas. Landscape is usually seen as a quality associated with land that has other, often agricultural, primary functions. In some cases, landscapes are also regionalized, usually in processes where man-made landscapes are protected in some way. A problem associated with landscapes is often the formulation of goals. For a long time, landscape conservation was backward-looking and only reactive, which made it difficult to work with forward-looking landscape architects. In the early years of this century, historic preservation, which includes historic landscapes, moved from a defensive posture to a more open, offensive approach (Janssen et al. 2017, 1656). Today, the goal is no longer to protect landscape objects that have survived 20th-century modernizations, but to use the experience of historic landscapes profitably in the design of future landscapes.

Nevertheless, it remains difficult to formulate landscape goals because only designers take steps in this direction. For nature, such a normative approach is much easier, because the general assumption is that greater biodiversity is always better and that any landscape is improved by eliminating or minimizing human influence. Attempts to create more or less natural ecosystems are often referred to as "new nature" or "new wilderness," sometimes with claims of restoring "complete" or "pristine" nature (Renes, 2018, 47). Furthermore, the 'wilderness' concept excludes the human factor. The definitions of national parks, as still proclaimed by the International Union for the Conservation of Nature (IUCN), have led to human rights abuses elsewhere-in the past in the United States (e.g., Yellowstone and Yosemite) and even today in parts of Africa-where groups of people who have managed the area for thousands of years and who have been responsible for many of the values have been displaced in the name of nature. They have been labeled poachers, which is best defined as hunters who belong to the wrong social class. Wilderness is an idea rather than a biophysical reality. It is interesting to consider the physical boundaries of the Wadden Sea as a natural World Heritage Site.

From the perspective of cultural studies, the aestheticized perception of selected areas dominates the classical bourgeois concept of landscape, which are understood as homogeneous in themselves: Landscape as 'beautiful nature'. Historically, landscape does not only act as material heritage but also as a source of ideas and perceptions in the modern era (Krzywinski 2009, 9, 16-18 as cited in Fischer 2012). Dominant to the bourgeois era remained the holistic character of landscape. In the course of the 19th century, landscape became at the same time - in the sense of 'rural area' - the antithesis of city. This antithesis became more and more important in the age of industrialization and

urbanization. The original meaning of landscape, prefigured by painting, flowed in insofar as it underlay the city dweller's romantic view of a space ideally perceived as unadulterated-rural (Fischer, 2012).

In the course of the 20th century, the classical bourgeois understanding of landscape became increasingly dissolved and particularized. Boundaries between urban and rural areas have become blurred, and the urban-rural antithesis has become less important, at least in Europe (ibid.). Nevertheless, the classical European understanding of landscape has not been lost as it is reflected above all in the concept of cultural landscapes, which was integrated, among other things, into the definitions of the European Landscape Convention. Here, the concept of protection is emphasized: "'Landscape protection' means actions to conserve and maintain the significant or characteristic features of a landscape, justified by its heritage value derived from its natural configuration and/or from human activity" (European Landscape Convention 2000).

In contrast, there is a new, particularistic concept of landscape which stretches both concepts of cultural landscape understood as ontological and the classical idea of self-contained, homogeneous spaces. The landscape researcher John Brinckerhoff Jackson founded Cultural Landscape Studies where he includes the temporary, the particular and the 'ugly' in the concept of landscape. With the concept of 'vernacular landscapes', Brinckerhoff Jackson opened the concept of landscape to the spatial originality of modern or postmodern spheres (Brinckerhoff Jackson 1994 as cited in Fischer 2012). This concept led to the so-called "microlandscapes" forming subspaces that initially seem like foreign bodies in their environment but being adapted or changed over time and eventually representing a new kind of dynamics of space (Franzen & Krebs 2006). The concept of micro landscapes understands space and landscapes as patchwork like carpet of small partial landscapes forming one entity instead of being closed, homogenous landscapes. Being regarded as "agglomerations of the most diverse states of environment experienced in motion" (Franzen & Krebs 2006: 14-16), they include the acting human being and analyze the "patchwork" as a social-cultural construct and reflection. Jackson's systematics and terminology show pragmatic and process-related quality (Prominski 2004b, 59) and are opposed to a concept of landscape that is understood as aesthetically based and is criticized as exclusive, static, and oriented towards past forms of land use. A replacement of the aesthetic concept of landscape "with its Arcadian, scenic images" (Prominski 2006b, 246, as cited in Hokema 65) seems necessary because landscapes are changing faster and faster and correspond less and less to the "Arcadian" images.

Prominski characterizes the "Arcadian" and common notion of cultural landscape as a diverse mosaic of agricultural and forestry cultural products located outside of urban space. In contrast, he sees contemporary cultural landscapes as a "product of our contemporary culture" (ibid., 243), whose components include infrastructure routes, commercial areas, or urban spaces. The new landscape concept to be developed should dispense with the juxtaposition of city and landscape, so that, for example, the intermediate cities with ever-growing infrastructure can also be integrated into the landscape concept. Meanwhile, an aesthetic understanding of landscape is no longer the appropriate approach to be able to "[see, understand, and shape] the spatial expression of contemporary culture" (ibid., 249). The use of the concept of landscape in the sense of "Landschaft Zwei" (landscape two) leads to a "semantic" and "political" misunderstanding due to the contained semantic of a dualistic, romantic nature and in view of the construct character even of nature reserves or the "artifactual character even of the 'free' fields of agriculture" (ibid.) lead to ambiguities.

In summary, one can argue that a "transdisciplinary landscape concept" encompasses five dimensions (Tress & Tress, 2001). First, landscape as a spatial entity. Second, landscape as a mental entity. Third, landscape as a temporal dimension. Next, landscape as a nexus of nature and culture and last landscape as a complex system. Landscape studies often have focused on some but not all of these attributes. The concept of landscape presents a common ground for all the various disciplines dealing with landscape, including archaeology, ecology, geography, geology, history, landscape architecture, and regional economics. To achieve its interdisciplinary and transdisciplinary goals, landscape ecology needs to appreciate and integrate the multifaceted perspectives on the culture-nature/people-place relationships that are offered by these diverse disciplines.

As becomes clear in the very next chapter, we cannot only focus on 'landscape' but rather on 'cultural landscape', a fitting concept for the region Wadden Sea. The region and the analysis in the later chapters will exhibit the problematic of finding and identifying the one term or definition of landscape.

> "The distinction between cultural and natural landscape is questionable today (above all in Europe) since the earth has been colonized completely. [. . .] And even if one has left no traces, the territories are mapped and therefore scientifically domesticated, and photographed and painted and therefore aesthetically and mentally seized."
>
> Raith (2006: 209)

As already mentioned, landscapes are, in our case, often described as cultural landscapes, representing a construction and product of human interaction with the natural environment (Scheller 2020). Hence, this opens up the question whether all landscapes would be cultural landscapes. Nature, in this context, is the counterpart to human society; both are dynamic forces, sharing the landscapes (Plachter and Rössler 1995). A cultural landscape is a complex phenomenon with a tangible and an intangible identity. The intangible component arises from ideas and interactions which have an impact on the perceptions and shaping of a landscape, such as sacred beliefs closely linked to the landscape and the way it has been perceived over time. Cultural landscapes mirror the cultures which created them (Plachter and Rössler 1995).

The UNESCO has adopted this concept and has defined cultural landscapes as cultural properties that "represent the combined works of nature and of man" (UNESCO, 2019), a definition that goes along with previous mentioned definitions and concepts. Further, cultural landscapes represent the evolution of society over time, influences by physical constraints and possibilities caused by nature. In that way, cultural landscapes reflect vital and well-defined cultural features of a region. The UNESCO's Operational Guidelines for the implementation of the World Heritage Convention sections cultural landscapes into three parts:

> "1. Landscapes designed and created intentionally by man. These include garden and parkland landscapes constructed for aesthetic reasons which are often […] associated with religious or other monumental buildings and ensembles.
> 2. Organically evolved landscapes. These result from an initial social, economic, administrative, and/or religious imperative and have developed their present form by association with and in response to their natural environment. Such landscapes reflect that process of evolution in their form and component features. They fall into two subcategories
> i - a relict (or fossil) landscape is one in which an evolutionary process came to an end at some time in the past, either abruptly or over a period. Its significant distinguishing features are, however, still visible in material form.
> ii - a continuing landscape is one which retains an active social role in contemporary society closely associated with the traditional way of life, and in which the evolutionary process is still in progress. At the same time, it exhibits significant material evidence of its evolution over time.
> 3. Associative cultural landscapes. These have powerful religious, artistic or cultural associations with the natural elements of the landscape rather than material cultural evidence, which may be insignificant or even absent."
> (UNESCO, 2019, 5)

As the following chapters and the case study about the Wadden Sea region will show, the investigated region belongs to the second category. Although it rather fits in category 2.ii, the Wadden Sea region combines both subcategories. The connection gains particular relevance through changes in physical space, which are interpreted as 'landscape change' - and this as a result of processes of social change such as the expansion of renewable energies and the expansion of the electricity grid, but also changes in recreational preferences as growing tourism. Moreover, climate change has shaped the regions surface ever since and is becoming a threat for the future through human-accelerated climate change. The changes of landscape and the drivers responsible for the change in the analyzed region are clarified and described in the following chapters.

3 Driving Forces of Landscape Change

Landscapes are dynamic. They are constantly changing and challenged as the use of land is shifting continuously with changing natural circumstances and human ambitions (García-Martin et al., 2020, 18). Currently, we are living in an era that scientists and scholars describe as the 'Anthropocene'. The scale of human impact on nature is as high as it has never been before in human history – mostly increased by technological development. The term "Anthropocene" refers to a new geological age in which humankind has the dominant geophysical influence on the Earth system and from which human responsibility for the future of the planet is derived (Ahlborg et al., 2019, 1). The concept "Anthropocene" also contains a call to rethink the position and responsibility of humans towards nature. It is vital for us, to become more mindful and sustainable in our use of limited natural resources. However, we are witnessing numerous environmental trends across the globe that exhibit a lack of such responsibility and sustainability. Climate change, loss of biodiversity, chemical pollution, degradation of agricultural lands and fishing grounds are just a few serious environmental damages and challenges for landscapes to be mentioned. The human capacity to modify landscapes have reached a point, where it endangers our ecosystems and their functionality. This raises concerns about the consequences these changes will bring for humans' and natures' well-being. To prevent and mitigate environmental pressures, to reduce land use conflicts and to predict future scenarios, the knowledge about land use forms, rates of land use change and the drivers behind them are all important to develop strategies in order to be able to achieve a more desirable future.

Natural and man-induced changes shaped and transformed European landscapes continuously. As historical and ongoing changes differ in character and intensity from time to time and from region to region whereas landscapes themselves differ in their responses, temporal and regional specification is required. Consequently, policy and decision makers have to ask following questions: What is the direction of change? At which rate does the change occur? How can the change be measured and eventually evaluated? Is an intervention necessary? If it is, how is an intervention possible? Opportunities vary from compensation measures and effect mitigation to directly tackling the respective driving forces. Proactive policies are mainly preferred to reactive policies and end-of-pipe actions. To sustain conscious choices, one should identify underlying causes and processes (i.e., driving forces), cause–effect tracks and possibilities to intervene. The concept of driving forces is explained and elaborated, specifically for landscapes. We use

two related conceptual models; the first based on the DPSIR (Driver-Pressure-State-Impact-Response) concept and – more targeted– a 'mental map' for landscape change. A third concept helps to distinguish decision-making philosophies or stages according to their scope and time horizon. Current and foreseeable trends in Europe herald major changes affecting biodiversity, cultural heritage, scenery, environmental quality and economic values. Important driving forces are the global change in climate and sea level rise, the land-use change in rural areas, related to a change in demography, technological development, geopolitical change, macroeconomic change and sociocultural changes; and the urbanization processes (Klijn 2004).

This chapter shall serve as an overview for understanding the dynamics of these changes and their reasons. We will focus on postmodern and Anthropocene landscape changes in the 20th and 21st century as overviews for prehistoric, antique and medieval landscape changes have been investigated elsewhere. However, for the chapter on driving factors of landscape change in the Wadden Sea region, a short outline on historic changes and natural evolution will be provided to understand the system, functioning and identity of this unique region.

3.1 Theory of Landscape Change

In recent decades, the transformation of European landscapes has occurred at a rapid pace. Both the intensification of agricultural use and the development in the opposite direction, extensification, the fallowing of land elsewhere, but especially the extensive growth of settlement areas contributed decisively to landscape changes. In addition to quantitative losses of open space, structural changes are of great importance: the fragmentation of open spaces by traffic routes and settlement areas is increasing, and the functions of natural protected assets and the possibilities for recreational use are being restricted. Thus, today's landscapes on the one hand correspond less and less to the ideal image of the "narrow" concept of landscape. On the other hand, since the growth of settlement areas is primarily at the expense of previously undeveloped spaces, the quality of fragmented open spaces, especially in the vicinity of cities and in urban regions - in other words, the overall character of the "extended" landscape - is becoming increasingly important for the quality of life of its inhabitants (cf. Gailing 2007 as cited in Hokema, 2013). Beyond the current conditions, landscape change is also discussed under the future-related aspect of sustainability: The "extended" landscape concept allows the

thematization of a protection of natural resources far beyond the classical protection topics of topics of "species and biotopes" or "landscape", for example, in that the long-term the long-term effective adaptation of land use can also be included (Hokema, 2013, 96)

Contemporary concern with climate change, global environmental change, and sustainability has revived research focusing the human influence on and interactions with the global surface and landscapes. Changes in land systems hold major consequences for climate change, biodiversity and ecosystem services, land degradation, and the vulnerability of coupled human–environment systems. Understanding the dynamics of these changes requires attention to land cover (biophysical conditions) and land use (human uses) as a connected human–environment system (Rindfuss et al., 2004: 1376). The diverse community of researchers engaged in these efforts has constructed a so-called "land change science" which is partly consistent with the first phase of global environmental change studies and their related international programs. Land scape science has sought to improve understanding of land-use and land-cover forms and dynamics affecting the structure and function of landscapes.

The objectives of this science require extensive research at various spatiotemporal scales of analysis for the documentation and monitoring of land-cover changes, the explanation of coupled human-environment system dynamics that generate these changes, as well as the use of the gained knowledge to improve spatially explicit land-change models that are compatible with Earth system models (Rintfuss et al., 2004, ibid.). Since the interactions between human and their environment cause land-use and land-cover change, the objectives mentioned require integrative approaches from multidisciplinary teams from diverse disciplines of natural, social and spatial sciences.

Over thousands of years, landscapes have been formed and preserved by people and their actions and have experienced essential adjustments and changes, both today and in their history. Several causes influence the reshaping of the European landscapes, not only mirroring global trends, but also revealing regional characteristics (Plieninger et al., 2016, 205). Among the causes of landscape change are urban sprawl, agricultural intensification, land abandonment, forest expansion, international commerce and trade, new demands of land for nature conservation, as well as advancing renewable energy uses (Plieninger and Bieling, 2012). With diverse directions and pace, the ongoing trends vary strongly at regional level, depending on current social ecological conditions (Pinto-

Correia and Kristensen, 2013, 249). For example, agricultural intensification is most expressed in those European regions where biophysical and structural conditions for agriculture are favorable, e.g., in many areas of Northwestern Europe (Pinto-Correia and Kristensen, 2013, 250).

All in all, driving forces can be regarded as forces that are independent, autonomous, separate forces impacting a system directly or indirectly (Chorley and Kennedy, 1971 as cited in Klijn, 2004, 202). These forces can either be necessary to keep systems functioning in balance (e.g., precipitation feeding rivers or aquifers), or they can cause a temporary or permanent change in condition (e.g., high rainfall causing flooding) (ibid.). Looking at the landscape as a system, it is possible to identify "external forces" that are responsible for landscape changes. The European Environment Agency (EEA 2002) defines driving forces as "social, demographic and economic developments in societies and the corresponding changes in lifestyle, general consumption levels and production patterns." This definition is limited to social processes and does not include biophysical or natural developments. Others have explicitly included the latter (Turner et al. 1995). Together, the concepts go along with previous definitions of cultural landscapes, according to which landscape changes through natural but also human-induced patterns (Bürgi 2004, European Landscape Convention 2000).

3.2 Types of Driving Forces

Cultural landscapes reflect, as already discussed, the long-term interactions between people and their natural environment, suggesting that landscapes have been shaped over time by an interactive process that links human needs with natural resources and features in a particular topographic and spatial setting. As a dynamic system, today's landscape is the result of past processes and forms the basis for the creation of future landscapes. Traditional land-use activities are at least partially responsible for maintaining the high ecological quality of landscapes. Accordingly, landscapes change in a rather chaotic manner, while human interventions help to control this evolution on a regular basis through planned actions that are, however, rarely implemented as intended (Pena et al. 2007: 98.) In conclusion, the driving forces of landscape change and the change in itself, are not always negative but work sometimes to regulate and protect.

Driving forces are, as mentioned above, the forces that cause observed landscape changes, i.e., they are influential processes in the evolutionary course of the landscape.

The study of such driving forces of landscape change has a long tradition in geography and landscape research. Driving forces form a multifaceted scheme of dependencies, interactions, and feedback loops and they affect several temporal (i.e., years, decades, centuries) and spatial (i.e., landscape element, landscape, region, state or continent) levels. Consequently, landscape-change studies document and interpret the change of the landscape over time (Bürgi et al., 2004, 859).

Given the extent of landscape changes, concern about the sustainability of landscapes increases. That means, the capacity of landscapes to provide landscape specific ecosystems services that are essential for maintaining and improving human well-being like recreation (Wu, 2013). Landscape research focusses on understanding the reasons behind landscape changes and on the "driving forces", i.e., the forces that drive changes in and of a landscape (Bürgi et al., 2004, 858). Initially, the concept of driving forces was introduced in the late 1990s as an indicator framework for environmental policy. Here, the "driving Force-State-Response" (DSR) framework addresses a set of questions related to the complex web of agri-environmental linkages and feedbacks, including the causes of environmental conditions (driving forces), the effects on the state and the condition of the agricultural environment, and the responsive actions to change the state of the environment (OECD, 1999, 12). Today, the concept of driving forces is rather applied as a knowledge-basis about causes, developments, and results of landscape change. It has become fundamentally indispensable for the evaluation of policy interventions (Klijn, 2004, 202). As attention moves away from the traditional sectoral policies towards the before mentioned transdisciplinary landscape approaches, the understanding of these driving forces becomes more and more important. In the European context, this view has been reflected in the cross-sectoral approach of the European Landscape Convention that calls for the integration of protection, planning, and management of landscapes (Jones et al., 2007, 208).

To explain changes in a specific landscape, the distinction between intrinsic and extrinsic driving forces is helpful. For example, if the system includes an entire municipality, the community-level regulations are intrinsic driving forces, whereas legislation and regulation on the state and international level are extrinsic driving forces, i.e., they are part of the context. Landscape change is not always a result of planned and intentional actions. It also can 'happen' as an unexpected side effect. Thus, it is advisable to distinguish between intentional and accidental landscape changes and their respective driving forces.

The concept of driving forces distinguishes between proximate and underlying drivers of change. Proximate drivers refer to human activities at the local level that result in landscape change, such as agricultural expansion or urban sprawl. Underlying drivers comprise the fundamental social and natural processes (e.g. human population dynamics, agricultural policies, markets, or culturally embedded attitudes and beliefs) that underpin the proximate drivers and either operate at the local level or have a more indirect impact from the national or global level (Geist and Lambin, 2001; Geist and Lambin, 2002). Underlying drivers can comprise political, economic, cultural, technological, and natural factors (Brandt et al., 1999; Bürgi et al., 2004). Further, there are distinctions between interpreting human impacts as one of many influences and studies focusing on the interrelationship between humans and nature.

Mentioning Brandt et al. (1999), Bürgi et al. (2004) specify five types of driving forces and suggest standard procedures for the investigation of them:

- Socioeconomic Forces
- Political and Institutional Forces
- Technological Forces
- Natural Forces
- Cultural Forces

In the following, the concept of underlying and proximate forces will be shortly explained to give an overview for the practical part of this master's thesis. It is important to note that these factors are usually combined and never occur distinctively from another (Plieninger et al. 2016).

Underlying Driving Forces

Underlying driving forces are, as mentioned above, basic social processes, such as demography or policies, that establish the proximate causes and either operate directly at the local level or have an indirect impact from the national or global level.

The socioeconomic forces are the most important and challenging drivers of land change (Wu, 2013, 5778). They are basically based on economic decision-making. Strong drivers are globalization, market economy and effects of regulations and agreements by supranational institutions, like the World Trade Organization or the European Union (Bürgi et al., 2004, 859) that affect the local and regional economy. The ELC states in its preamble that sustainable development in the sense of balancing social needs,

economic activity and the environment is important. Moreover, there is public interest in the landscape, which is an important resource for economic activity and job creation (ELC, 2000). This statement already proves the importance of moderate socioeconomic conditions. These forces strongly influence land-use dynamics. Not only on regional, national and global level but also on the very local level, when prices of input factors and products change, or alternative income possibilities arise. This is especially important for rural landscapes (Brandt, 1999, 83). Strongly interlinked with the socioeconomic forces are the political and institutional forces as the economic and social needs are articulated in political programs, laws and policies (e.g., agricultural and fishery policies, spatial development policies and property rights). When addressing the effects of policies, one must not forget that disagreements between the intents and the ability to implement decisions may occur (ibid.)

The increasing application of new technologies is clearly visible in landscapes and is usually followed by a growing number of guidelines and policies. This process often brings along negative side effects on the environment (Brandt et al., 1999, 82). Linke (2017, 94), mentions the emergence of energy landscapes and the effects of the energy transition on landscapes. The energy transition and the associated spatial changes are discussed very controversially. Besides great approval, there are many critics who see a negative development in these changes, e.g., because the quality of the environment is emotionally perceived as threatened. In some cases, there is even talk of a destruction of the cultural landscape This statement contradicts the meaning of cultural landscape, both from a positivist (landscape as a cultural space modified by humans) and a constructivist (landscape as a construction of a society) perspective. An energy landscape is a cultural landscape.

Natural forces are, obviously, the natural conditions that landscapes face. Constituted by site factors (e.g., soil characteristics, spatial configuration, topography) and natural disturbances (from storms and floods to climate change) they affect regional and local variations in land use dynamics (Brandt et al., 1999, 83). The understanding of the natural conditions and consequences of this land use change in different landscapes affects the landscape as well. The occurring environmental trends are driven by several linked factors, which are not easily disentangled into manageable specific problems to be solved by specific policies. The complex nature of the phenomena requires that researchers who aim to inform policy making collaborate across disciplines and with societal stakeholders in order to address the challenges in an effective and realistic manner,

while also being aware of the plural ways of understanding and evaluating more specific situations. We need to understand not only the respective phenomena in depth but also the systemic nature of these and the various kinds of relationships that link them together (Ahlborg et al. 2019). Lastly, cultural forces are the most complex and the vaguest dimension of aspects. Cultural differences, ideologies and changing priorities and views influence the shaping of landscapes strongly, depending demographic trends, attitudes and behavior of inhabitants and other stakeholders (Brandt, 1999, 83).

Proximate Driving Forces

Proximate causes are the effects on landscapes at the local level, such as agricultural expansion, agricultural intensification and marginalization, urban sprawl and landscape fragmentation through road construction. Furthermore, new emerging landscapes, e.g. 'energy landscapes' with on- and off-shore wind turbines, but also climate change, rising sea level that leads to floods and therefore causes physical, economic and social damage at the local level are proximate drivers. The drivers that occur in the Wadden Sea region are analyzed in the practical part (Geist et al., 2002, 145).

4 Methodology

With the above elaborated theoretical basis at hand, the practical part of this thesis starts with this chapter. The aim of this study is to provide a synthesis of proximate and underlying driving forces of landscape change at the Southern coast of the North Sea – the Wadden Sea.

Evidence review and synthesis methodology has emerged as a widespread use in sectors of society where science can inform decision making and has become a recognized standard for accessing, appraising and synthesizing information. The need for rigor, objectivity and transparency in reaching conclusions from a body of scientific information is evident in many areas of policy and practice, from clinical medicine to social justice. Our environment and the way we manage it are no exception and there are many urgent problems for which we need a reliable source of evidence on which to base actions

The systematic review of driving forces of landscape change identifies and catalogues the available information from a wide variety of sources across different disciplines and institutions. The systematic review aims to identify, characterize and classify the proximate and underlying causes and driving forces of landscape change in the Wadden Sea. Furthermore, the objective of this work is to classify these driving forces in order to identify interactions between the proximate and underlying drivers. In this way, knowledge gaps can be identified that stand in the way of understanding and managing landscape change. In the following, we use the term cultural landscape as defined by the European Landscape Convention, according to which landscape is "an area perceived by man, whose character is the result of actions and interactions of natural and/or human factors" (ELC, 2000).

Although the study of driving forces is problem oriented and in practice not restricted to a specific method or framework, the methodological approach of most studies roots in general systems theory (Bürgi et al., 2004). The identification, definition and characterization of the studied region represents a crucial part. The systems approach allows describing the state of the landscape, the processes within the landscape, and the long-term reactions of landscape (ibid.). To underline the review, pictures of landscape elements and aspects will be added. Further, facts and data on main groups of actors, and most important socio-economic, political, technological, natural, and cultural driving forces will be added to the analysis.

Given the complexity of landscapes and landscape related processes, a clear concept regarding the aim of the study is especially vital. Here, the system definition includes a definition the study area and the grain of the study, the study period and the temporal resolution, as well as the landscape facets of interest. While defining the system under study, data availability and quality has to be considered, bearing in mind that retrospective studies are often limited by the characteristics of historical sources. The system analysis focused on the change of physical landscape elements, the actors and institutions, and the driving forces. First, change over time was determined. Before starting to collect data about potential driving forces, the system had to be defined. Relevant actors and institutions were selected based on their demands, interests, and potential impacts on the landscape under study. They can be located within or outside the spatial boundaries of the system. Based on general information about the study area and the major landscape changes, the potential driving forces from the five major groups of driving forces (socioeconomic, political, technological, natural, and cultural) are named. Most landscapes are affected by driving forces from all five groups. In the final synthesis, the actors, institutions, and driving forces were linked in causal relationships and their impact on the landscape elements under study was defined. The system synthesis is a challenging but crucial part in studies of driving forces (Bürgi et al., 2004, 861).

Although other methods would be appropriate for this topic such as interviews or survey, I chose this theoretical oriented approach due to feasibility. To be adequately representative, the data that would be needed for this master's thesis would exceed the scope of this paper as qualitative data would have to be gathered from a multitude of stakeholders. The concepts elaborated in the theoretical part show the amount of data to be analyzed and concluded in a reasonable and appropriate manner. Focusing on the interactions between physical and material aspects of landscapes and landscape changes, representations, the systematic review of existing research is the best option. Perspectives on the temporality and dynamics of landscapes, adaptation to climate change in the context of historical and contemporary transformations and the built environment, multidisciplinary, integrative, and comparative approaches from geography, spatial, social, and natural sciences, history, archaeology, and cultural studies to understand the evolution of human-nature interactions over time, and to examine the natural, cultural, and social values of places and landscapes are just a few elements that would have required investigation in a field study.

5 Case Study: Wadden Sea Region

After defining and explaining the principles of landscape, nature and landscape change, we will now apply the theory to the Wadden Sea region. First, we will narrow down the region to be studied. Next, we will address the question of whether the Wadden Sea is indeed a cultural landscape. For this reason, the regional history will be explained briefly to comprehend the very specific and globally unique relationship between nature and human. On this basis, the driving forces for landscape change in the region and its consequences will then be examined.

5.1 Study Region

We will start this chapter by introducing some key facts about the region to distinguish it from the rest of the large North Sea region. As already mentioned in the beginning, the Wadden Sea is the world's largest uninterrupted system of intertidal sand and mud flats worldwide. The Wadden Sea is an area of Outstanding Universal Value (UNESCO 2019) shared by three countries and as such of national and international importance. The region covers the North Sea coastal zones of Denmark, Germany and the Netherlands (cf. Figure 1), an area that covers broadly 22,000 km^2 and that forms the transitional zone between the European continent and the southern North Sea. The wetland area stretches from Blåvandshuk in Denmark to Den Helder in the Netherlands. The Wadden Sea as such consists of tidal creeks, mudflats, and salt marshes. The tidal mud flats, shoals, barrier islands and fertile marshlands (that are mostly lying behind the dikes) that are characteristic for this landscape, are almost equally divided between water and land. The land area measures approximately 10,700 km^2 is made up of about fifty Wadden or Frisian islands (1,120 km^2) separating the Wadden Sea from the North Sea, and the adjacent and diked marshlands on the mainland (9,555 km^2) (Schroor et al. 2017). Most landforms in the Wadden Sea region have formed and evolved from a marine tidal system over a period of more than 9000 years. The very distinct geographical landscape types within the area were classified by the CWSS in 2001 (see annex 1)

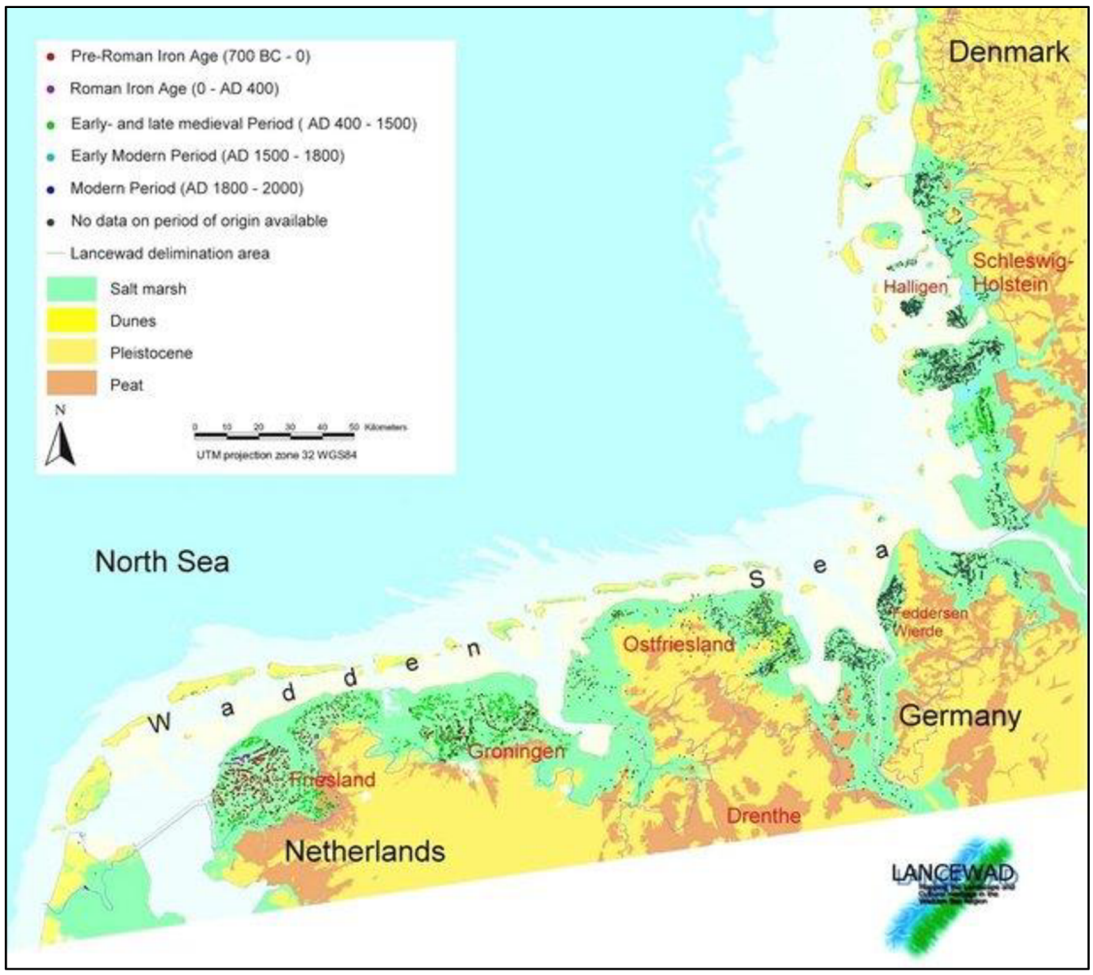


Figure 1 The Wadden Sea region along the coast of the northern Netherlands, north-western Germany and southwestern Denmark, with in the salt marsh areas thousands of terps, of different ages (dots, see legend). Dates give an indication but are not accurate (Vollmer et al., 2001).

The islands can be roughly divided into two categories: The larger group is the island-watt system with the sandy islands from Texel in the Netherlands to Skallingen in Denmark. The other, smaller group is that of the Halligen, which lie in North Friesland (Schleswig-Holstein, Germany) between the large sand islands and the coast and are remnants of former mainland marshes that the sea had broken up during storm surges. The islands not only separate the Wadden Sea from the North Sea but are also the most dynamic area of the Wadden Sea region, with their ancient societies shaped by agriculture and the sea.

The mainland consists of three main landforms. First, there is the low-lying, fertile, sea-created marsh, which forms today's salt marshes and diked marshlands, called 'polder' in the Netherlands, 'groden' or 'köge' in Germany, and 'koge' in Denmark. Second, the Geest as the high-lying, predominantly sandy moraines and outwash plains that were

formed during the last two ice ages. Third, the peat bogs of varying extent that lie in the hinterland. In some cases, lakes have formed as a result of peat cutting; in other places, the peat is still sealed by a layer of marsh clay.

Numerous other sedimentary coastal areas, such as the Mississippi Delta, the Banc d'Arguin, or the Arctic Lena Delta, have morphological similarities to the Wadden Sea in one way or another. However, in terms of climate, influence of rivers, tides or waves, there are differences, and many of these areas are much smaller. The Wadden Sea alone occupies about two third of the tidal area on the coasts of the Northeast Atlantic. Another distinctive feature is that sediments in the Wadden Sea are built up almost exclusively by the adjacent sea, while the influence of rivers is small or only locally present. Salinity corresponds to values between 20 and 30 psu, which is lower than the salinity of the open sea, but higher than that in estuaries, where most other intertidal areas are located. This is one of the reasons why the Wadden Sea is considered one of the most important areas internationally for migratory birds, and biodiversity is globally dependent on this area (CWSS 2021). In Europe, the tidal flats and associated salt marshes represent the largest contiguous habitat of this species. They are an essential element of the Wadden Sea ecosystem, which is a highly biologically productive ecosystem of great natural, scientific, economic and social importance. The rich and diverse transition zones of the Wadden Sea provide many habitats that form the basis for ecological diversity under extreme conditions (see Figure 2). According to the Wadden Sea Status Report conducted by the CWSS (2017), salt marshes alone contain approximately 2,300 species of animals and plants. In addition, the marine and brackish water areas are home to another 2,700 species. In its entirety, the Wadden Sea area provides biotopes for up to 10,000 species. The size of the Wadden Sea allows different species to survive by spreading across multiple habitats or occupying a range of niches over time. In this way, new areas are constantly being opened up to other individuals or species, and there is a high capacity for hosting migratory species. The rich and diverse habitats are important for many migratory bird species. Therefore, the Wadden Sea is essential to the existence of these bird species. Serious degradation of the Wadden Sea would mean a global loss of biodiversity.

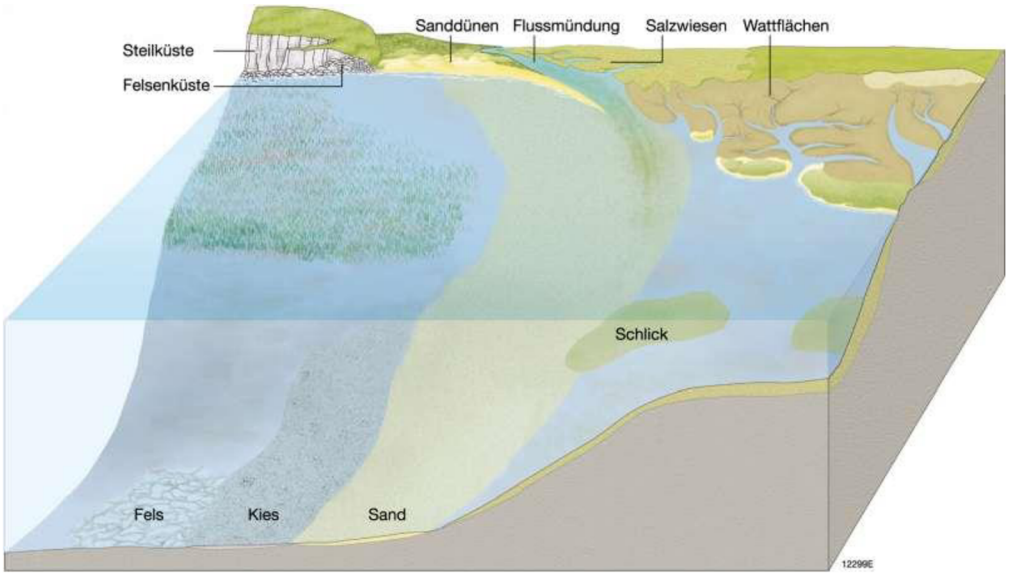


Figure 2 Ecosystem North Sea (Diercke Weltatlas, 2008)

5.2 The Wadden Sea Region – A Cultural Landscape

Although the Wadden Sea is primarily a natural landscape, it contains significant elements of cultural heritage. The numerous shipwrecks from the Middle Ages and early modern times, especially in the western part of the Dutch Wadden Sea, as well as the many submerged archaeological traces of settlement, agriculture and salt production in the Dollart, the Jade Bay and North Friesland, are just a few examples.

Despite regional and local differences, the Wadden Sea region forms a coherent landscape and cultural unit stretching from south of Den Helder in the Netherlands to Blåvandshuk in Denmark. Its unique landscape (see annex 1) and cultural-historical heritage are products of the transformation of land that has affected people, their culture and history so deeply unlike any other European region (Bauer et al. 2001: 119). The cultural heritage covers an area that goes deeply into the mainland. The cultural identity with the Wadden Sea and its coastal zones reaches till the large cities Hamburg, Bremen, Oldenburg (see Figure 3).

Many authors have used different terms and descriptions for the Wadden Sea region and its landscape. Without doubt, its diverse and unique characteristics make it difficult to find one fitting term: Natural landscape, bureaucratic natural landscape, a half-natural or half-cultural landscape, a maritime cultural landscape or a maritime agricultural landscape (Egberts et al. 2018: 19). In this part, we will concentrate on the terms cultural landscape and maritime cultural landscape. These different names all reflect

different aspects of this landscape that together encompass the Wadden Sea and its surrounding mainland and islands (see Figure 3). During the research for this master's thesis, nature, culture, heritage, landscape as well as governance of the area represented specific characteristics of the region, allowing to use all these different terms and creating the image of the Wadden Sea in a process.

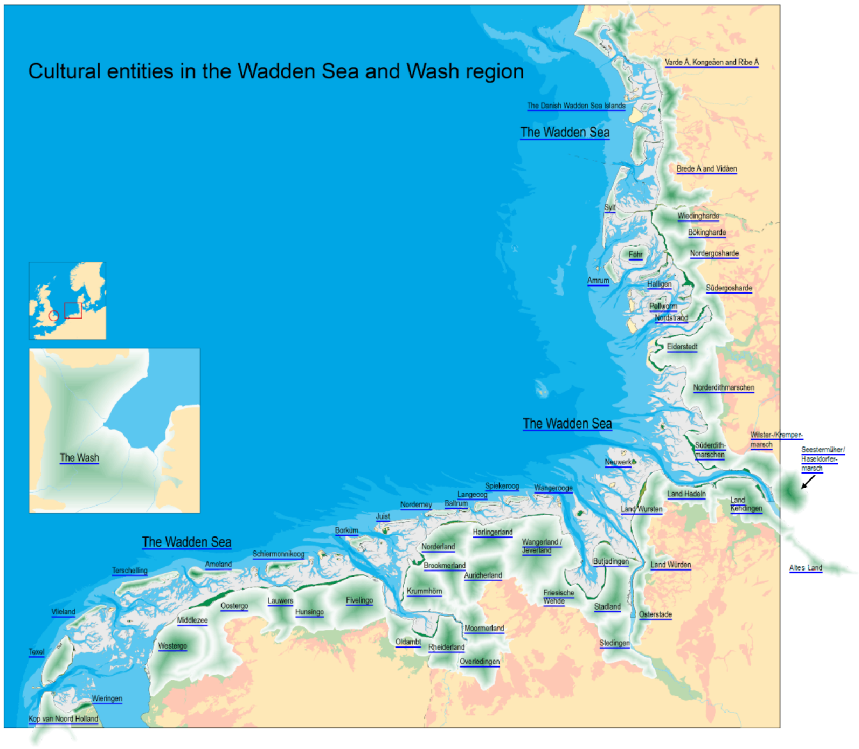


Figure 3 Cultural Atlas of the Wadden Sea (Lancewad Plan, 2008)

In 2001, a perception map of the region was created, exhibiting first associations and perceptions that people have with the Wadden Sea (Van Marrewijk, 2001, 169 as cited in Renes, 2018, 45). When thinking about the Wadden Sea region, the first association people have is the unique nature. The perceptions range from silence, space, vegetation and weather to human activities and the history of landscapes (Renes, 2018, 45). That is why the Wadden Sea region is not only nature but also and most foremost a (marine) cultural landscape. Its coastal landscape and its cultural heritage are manifested in its history and the maritime-agricultural landscape. The developed approaches to water management and respective organizations have set global standards for land reclamation. However, the perceptions on the Wadden Sea region have not been as harmonious forever. People's relationship with the sea has changed. For thousands of years, the unpredictable sea posed a danger:

Storm surges could flood fields, destroy farms, and even kill people and animals. Travel by land was very difficult due to soggy paths and bogs. Life on the coast was hard. The beauty of the coast and the healing effects of the sea air were only discovered during the end of the 18th century. More and more visitors came from far away to find rest and healing. They discovered the aesthetics of the coast, islands and mud flats. Now suddenly the landscape on the North Sea coast was perceived as something pleasant, special, relaxing and unique. The image of the sea changed in people's minds. A fascination for the Wadden Sea landscape developed, which still attracts many tourists to the coast today. The Wadden Sea is a special natural area, but it is no longer untouched nature. In generations of human effort to come to terms with the incredible forces of nature in this region, a cultural landscape has emerged. In the Wadden Sea region, the natural and cultural landscape merge with history to form an inseparable whole.

Figure 4 Typical Wadden Sea Landscape (Photo: Ko Hon Chiu Vincent, 2015)

Over the last thousand years, the art of human engineering has had an expanding influence on the Wadden Sea region. In both the late medieval as well as the early modern period, human activities such as land reclamation, peat cutting, salt extraction, diking, dredging, and harbor construction, together with climatic changes have strongly transformed the area's landscape structure. Both the northern parts (around the so-called Halligen) and the very western sections of the Wadden Sea are basically drowned landscapes and the result of ill-considered, unplanned interventions. As early as the 8th

century, Frisians migrated from the southern part of the Wadden Sea region to the west coast of Schleswig-Holstein and southern Jutland, bringing their land management techniques with them (Schroor et al., 2017).

Many methods of hydraulic engineering and peatland colonization for which especially the Dutch became renowned were initially established by Frisians living in and around the western Wadden Sea. From there, these practices were taken to the wetlands of Holland and Utrecht, and later, from the 12th century to the banks of the Weser, Elbe and Eider rivers, and then exported to England, France and Poland. Eventually, the Wadden Sea area thrived on modern commercial agriculture and maritime trade. From at least the 16th century and until the mid-19th century, population density in the region was twice that of inland areas. From a cultural perspective, the Wadden Sea region has been a laboratory for water management and environmental stewardship for at least 2500 years. One of the essential characteristics of the area is its island character, which includes not only the islands but also the marshes on the mainland, divided into peninsulas by inlets and estuaries. Compared to other coastal areas, urbanization was limited. Prosperity was expressed by the number of villages with fortified houses, which were transformed into manor houses and noble farmhouses around 1600, but not much of them can be seen today.

There is hardly any part of Europe where man has had such a profound and lasting influence on the shaping of the land. Until 1870, the Wadden Sea region was a supplier of tonnage and crews, dairy products, grain, building materials and even luxury goods (tiles, silver) for the North Sea trading metropolises (Amsterdam, Bremen, Hamburg). At the same time, it was a catchment area for immigrants and seasonal workers from the hinterland, attracted by the prosperity, the demand for labor and the high wages in the marshes. The fact that this traditionally prosperous early modern area, more or less overtaken by time, fell into the slipstream of commercial and industrial concentration has contributed to the preservation of numerous artifacts and landscapes of cultural and historical value.

Urban culture and cosmopolitanism were the result of centuries of maritime trade. Although coastal trade stagnated after about 1870, the region maintained close ties with urban centers through the supply of high-quality food.

Today, the natural areas of the Wadden Sea are particularly important and serve as tourist destinations for populations in urbanized inland areas. Continued human

interaction with nature has resulted in a great diversity of geographic landscapes and natural wealth. The current landscape bears witness to memories of the past and depicts different layers of cultural development. This ranges from archaeological remains to ephemeral vernacular architecture and fragile cultural artifacts (Knotterus, 2001, 12). The five main periods can be briefly characterized:

1. Prehistoric settlements on natural elevations and artificial dwelling mounds (before 400 AD)
2. Medieval long-distance trade (400-1050 AD)
3. Village life behind the dykes (1050-1500 AD)
4. Maritime commerce (1500-1800 AD)
5. Modern agriculture (1800-1900 AD) and the recent transformation of rural societies (1900-2000 AD).

For a more detailed overview, a table in annex 3 is provided (Lotze et al., 2005).

The importance of the area's cultural heritage goes far beyond the Wadden Sea Region itself. Few areas in the world have comparable physical circumstances. The amphibious landscape with its inherent dynamics required equally flexible strategies of survival. The adaptive strategies developed here provided a model for the reclamation of wetland areas all over Europe and beyond. Agricultural innovations, specialized crops, and novel breeds of domestic animals have gone all over the world. The indigenous traditions of self-government can be reckoned among the forerunners of modern democracy. Local pride and self-awareness have been admired by a wide range of writers and novelists (e.g. Theodor Storm's Der Schimmelreiter, Gustav Frenssen, Theun de Vries), whereas the landscape has inspired many artists as well (e.g. Emil Nolde) (Knotterus, 2001, 13).

5.3 Driving Forces of Landscape Change

This chapter represents the analytical part of the thesis. The beforementioned underlying and proximate driving forces that are responsible for landscape changes across Europe will be applied to the Wadden Sea region. Therefore, it is necessary to keep in mind that both the underlying and proximate forces are interconnected and cannot be regarded as lone standing. Several proximate changes are effects, causes or parts of underlying forces. A fitting example are the underlying natural forces as climate change that are influenced by socioeconomic activities and technologies. The proximate causes are consequently

entangled as well as climate change for example leads to a rise of the sea-level, more droughts, more floods and therefore has economic consequences. Additionally, political and institutional forces through policies will be needed to react to or prevent such negatives effects. In the following, the most important driving forces of landscape change will thus be analyzed. To start the chapter, a broad overview on the evolution of the Wadden Sea landscape will be given. The focus afterwards lies on landscape changes that have affected the Wadden Sea especially in recent times and the future.

5.3.1 Natural Forces and Evolution

The North Sea region is characterized by particularly high dynamics, which can be seen in the following features. Probably the most striking feature is the high tidal range and the resulting fluctuation of sea level (see annex 4). In addition, the location of the bay is open to the main northwest wind direction, which means that there are both stronger swells and stronger currents here than in other marine and coastal areas. A third, more inconspicuous feature is caused by glacial loose material of sediments in the sea, as this constantly changes the relief of the seabed. This is also directly noticeable on the coasts of the North Sea states, as it creates erosion opportunities that lead to corresponding morphological changes (Lüder 2014).

The natural dynamics were restrained by the underlying geological framework. Scientists found that geologic evolution was dominated by moraine plateaus, drumlins, and ridges formed by various stages of glacial extension during the last ice age. Several moraine ridges extend far into the sea and serve as fixed points for coastal erosion and sedimentation. Eroded moraine banks off Blåvandshuk, Fanø, Amrum and Texel also testify to sunken islands (Vollmer et al 2001: 27).

During the coldest phase of the last ice age, 20,000 to 18,000 years ago, global sea levels were 120 meters lower than today. The glaciers and polar ice sheets trapped a lot of water on the land. As a result, what is now the North Sea was a vast plain as large as the Netherlands, Denmark and the northern German coastal countries combined. The then tundra with forests and rivers served as a habitat for flora and fauna and as hunting grounds for humans (see annex 5). The area at that time between today's Great Britain, Denmark, Germany and the Netherlands is called Doggerland, although the exact location of land mass, glaciers and rivers is uncertain. As sea levels rose, Doggerland shrank until it disappeared altogether about 7000 years ago.

Toward the end of the last ice age, sea level rose rapidly, by about a hundred meters in 10,000 years. The flat plain of the southern North Sea became submerged. The English Channel opened between England and the European continent, and the Dogger Bank was flooded. On average, the sea level at that time rose by about one meter in a hundred years. This is about the same rise that is expected by the end of our century, triggered in part by the burning of fossil carbon stocks, leading to warming of the lower atmosphere and the upper layers of the ocean.

When the great ice sheets of Canada and Scandinavia had largely melted 8,000 years ago and the meltwater had reached the sea, further ocean rise slowed to 15 centimeters in a hundred years (see Figure 5). Only now could a tidal flat emerge. As elsewhere (e.g., delta of the Nile, the Mississippi, the Ganges) in the world, the almost stagnant sea level allowed the accumulation of sediments in the coastal area. Since then, the rise has been more or less balanced by sediments deposited in the tidal flats by a rough North Sea.

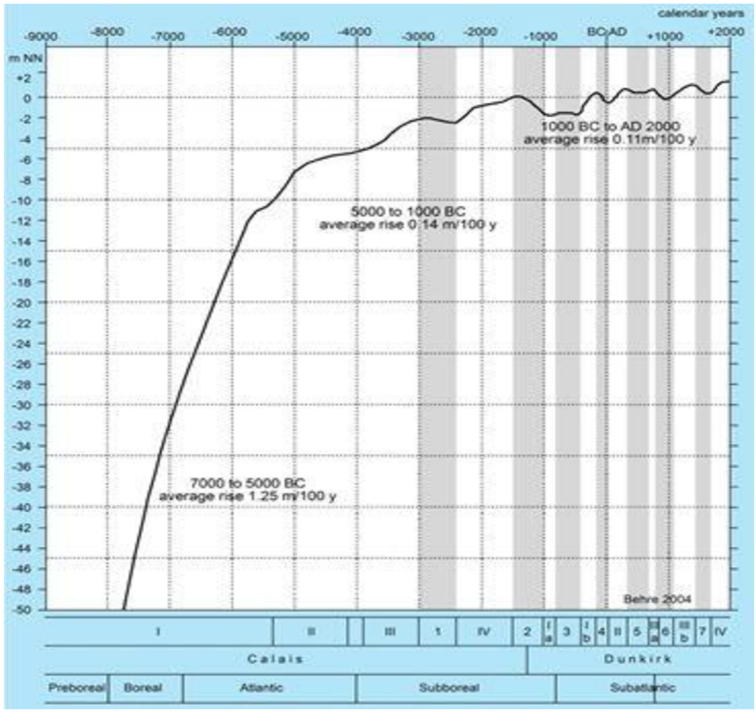


Figure 5 Transgression curve of the average tidal high water in the southern North Sea. K.-E. Behre, 2004

However, the slowing of the sea rise is not a sufficient explanation for the formation of the Wadden Sea. The coincidence of other conditions was crucial: The shallow North Sea was and is a very rough sea. Low pressure areas from the North Atlantic drove heavy seas in front of it, especially in winter. Where waves came into contact with

the bottom, they transported sand to the shore. During storm surges, the sea level rose to as much as three meters above normal tidal high water. The tides washed over land, bringing with them churned-up sediments. Thus, the land grew along with the slow rise of the sea. As sea level rose, so did the tidal range. Where it is less than 1 m, currents and wind form long spits of sand. Such are found today west and north of the Wadden Sea. At higher tidal ranges with stronger currents, the spits dissolve into island chains and sandbars. This is characteristic of today's southern and northern Wadden Sea. Where the tidal range rises to more than three meters, islands can no longer hold permanently, as in the central Wadden Sea. The increase in tidal range from the ends to the center of the Wadden Sea is favored by the right-angled bending of the coastline. Finally, large amounts of sediment are stored in the shallow North Sea, without which a Wadden Sea could not have formed. The North Sea basin filled with sand over millions of years, which allowed sandbanks, dune islands, and mudflats to grow. Tidal flats and salt marshes also grew as a result of organic sediments derived from the plankton of the North Sea and from mineral-organic suspended sediments, especially those formed in the brackish water of river estuaries. As a result, silt enters the Wadden Sea (Reise et al., 2014, 51).

The Wadden Sea with its dune islands, wide mudflats and salt marshes of sand and silt thus owes its origin to the interplay of the following four main factors: episodic storm surges, the high tidal difference due to the rectangular coastline, the constant sand input from the bottom of the North Sea, and the deposition of fine material from the rich North Sea plankton and floc formation in the river mouths. Thus, the amount of sediment washed up was more or less sufficient for the coast to rise with the sea. The coastline did not shift continuously further landward for 7,500 years as it had in previous millennia, when the sea level rose too fast for sedimentation to keep up. The Wadden Sea acts as a kind of buffer between the open sea and the mainland. Salt marshes and tidal flats added layer upon layer as sea level rose steadily. The outer sandbanks and dune islands were mostly shifted landward in the process (Reise et al., 2014, 43).

Today, the German Bight, has the tidal range the most pronounced (today 3 to 4 m), which is why barrier islands could not develop. At the outer margins of the Wadden Sea, the tidal range is lower (1 to 2 m), which favored the formation of continuous beach barriers. Barrier islands dominate the rest of the coastal area. However, many details of coastal evolution are still controversial, as the reconstructed phases of maritime transgression and regression are not generally accepted (Vollmer et al 2001: 27). The most

recent change can be observed at the German coast in Lower Saxony. In recent years, the Wadden Sea off Cuxhaven, the course of tidal creeks, has changed significantly. A special focus in this area is the tidal flat ridge between the Elbe and the Weser. This, relatively high, tidal flat ridge is practically the land connection between the island of Neuwerk and the mainland at low tide. A considerable part of the supply is carried out via the mudflats. Supplying the island by water alone is practically impossible. Due to changes in the tidal flat system, especially the deepening of the "Duhner and Sahlenburger Lochs", this connection is in danger. The satellite images (see annex 6), show the changes in the tidal flat system between 2015 and 2020. Within only five years, the "Duhner Loch" has breached the tidal flat divide between the Elbe and the Weser (Neuhäuser 2020). Here, the underlying forces are not only natural, but a mix of economic, natural and political forces.

Figure 6 The problem areas on the Wattenweg to Neuwerk, the "Duhner Loch" with the "Big Bag Damm" as well as the "Sahlenburger Loch" with the "Steinernen Furt" (Neuhäuser, 2020).

In short, a wide variety of barrier islands, channels, sand and mud flats, gullies, marshes were built under temperate climate and rising sea level, but also human intervention. The last one has expanded especially within the last century. The Holocene Wadden Sea has been able to keep up with relative sea-level rise as the Dutch basin and

its expansion prove. Relative sea level rise caused the basin to expand, increasing the volume of sediment holding space and resulting in net sediment transport landward. Erosion of adjacent shorelines represented a significant sediment supply that resulted in landward retreat of the entire barrier embayment basin system while retaining its basic features (Elias et al., 2012: 293). With the natural drivers of landscape change elaborated, we now move on to the next chapter, where the man-made causes of landscape change in the southern North Sea will be outlined.

5.3.2 Human Interaction

Increasing population density, extensive coastal development, and coastal protection structures such as dikes, walls, revetments, groins, and jetties have increasingly impaired or restricted the natural dynamics of many coastal systems, including the Wadden Sea. As measurements show, the mean sea level has increased continuously for 0.20 m per century over the last 150 years (Figure 7) and is likely to accelerate in the future due to global warming (Figure 8). Most European coastal regions experience increases in both absolute sea level (as measured by satellites) and relative sea level (as measured by tide gauges), the latter being more relevant for coastal protection. There are sizeable differences in the rates of sea level change across Europe.

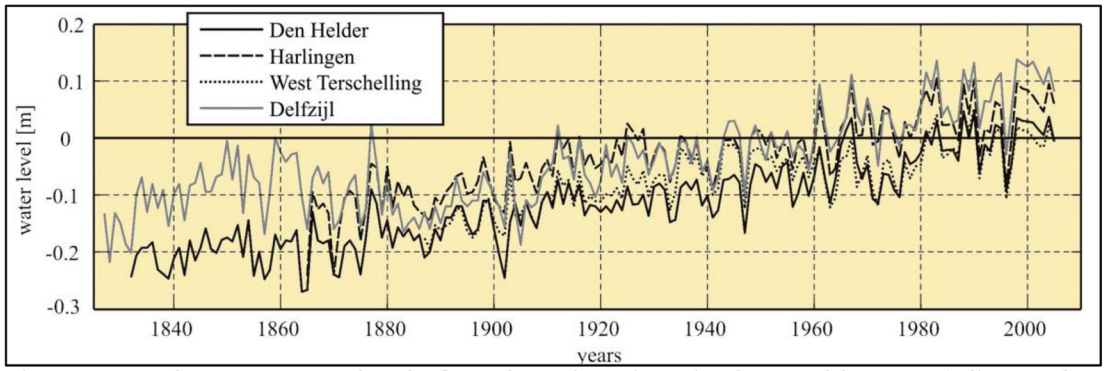


Figure 7 Yearly mean water levels for selected stations in the Wadden Sea (Elias et al., 2012)

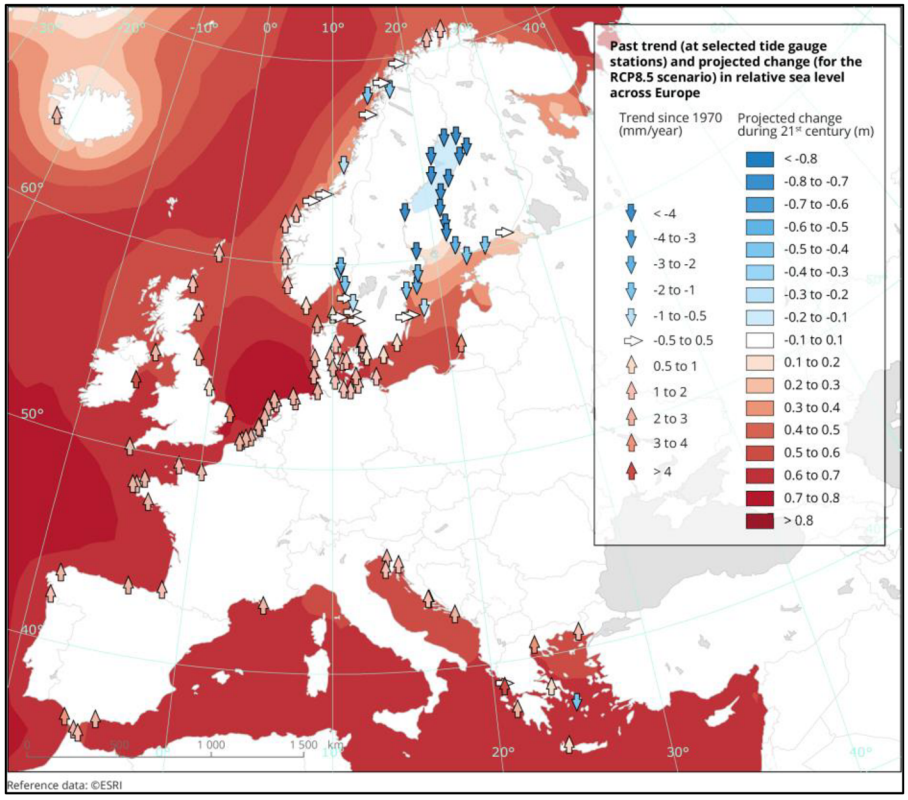


Figure 8 Past trend and projected change in relative sea level across Europe (EEA, 2020)

5.3.2.1 Protection Against the Rough Sea

The first major transformation of landscape occurred during the medieval ages as mentioned in chapter 2.5. This change began in the hydraulic engineering society of the Netherlands, from where the new landscape architecture spread east and north through the Wadden Sea region. From the 10th century onward, dike construction replaced the construction of terps and transformed the salt marshes, some of which had been settled for more than a thousand years, into diked marshlands crossed and drained by a system of ditches and freshwater lakes. In the beginning, small so-called ring dikes were to protect the individual polders. Later, whole systems of linear dikes developed, which are the massive dikes of today. In many places, entire systems of deserted, replacement and other back dikes have survived, some of which are still in use. Together with sluices, culverts, windmills, and other coastal protection structures, dike culverts, ponds reminiscent of earlier dike breaches, and circular channels and dikes around reclaimed lakes provide indispensable information about the evolution of the cultural landscape (Schroor et al., 2017).

The construction of the dikes had far-reaching consequences. The inundation space for the water masses rising during storm surges became smaller and the wave

energy could no longer spread over wide salt marshes, but often hit the dikes directly. The larger the diked area became, the stronger the dikes had to become to withstand storm surge situations. In addition, the dikes blocked sediment from entering the land through storm surges, so that the diked areas could no longer grow with the rise of the sea. In addition, rainwater in the diked areas was collected in ditches and drained through channels and sluices into the Wadden Sea at low tide. This drainage accelerated mineralization in the marsh and fen soils, and these soils subsided. The diked marsh began to subside and slowly, but widespread, fell below sea level. The risk of flooding increased accordingly, and the dikes had to be reinforced (. The difference in elevation between land and sea also increased in places due to peat cutting. The peat was used as fuel and the soil underneath could be used for agriculture after the water was pumped out (see Figure 9). Peat extraction was also carried out in the past on the un-diked marsh. There, the peat had absorbed seawater, and after extraction it was dried and burned so that salt could be extracted from the ashes (Reise et al., 2014, 53). Regionally, the salt trade was of great economic importance and ensured prosperity, but inevitably led also led to land losses.

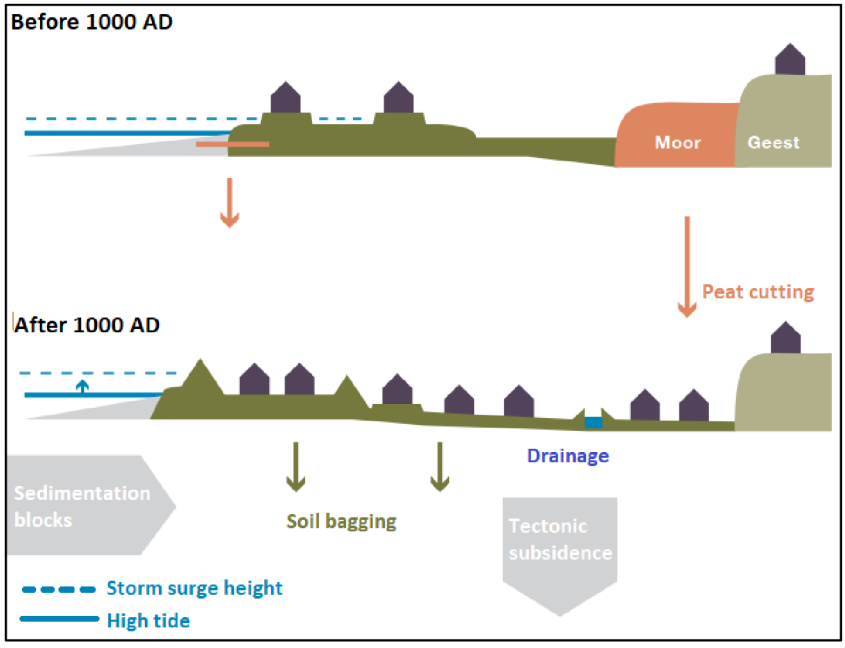


Figure 9 Schematic profile of the marsh landscape before and after 1000 AD (after Reise et al., 2014)

Behind the dikes, new buildings and houses were no longer adapted to the rising storm surge level and were built at ground level. Settlement density increased because the diked land allowed for highly intensive agriculture. The first line of dikes was intended to protect all of these. There was no spreading of the risk of flooding. Where

dikes could not withstand a storm surge, disaster ensued. This could only be avoided by constantly improving dike protection. But when additional external or internal stresses were experienced, such as malaria or the plague, hunger, political instability or even war, it was no longer possible to take sufficient precautionary measures, which resulted in increased dike breaches and flooding. It was difficult to pump the water back up from the deep land into the sea. Thus, the Wadden Sea continued to expand. The Zuiderzee, the Middelzee, the Lauwerszee, the Dollart, the Leybucht, the Harlebucht, the Jadebusen and the North Frisian Wadden Sea expanded over land where previously mostly people had lived and farmed (Reise, 2005).

Storm surges were not the sole cause of this development. The long-term effects of dike construction could not have been foreseen when the first dikes were built. Social structures were no longer up to the ever-increasing task of coastal protection due to a rising sea and sinking land at the same time. Disasters became almost inevitable. Many people died in the floods and those who lost their property had to leave. However, the landscape did not evolve back to a natural coastline. The remaining and restored dikes maintained the sharp boundary between sea and land. The gradual transition from mudflats to a broad belt of salt marshes or brackish reeds and from there to marshes or forests was lost forever and never regenerated (see Figure 10).

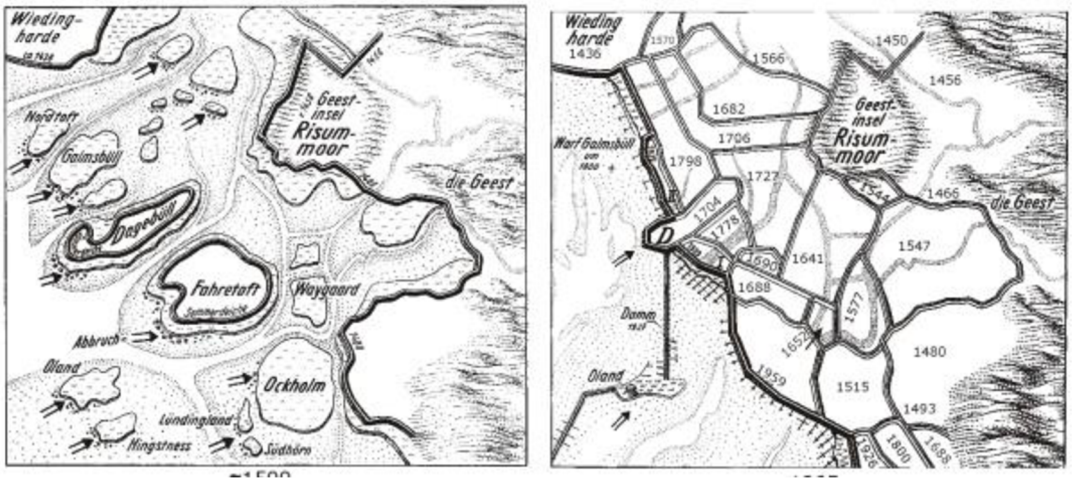


Figure 10 An approximately 20 km long coastal section in North Frisia around the village of Dagebüll 500 and 40 years ago. From an island and bay-rich coastline, a relatively straight coastal front was created by successive embankments. Arrows indicate receding shores. Polders with year of embankment (after Reise 2005)

The fears of the North Sea burned deeply into the mentality of the coastal inhabitants and an enemy image towards the wild and dangerous North Sea emerged (Jakubowski-Tiessen, 2011). Nevertheless, a turnaround in coastal design failed to materialize,

and a solution was seen in technological progress, which allowed the construction of dikes that were much stronger than before. In addition, new land reclamation methods were used to reclaim lost land. A so-called foreshore was created in front of the dikes to take the force out of the storm surge waves before they hit the dikes. This foreland was drained by a system of ditches after flooding. At the same time, the foreland served as pastureland. Seaward, scrub slopes dampened the force of waves, increased sedimentation, and encouraged pioneer salt marsh vegetation, which replaced natural salt marshes and significantly reduced biodiversity.

Coastal protection became increasingly expensive and eventually became entirely the responsibility of the state (Knotterus, 2005), and defense against the sea became more steadfast. By the 20th century, coastal protection technology and the professionalism of coastal engineers had developed to the point where large-scale embankment projects could be planned could be planned. Dams were built across tidal flats and through deep tideways. Most bays were diked and thus became farmland. The reasons for these projects were economic on the one hand, and cultural on the other. People felt an obligation to reclaim the land once lost to the sea. Taking advantage of all of all technical possibilities, tidal flats were diked that had never been land before. In large steps, the Wadden Sea became smaller again (Reise, 2005).

The most extensive project was the damming of the large Zuiderzee in 1932. This brackish water bay was partly transformed into agricultural polders and partly into a freshwater lake (the Ijsselmeer). In other places dams were built through the mudflats to the islands of Sylt with the Hindenburg Dam (1927) and Rømø (1948). These dams were for transport access and were also intended to promote land reclamation. Eventually, there were even plans to connect the dune islands by damming the lows, thus converting the entire Wadden Sea into land. However, these plans were no longer implemented (Kabat el al., 2012, 8). A schematized cross-sectional reconstruction as an example of dike construction is provided with annex 7.

5.3.2.2 Protection of the Natural Wadden Sea

As a result of several independent developments, attitudes toward the Wadden Sea changed fundamentally beginning in the 1960s (Wolff, 1992). The changing economic situation in Europe put an end to the need for new farmland through elaborate diking. New dikes were thus built only to improve infrastructure and increase safety. Further, as a result of the dike strengthening programs, people began to feel increasingly safe behind

the dikes. As a result, the sea was no longer perceived primarily as a threat, and the public began to be increasingly concerned about the state of nature worldwide. In particular, tourists and conservationists also saw the Wadden Sea in danger (Goeldner, 1999, 25). Pollution, excessive hunting and overfishing, urbanization, industrial agriculture, eutrophication in rivers and coastal waters were the many reasons for raising concern. In the Wadden Sea, there was more resistance with each additional loss of salt marshes and tidal flats (Wolff, 1992; Goeldner, 1999, 25).

The value of remaining natural areas became increasingly important and relevant in public opinion relative to traditionally used lands. Where further loss of natural areas could not be avoided, compensation was now required by law. Mudflats and natural salt marshes were thus protected from encroachment. Attractive natural areas became an economically important factor for the burgeoning tourism industry on the Wadden Sea islands. The recreational value of the coast was no longer limited to the sandy beaches, the surf and the fresh sea air, but now also included quality features such as biodiversity and species diversity. Guided tours of the tidal flats became a tourist attraction. Young volunteers explained the nature of the Wadden Sea to visitors. Vacation camps for young people were organized to study the distressed nature, and in schools the unique Wadden Sea became a teaching topic. Books and films about the pristine nature and dynamics of the Wadden Sea reached a wide audience. All this led to a change of mentality on the coast.

Since 1978, the Netherlands, Germany and Denmark have been pursuing a common nature conservation policy in the Wadden Sea (Kabat et al., 2012). In 1982, a joint declaration on the protection of the Wadden Sea was signed, in 1987, a Joint Wadden Sea Secretariat was established for better coordination, and since 1991, environmental parameters have been collected on a large scale and in a standardized way, which are summarized and published in quality reports every five years. A trilateral management plan for nature in the Wadden Sea was adopted in 1997 and updated in 2010. Uninhabited areas of the German Wadden Sea were declared national parks in 1985 and 1986. In 2009, UNESCO included the Wadden Sea in the World Heritage List. Since 2014, the entire Wadden Sea has been a World Heritage Site (CWSS, 2020).

Some provocatively consider a discussion among researchers on the area's defining characteristics waste of time. However, in one way or another we have to deal with the fact that the area is officially designated by UNESCO as natural heritage based

on existing protection regimes at the national and regional levels. The ability to put an exclusive label on something is always an expression of a successful claim by a certain group on the object being labelled. In the case of the Wadden Sea (region), this is the successful claim of nature conservationists and their supporters, who have indeed revolutionized our view on the area since the 1960s (Reise et al., 2014, 7).

Once an obstacle for maritime navigation, once coveted by farmers as potential farmland, the Wadden Sea is now valued for its naturality. The perception of the Wadden Sea as a natural entity that transcends political boundaries first took shape in 1975. A group of Dutch-German-Danish scientists met on the island of Schiermonnikoog. They presented a white paper and recommended that the three governments jointly protect the Wadden Sea. Since 1978, Denmark, Germany and the Netherlands have cooperated to jointly protect and manage the Wadden Sea as an entity that makes the Wadden Sea one of the highest protected areas through national parks and nature reserves for the benefit of present and future generations (CWSS, 2018).

An exemplary cooperation started with regular ministerial meetings, a joint declaration of the governments on the protection of nature in the Wadden Sea, a secretariat for the cooperation, a management plan with nature conservation goals and a sophisticated monitoring program on the nature values, supported by joint research projects and the nature conservation associations in the region. The world's outstanding natural values, jointly protected by the governments of the Netherlands, Denmark and Germany - with the three state governments of Lower Saxony, Hamburg and Schleswig-Holstein - finally received international recognition with the designation of the Wadden Sea as a World Heritage Site by UNESCO. The Wadden Sea is now one of the most famous natural coasts in the world, together with the Everglades in Florida, the barrier reef of Australia, the Galapagos Islands or the Sundarbans in India and Bangladesh (Reise et al., 2014, 7).

Figure 11 The Wadden Sea World Heritage Site (CWSS, 2020).

5.3.2.3 Economic Activities

The Wadden Sea has always been a dynamic landscape. With only minor changes in sea level, large areas could sink into the sea, become uninhabitable, or become available again as a settlement area. Storm surges made life on the coast difficult, as did the numerous marshes and bogs. The early settlement history is therefore incomplete, archaeological sites sank into the sea just as people avoided the area again and again for centuries. To this day, coastal protection is a dominant theme for life on the tidal flats; the mainland is characterized by dike construction and drainage, and the sea and its sediments continue to define the cultural area to this day.

Although the traditional economy of most of the Wadden Sea region was farming, the economic importance of the sea itself cannot be overestimated. On the islands fishing, whaling and other maritime activities were economically dominant during the 18th century. On the Dutch Frisian islands, the supply of ships with provisions and water as they waited in sheltered anchorages in the lee of the islands was a significant part of the economy. The importance of seafaring to the Wadden Sea and the treacherous nature of the sand flats and navigable channels means that structures relating to navigation are widespread. Lighthouses are a particular feature of the Frisian islands (Schroor et al., 2009, 9).

Sea born trade was important from at least the middle of the 1st millennium AD, (and may well have been so from later prehistory). Such was the importance of water born trade and transport that harbors and wharfs were widespread. Many of the dwelling mounds had such facilities and harbors developed around sluices in sea dikes. In the Viking period, Ribe, the oldest town in Denmark, was one of the foremost trading centers in southern Scandinavia. During the medieval period, many towns including Tønder, Husum, and Meldorf were active trading ports. The Wadden Sea was a stronghold of the Hanseatic League with the Weser and the Elbe, providing access to the great trading towns of Bremen and Hamburg (Schroor et al., 2009, ibid). As part of the North Sea, the Wadden Sea lies along some of the busiest shipping routes in the world. Within and near the Wadden Sea are some of the largest ports in Northern Europe, which are of great economic importance to the region as well as internationally. The most important ports in the Wadden Sea area are the German ports of Hamburg and Bremen/Bremerhaven, the oil refinery and port of Wilhelmshaven, and the ports of Esbjerg in Denmark and Delfzijl in the Netherlands. In addition, the routes to the ports are used to connect

the Baltic Sea with ports around the world via the Kiel Canal. The area seaward of the Wadden Sea is increasingly being used for the construction of offshore wind farms, resulting in significantly increased shipping traffic for maintenance work than previously expected (Bahlke, 2017).

The importance of ports in the region was not only linked to trade but also to military activity. The city of Den Helder lies at the southernmost point of the Wadden Sea region, the town was a major naval base from the late 18th century and has a series of historic defenses from the Napoleonic period onward. Ports were developed at a number of coastal locations in the 19th century including Glückstadt, and Esbjerg, and a major naval base was created at Wilhelmshaven, now somewhat in decline and seeking opportunities for regeneration.

The Weser and Elbe estuaries were heavily modified, especially in the 19th and 20th centuries, to facilitate their role as important transport routes. In contrast, the Varde estuary in Denmark is the best example in the entire Wadden Sea region of an un-diked estuary where marsh processes have not yet been completed. Numerous natural and man-made watercourses were the main means of transport for centuries. Although water transport is now largely superseded by road transport, the road and rail network are not well developed by modern standards and the area is not particularly well served by major roads. Den Helder is served by two major roads, and a main railway line makes this area one of the better-connected parts of the Dutch Wadden Sea area. The construction of the Kiel Canal at the end of the 19th century had a significant impact on the southern part of Schleswig-Holstein. In the 21st century it is likely that major infrastructure projects in some parts of the Wadden Sea may have similar effects. Historically wind power has been of significance throughout the Wadden Sea and historic windmills are features of many parts of the region (Schroor, 2009). However, over the last 20 years huge wind turbines with a span of over 150m have become common in many parts of the area and have had and will continue to have a significant impact. The dimensions of offshore wind turbines are gigantic. The total weight of a turbine can quickly exceed 1,000 tons. The turbines stand on foundations weighing up to 900 tons. The machine house alone can weigh between 300 and 400 tons. The 5-MW turbines installed in the alpha ventus test field, for example, have a rotor diameter of up to 125 meters and a total height of more than 170 meters above the seabed. Newer turbines in the 6 MW power class achieve rotor diameters of around 150 meters. The sector of renewable offshore energy

has created about 15,000 jobs from 2010 to 2015 alone (Stiftung Offshore-Windenergie, 2017) and new turbines are installed every year (see Figure 12)

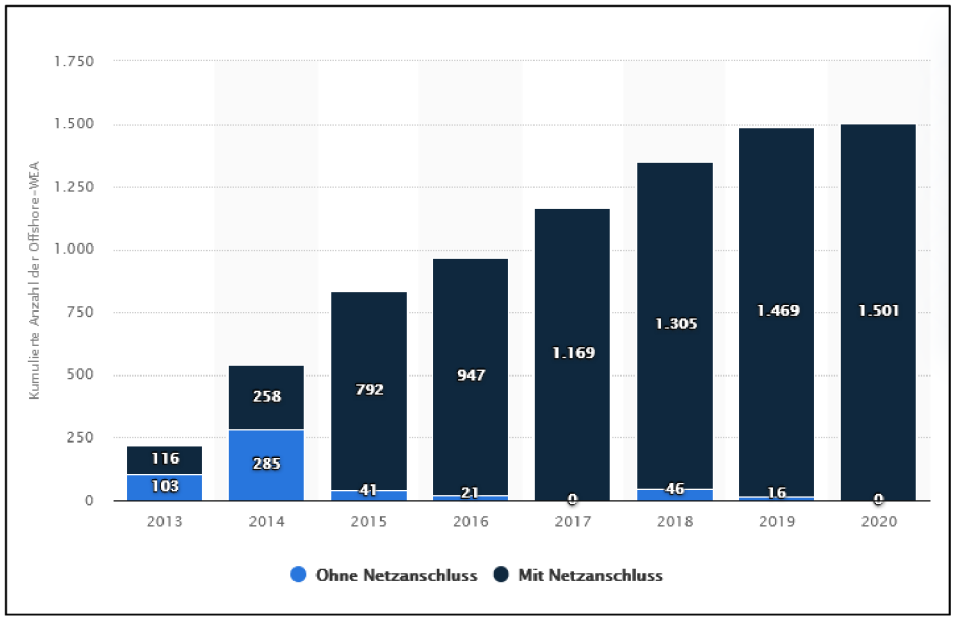


Figure 12 Number of offshore wind turbines in Germany in the years 2013 to 2020 (Statista, 2021)

Tourism began to develop in the late 18th and early 19th centuries as part of a wider European fashion for sea bathing. During the 20th century tourism became a major activity in the Wadden Sea region and now, on the Dutch Frisian islands, more than 40% of employment is related to tourism. Tourism has historically been concentrated on the coast and particularly on the islands, and despite the development, particularly in the second half of the 20th century, of a broader interest in the marshland landscapes and towns of the mainland this remains the case. Sylt is probably still the place with the highest number of tourists in the Wadden Sea. However, the immense impact and importance of tourism in the region may be illustrated by the fact that Neuwerk, with a permanent population of about 40 people, caters for around 120,000 visitors per year (Schroor et al., 2009). The tourism infrastructure has influenced the landscape in the Wadden Sea region very strongly (see annex 2, picture of Texel).

Tourism represents one of the most important economic pillars in Germany's, the Netherlands' and Denmark's coastal regions (23.8 million overnight stays in Germany in 2017) (Statistisches Amt für Hamburg und Schleswig-Holstein, 2017, Landesamt für Statistik Niedersachsen, 2017). Of the revenues generated by tourism in the coastal states, a portion becomes wages or salaries directly. These triggers further spending in the region through multiplier effects. It is a revenue generator and

contributes to the financing of public budgets through tax revenues. On the Schleswig-Holstein North Sea coast alone, tourism generated total gross sales of 1.7 billion euros in 2015, generating tax revenue of 153.1 million euros for the federal, state and local governments (Dwif, 2016).

A total of 40,000 employees were subject to social insurance contributions in the accommodation and catering sectors in the North Sea region of Lower Saxony in 2016 (Tourismusverband Nordsee, 2018). 226.000 employed persons in Lower Saxony made their living directly from tourism in 2015 (Nds. MW, 2017), while in Schleswig-Holstein there were a total of 151,000 employees in this sector in 2017 (Landesportal Schleswig-Holstein, 2018). However, the number of businesses declined slightly. In Schleswig-Holstein, value added of €4.5 billion was generated in tourism (including day tourists) in 2017 (Sparkassen-Tourismusbarometer Schleswig-Holstein2018). For Lower Saxony, a direct gross value added of around €8.1 billion was determined in 2015 (Nds. MW, 2017). Overall, the number of overnight stays has continued to increase since 2010 (Statistische Ämter der Länder, 2018).

The relationship between tourism and the environment is ambivalent. An intact nature and environment are an important basis for tourism. According to Reiseanalyse (2014), 68% of guests in Schleswig-Holstein want to experience nature on their vacation. In the Tourism Strategy Schleswig-Holstein 2025, the state acknowledges its commitment to advancing sustainability in tourism in cooperation with all stakeholders benefiting from tourism. According to the mission statement, sustainable tourism includes, among other things, protecting nature, resource conservation and management in operational activities, creating and communicating nature experience offerings, and working in partnership with nature conservation and environmental protection. In addition, many coastal tourist resorts are committed to clean beaches, for example through regular trash collection campaigns with locals and guests. On the other hand, however, tourism is also a potential pollution factor (e.g., trash and pollutant inputs, source of disturbance to marine organisms, habitat degradation, coastal erosion).

For the North Sea coast, the World Heritage status of the Wadden Sea has positive impacts on tourism. In order to maintain this attractiveness factor, to communicate it credibly and to profit from it in the long run, nature and environmental protection play and the protection of the cultural landscape play an important role. Increased sustainability in tourism is a prerequisite for the preservation of the values that have led to

the UNESCO designation. For this reason, a joint strategy for sustainable tourism in the Netherlands, Germany and Denmark have developed a joint strategy for sustainable tourism in the Wadden Sea Wadden Sea World Heritage Site was developed and presented at the Trilateral Intergovernmental Conference on the Protection of the Wadden Sea in Tonder in 2014.

6 Results and Discussion

Now that the state of the art of influences on the Wadden Sea region and landscape have been examined and described, the driving forces will now be discussed.

The region combines its heritage values with high ecological values. As such, the cultural landscape of the Wadden Sea faces not only one type of landscape change. This becomes evident when looking at the above-described historical changes. The Wadden Sea ecosystem has been changed by human impacts over millennia. During the interdisciplinary research and analysis, the human impact and the natural changes became clear. The forces of landscape change that impacted the region, its ecosystem and the inhabitants became evident as the interrelationship and interdependencies of these different forces responsible for the change. Especially socioeconomic and natural factors were identified for major changes in the Wadden Sea region. However, the review exhibited that there are not only one or two driving forces of landscape change at hand (Jepsen et al., 2015; Brandt et al., 1999; Bürgi et al., 2004). The landscape changes that occurred over the past centuries and the ones that occur until today have always been a combination of all underlying types of landscape change mentioned in chapter 3.1.

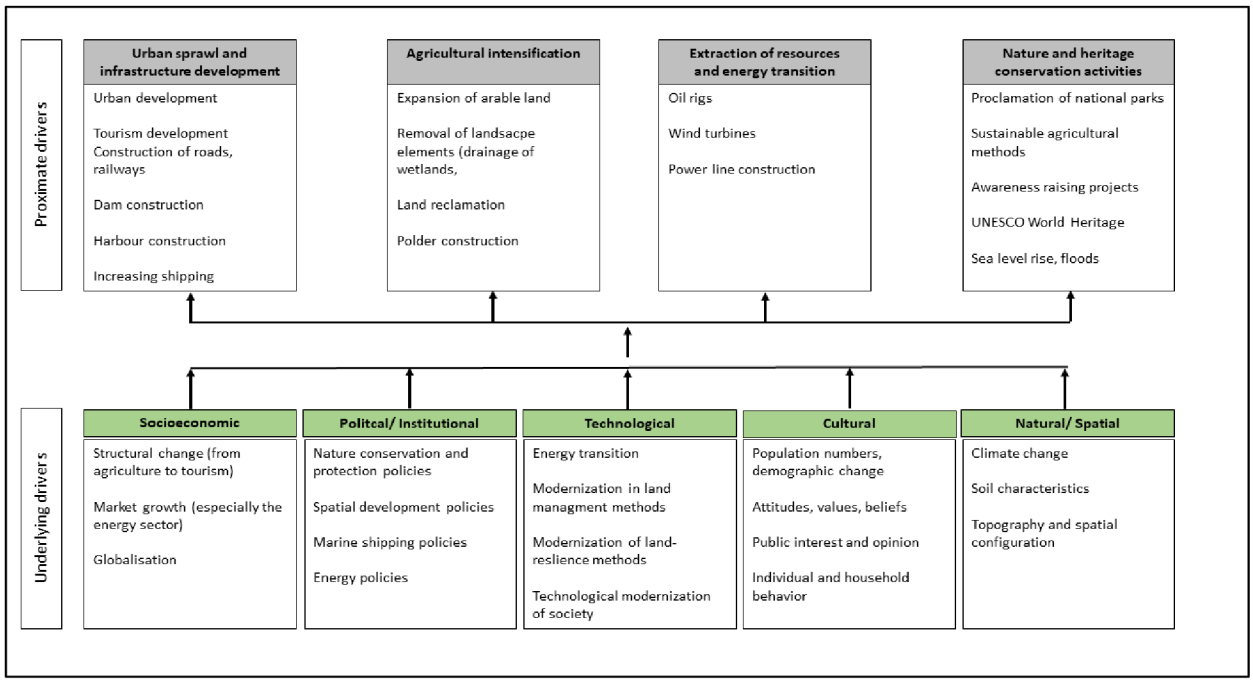


Figure 13 Interrelations between underlying and proximate drivers after Plieninger (2016)

Figure 13 shows that every proximate driving force is influenced by underlying causes and. The most obvious proximate drivers of landscape change were roughly displayed to show the embedding of proximate drivers in the context of several involved and interlinked underlying drivers. When we take the example of the first dike constructions in the medieval age, we have socioeconomic causes for the construction at first hand, as they shall protect the land from floods to ensure agricultural production on polders. However, this economic reason is not the only one as the dikes had to be built as the natural forces of the tides and floods and the constant climate change threatened the productivity and inhabitants and as such, made the dike building a necessity. As technological modernization occurred, the dams and dikes became stronger, and the people felt safer leading to a shift in the cultural sphere. Since the people did not fear the sea anymore, this public attitude led to new views on the sea and its use. The sea was now seen as a recreational space and tourism increased. Altogether, these are driving forces for environmental pressure and the reason for new landscape changes due to new functions and new societal demands in infrastructure for instance. New roads and highways were built to reach the destination Wadden Sea and the nearby ports of Bremerhaven, Hamburg or Rotterdam.

Further, the climate change and the direct affection of sea level rise on the inhabitants of the coastal zones have led in a shift of the public opinion on nonrenewable resources, especially fossil fuels and the construction of on- and off-shore wind energy. The energy resources (gas, oil and wind) are exploited right in or at least with consequences to the Wadden Sea. In the Netherlands gas subtractions partially cause subsidence effects, with impact to an ecosystem under the influence of changing sea levels. The only active oil field in the Wadden Sea is located in Schleswig-Holstein and is being exploited from an oil rig (Baer et al., 2017). The oil rig 'Mittelplate' is located 7km from the coast and started in 1987. Before and since the construction, there has been much protest against the construction as a major intervention into the landscape and the ecosystem Wadden Sea. In addition to fossil fuels still being harnessed exclusively in the Dutch and German Wadden Sea, all three Wadden Sea states have increased their wind farming activities. The vast majority of offshore wind power plants are positioned in the North Sea. However, transfer cables to the coastline are laid through the Wadden Sea causing impact. transition to a greener economy and the demands of people are responsible for a shift in landscape change (Baer et al., 2017).

However, perceptions have changed and the transition to a greener economy has started. Although the oil rig in the Wadden Sea is still online, it seems unlikely that the oil extraction will be expanded (Müller, 2019). Therefore, off-shore and on-shore windfarms will increase as mentioned in the previous chapter. Here, there has been much controversy as well, as the wind turbines endanger migratory birds, disturb the darkness and indirectly increase the shipping as the wind turbines need to be maintained.

Susanne Kost (2017) deals with 'images of space' in relation to social developments. The term 'landscape' moves between 'materiality and pictoriality', based on the assumption that certain structures in space constitute 'landscape' and at the same time certain 'images of landscape' are created in the mind through social values and attributions. Striking 'landscape changes' took place, for example, in the age of industrialization. Currently, the 'landscape image' is changing in the course of the energy transition. Based on a survey of young people in East Frisia, Susanne Kost investigates which 'images of space' they have and how current processes of change are inscribed in them. As it turns out, 'landscape' is primarily characterized by 'natural features' such as the sea, beaches and dunes, supplemented by structural elements, infrastructure and designations of 'landscape spaces'. In East Frisia, wind turbines seem to have already become an 'important element of landscape' for young people, which already expands the spatial image for this generation. How and what is perceived is again to be seen as part of a permanent learning process. Among other things, disputes about wind turbines or the construction of power lines by young people are named as conflicts - and thus topics of broad public debate. In addition to traditional images of space, changes are thus also taken into account, with which there should generally be a greater preoccupation. This shows how landscapes are subjectively considered aesthetic and under which circumstances new energy landscapes challenge this understanding of the aesthetic and the familiar. On a social constructivist basis, changes in the perception of landscapes can be identified here. These problems of acceptance are, especially in relation to changes in the course of the energy transition, one of the 'great challenges of our time'. Conversely, this means that if not only the 'beautiful' but also the 'sublime' and the 'ugly' were more accepted, opportunities for new 'energy landscapes' would arise. At the same time, landscapes have always been subject to processes of change - and this not only in the course of the construction of wind power plants, which is so controversially discussed today.

7 Conclusion

Knowledge of the history of the Wadden Sea and other ecosystems is enormously important because similar changes are taking place in other parts of the world. We have only just begun to understand how profoundly humans have affected and continue to affect landscapes, and how dramatic the consequences are for ecosystems and societies. In the Wadden Sea, coastal society, dependent for centuries on agriculture and a variety of fishing and hunting practices, experienced a cultural and economic collapse in the 19th and 20th centuries. It transformed from a diverse resource-based economy to a service-based economy. The current resilience of the Wadden Sea ecosystem and society to environmental change is likely low. However, history teaches us that long-lasting changes can be reversed if action is taken. Diversification, restoration, and recovery of species and habitats are necessary to improve landscape and ecosystem resilience.

This work has shown how factors that at first glance do not appear to be associated with local and regional changes in the landscape can all combine to produce those same changes. In the case of the Wadden Sea, it is primarily cultural changes that have caused the landscape to change, or changes have been made. In the sense of the concept of cultural landscape, this proves that almost all landscapes are cultural landscapes that have been influenced by humans in a broader sense. It would be interesting to observe and analyze people's attitudes over generations in order to compare, analyze and verify opinions on new landscape changes, whether the attitudes of the people and stakeholders involved change with landscape changes and whether generations that were previously strictly against landscape changes change this opinion with landscape change.

In summary, global causes are mainly responsible for landscape change in the Wadden Sea. Climate change and the associated sea level rise pose an extreme threat to the Wadden Sea and the mainland cultural landscape, and this is where policy must come in. Especially on a coast where the land is sinking and the sea is rising, dikes cannot be the solution in the long run. The current policy ends at the coastline and still gives too little thought to the inland behind the Wadden Sea. In the long term, attitudes toward the sea must change. In the marshes, people still live with their backs to the sea, and the sea should be as far away as possible so that conventional agriculture can be practiced. In view of rising sea levels, the land must be reconnected so that land and sea are once again in harmony. For this, economic forms must be developed that harmonize with

more water, such as aquaculture, fish farming and others. The usual agriculture with the draining of marshes, cannot be a future solution if the landscape continues to change.

8 List of References

Ahlborg, H., Ruiz-Mercado, I., Molander, S. & Masera, O. (2019). Bringing Technology into Social-Ecological Systems Research—Motivations for a Socio-Technical-Ecological Systems Approach. Sustainability, 11(7), 2009.

Antrop, M. (2005). Why landscapes of the past are important for the future. Landscape and Urban Planning, 70(1-2), 21–34.

Baer J. & Nehls G. (2017) *Energy*. In: Wadden Sea Quality Status Report 2017. Eds.: Kloepper S. et al., Common Wadden Sea Secretariat, Wilhelmshaven, Germany. Last updated 21.12.2017. accessed on 17 October 2021. qsr.waddensea-worldheritage.org/reports/energy

Bauer, Ellen & Fischer, Ludwig & Kühn, Hans & Maluck, Matthias & Meier, Dirk. (2001). The Schleswig-Holstein Wadden Sea Region. In: Vollmer, M., Guldberg, M., Maluck, M., Marrewijk, D. & Schlicksbier, G. (Eds.). Landscape and Cultural Heritage in the Wadden Sea Region – Project Report. Wadden Sea Ecosystem No. 12. Common Wadden Sea Secretariat. Wilhelmshaven, Germany.

Berr, K. & Kühne, O. (2020). "Und das ungeheure Bild der Landschaft…": The Genesis of Landscape Understanding in the German-speaking Regions (1. Aufl.). Springer eBook Collection. Springer Fachmedien Wiesbaden.

Bürgi, M., Hersperger, A. M. & Schneeberger, N. (2005). Driving forces of landscape change - current and new directions. Landscape Ecology, 19(8), 857–868.

Bürgi, M., Hersperger, A. M. & Schneeberger, N. (2004). Driving forces of landscape change – current and new directions. Landscape Ecology, 19(8), 857–868.

Brandt, J., Primdahl, J., & Reenberg, A. (1999). Rural land-use and landscape dynaamics - analysis of 'driving forces' in space and time. In R. Krönert, J. Baudry, I. R. Bowler, & A. Reenberg (Eds.), Land-use changes and their environmental impact in rural areas in Europe (pp. 81-102). Unesco. Man and the Biosphere Series No. 24

Bundesamt für Naturschutz. (2007). 100 Jahre staatlicher Naturschutz. Accessed on 10 October 2021. Retrieved from: https://www.bfn.de/ueber-das-bfn/geschichte/100-jahre-staatlicher-naturschutz.html).

Bürgi, M., Bieling, C., Hackwitz, K. von, Kizos, T., Lieskovský, J., Martín, M. G., McCarthy, S., Müller, M., Palang, H., Plieninger, T. & Printsmann, A. (2017). Processes and driving forces in changing cultural landscapes across Europe. Landscape Ecology, 32(11), 2097–2112.

Council of Europe. (2000). European Landscape Convention. European Treaty Series, No. 176. 7 p.

Droste zu Hülshoff, B. von (Eds.). (1995). Cultural landscapes of universal value: Components of a global strategy ; 5 tables. G. Fischer.

dwif e. V. & Consulting (2016): Wirtschaftsfaktor Tourismus für das Reisegebiet Nordsee (Schleswig-Holstein).

EEA. (1999). Environmental indicators.: Typology and overview. Technical report No 25. https://www.eea.europa.eu/publications/TEC25

EEA. (2007). Land-use scenarios for Europe: qualitative and quantitative analysis on a European scale (PRELUDE). EEA Technical report no. 9, retrieved: 30.09.2021 from: https://www.eea.europa.eu/publications/technical_report_2007_9

Egberts, L. & Schroor, M. (Eds.). (2018). Waddenland Outstanding. Amsterdam University Press.

Egberts, L. & Schroor, M. (2018). Waddenland Outstanding. Amsterdam University Press.

Elias, E., van der Spek, A., Wang, Z. B. & Ronde, J. de (2012). Morphodynamic development and sediment budget of the Dutch Wadden Sea over the last century. Netherlands Journal of Geosciences - Geologie en Mijnbouw, 91(3), 293–310.

European Commission. (2020). EU Biodiversity Strategy for 2030. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380. Accessed on October 10, 2021.

Figueroa B., E. & Aronson, J. (2006). New linkages for protected areas: Making them worth conserving and restoring. Journal for Nature Conservation, 14(3-4),

Fischer, N. (2012). Landschaftsgeschichte – Landschaftstheorie – Landschaftswandel. Konzeptionen und Fallstudien, in: Flusser Studies 14, www.flusserstudies.net/files/media/attachments/fischer-landschaftsgeschichte.pdf

Franzen, B., S. Krebs (Eds.). (2006). Mikrolandschaften. Landscape on the Move, Köln (Walther König)

Gailing, L. (2007). Regionalparks als stadtregionale Entwicklungsstrategien. Interkommunale Kooperationen für die Stadtlandschaft, 46(Nr. 1), S. 68-84.

García-Martín, M., Quintas-Soriano, C., Torralba, M., Wolpert, F. & Plieninger, T. (2021). Landscape Change in Europe. In T. Weith, T. Barkmann, N. Gaasch, S. Rogga, C. Strauß & J. Zscheischler (Eds.), Human-Environment Interactions. Sustainable Land Management in a European Context (Bd. 8, S. 17–37). Springer International Publishing.

Geist, Helmut & Lambin, Eric. (2001). What Drives Tropical Deforestation.

Geist, H. J. & Lambin, E. F. (2002). Proximate Causes and Underlying Driving Forces of Tropical Deforestation. BioScience, 52(2), 143.

Goeldner, L. (1999). The German Wadden Sea coast: reclamation and environmental protection. Journal of Coastal Conservation, 5(1), 23–30.

Hersperger, A. M., M.-P. Gennaio, P. H. Verburg, and M. Bürgi. (2010). Linking land change with driving forces and actors: four conceptual models. Ecology and Society 15(4):1

Hokema, D. (2013). Landschaft im Wandel? Springer Fachmedien Wiesbaden.

Jakubowski-Tiessen, M. (2011). Vom Umgang mit dem Meer: Sturmfluten und Deichbau als mentale Herausforderung. Küstenmentalität und Klimawandel.

Janssen, J., Luiten, E., Renes, H. & Stegmeijer, E. (2017). Heritage as sector, factor and vector: conceptualizing the shifting relationship between heritage management and spatial planning. European Planning Studies, 25(9), 1654–1672.

Jepsen, M. R., Kuemmerle, T., Müller, D., Erb, K., Verburg, P. H., Haberl, H., Vesterager, J. P., Andrič, M., Antrop, M., Austrheim, G., Björn, I., Bondeau, A., Bürgi, M., Bryson, J., Caspar, G., Cassar, L. F., Conrad, E., Chromý, P., Daugirdas, V., . . . Reenberg, A. (2015). Transitions in European land-management regimes between 1800 and 2010. Land Use Policy, 49, 53–64.

Jones, M., Howard, P., Olwig, K. R., Primdahl, J. & Sarlöv Herlin, I. (2007). Multiple interfaces of the European Landscape Convention. Norsk Geografisk Tidsskrift - Norwegian Journal of Geography, 61(4), 207–216.

Jones-Walters, L. (2008). Biodiversity in multifunctional landscapes. Journal for Nature Conservation, 16(2), 117–119.

Jongman, R. H. G. (Eds.). (2004). Wageningen UR Frontis Series. The New Dimensions of the European Landscape. Springer Netherlands.

Kabat, P., Bazelmans, J., van Dijk, J., Herman, P. M., van Oijen, T., Pejrup, M., Reise, K., Speelman, H. & Wolff, W. J. (2012). The Wadden Sea Region: Towards a science for sustainable development. Ocean & Coastal Management, 68, 4–17.

Keisteri, T. (1990). The study of changes in cultural landscapes. Fennia - International Journal of Geography, 168(1). Retrieved from https://fennia.journal.fi/article/view/8852

Kirchhoff, T., Trepl, L., & Vicenzotti, V. (2013). What is landscape ecology? An analysis and evaluation of six different conceptions, landscape research.

Kizos, T., Verburg, P. H., Bürgi, M., Gounaridis, D., Plieninger, T., Bieling, C. & Balatsos, T. (2018). From concepts to practice: combining different approaches to understand drivers of landscape change. Ecology and Society, 23(1).

Klijn, J. (2004). Driving forces behind landscape transformation in Europe, from a conceptual approach to policy options. In R. H. G. Jongman (Eds.), Wageningen UR Frontis Series. The New Dimensions of the European Landscape (Bd. 4, S. 201–218). Springer Netherlands.

Knottnerus, O. S. (2005). History of human settlement, cultural change and interference with the marine environment. Helgoland Marine Research, 59(1), 2–8.

Koomen, E., Stillwell, J., Bakema, A. & Scholten, H. J. (Eds.). (2007). The GeoJournal Library. Modelling Land-Use Change. Springer Netherlands.

Kost, S. (2017). Raumbilder und Raumwahrnehmung von Jugendlichen. In O. Kühne, H. Megerle & F. Weber (Eds.), Landschaftsästhetik und Landschaftswandel (S. 69–86). Wiesbaden: Springer VS

Krzywinski, K., O'Connell, M. & Küster, H. (2009). Cultural landscapes of Europe, fields of Demeter haunts of Pan.

Kühne, O., Megerle, H. & Weber, F. (2017). Landschaftsästhetik und Landschaftswandel. Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-15848-4

Kühne, O., Weber, F., Berr, K. & Jenal, C. (Eds.). (2019). RaumFragen: Stadt – Region – Landschaft. Handbuch Landschaft. Springer Fachmedien Wiesbaden.

Landesamt für Statistik Niedersachsen (2017) Statistische Berichte Niedersachsen, Beherbergung im Reiseverkehr – Jahr 2017. Accessed 15 October 2021 http://www.statistik.niedersachsen.de/themenbereiche/reiseverkehr_gastgewerbe/themenbereich-reiseverkehr-gastgewerbe---statistische-berichte-87582.html

Landesportal Schleswig-Holstein (2018). Schleswig-Holstein – Zahlen zum Tourismus. Accessed 14. October 2021. Retrieved from: https://www.schleswig-holstein.de/DE/Fachinhalte/L/landLeute/zahlenFakten/tourismus.html.

Lebensraum Nordsee. *Diercke - Weltatlas* [299 S] [Vollst. Neubearb.], 1. Aufl., Dr. A, [Nachdr.]. (2012). Westermann. Braunschweig. Accessed on 15 October 2021. Retrieved from https://diercke.westermann.de/content/nord-ostsee-umweltbelastung-

Leemans, R. (Eds.). (2013). Ecological Systems. Springer New York.

Lotze, H. K., Reise, K., Worm, B., van Beusekom, J., Busch, M., Ehlers, A., Heinrich, D., Hoffmann, R. C., Holm, P., Jensen, C., Knottnerus, O. S., Langhanki, N., Prummel, W., Vollmer, M. & Wolff, W. J. (2005). Human transformations of the Wadden Sea ecosystem through time: a synthesis. Helgoland Marine Research, 59(1), 84–95.

Lüder, I. (2014). North sea territory. A cultural landscape in a process of change. EWT / Eco Web Town Magazine of Sustainable Design.

Meyfroidt, P. (2016). Approaches and terminology for causal analysis in land systems science. Journal of Land Use Science, 11(5), 501–522.

Müller, K. (2019. DEA will Ölförderung im Nationalpark Wattenmeer erweitern. Schleswig-Holsteinischer Zeitungsverlag. Accessed on 22 October 2021. https://www.shz.de/regionales/schleswig-holstein/politik/dea-will-oelfoerderung-im-nationalpark-wattenmeer-erweitern-id26103412.html

Neuhäuser, C. (2020). Wattenmeer: Durchbruch am Duhner Loch im Satellitenbild. Retrieved from https://wasserundeis.com. Accessed 28.09.2021

MW 2017: Wirtschaftsfaktor Tourismus - Erstes Tourismussatellitenkonto für Niedersachsen. Niedersächsisches Ministerium für Wirtschaft, Arbeit und Verkehr, accessed 15. October 2021. Retrieved from: https://www.mw.niedersachsen.de/download/124126/Wirtschaftsfaktor_Tourismus_-_erstes_Tourismussatellitenkonto_fuer_Niedersachsen.pdf

OECD. (1999). Environmental Indicators for Agriculture. OECD.

Peña, J., Bonet, A., Bellot, J., Sánchez, J. R., Eisenhuth, D., Hallett, S. & Aledo, A. (2007). Driving Forces Of Land-Use Change in a Cultural Landscape Of Spain.

In E. Koomen, J. Stillwell, A. Bakema & H. J. Scholten (Eds.), The GeoJournal Library. Modelling Land-Use Change (Bd. 90, S. 97–115). Springer Netherlands.

Pinto-Correia, T [T.] & Kristensen, L. (2013). Linking research to practice: The landscape as the basis for integrating social and ecological perspectives of the rural. Landscape and Urban Planning, 120, 248–256.

Plachter, H., and Mechtild, R. (1995). Cultural landscapes: Reconnecting culture and nature. In: Cultural Landscapes of Universal Value. Components of a Global Strategy. Gustav Fischer Verlag, UNESCO, Jena, Stuttgart, New York, pp 15-18

Plieninger, T. & Bieling, C. (2012). Resilience and the Cultural Landscape. Cambridge University Press.

Plieninger, T., Draux, H., Fagerholm, N., Bieling, C., Bürgi, M., Kizos, T., Kuemmerle, T., Primdahl, J [Jørgen] & Verburg, P. H. (2016). The driving forces of landscape change in Europe: A systematic review of the evidence. Land Use Policy, 57, 204–214.

Prominski, M. (2004). Landschaft entwerfen: Zur Theorie aktueller Landschaftsarchitektur. Teilw. zugl.: Berlin, Techn. Univ., Diss., 2003 u.d.T.: Prominski, Martin: Komplexes Landschaftsentwerfen. Reimer.

Prominski, M. (2019). Landschaft Drei. In O. Kühne, F. Weber, K. Berr & C. Jenal (Eds.), RaumFragen: Stadt – Region – Landschaft. Handbuch Landschaft (S. 667–674). Springer Fachmedien Wiesbaden.

Raith, K. (2006). Kulturlandschaft ist überall. Oder: Die praktische und die projektive Landschaft. In: I. Kazal, A. Voigt, A. Weil, A. Zutz (Eds.) Kulturen der Landschaft: Ideen von Kulturlandschaft zwischen Tradition und Modernisierung, Berlin: TU Berlin

Reise, K. (2005). Coast of change: habitat loss and transformations in the Wadden Sea. Helgoland Marine Research, 59(1), 9–21.

Reise, K. & Enemark, J. (2014). Eine Naturgeschichte vom Wattenmeer: Von Zufällen durchdrungen. Waddenacademie.

Reiseanalyse (2014) Forschungsgemeinschaft Urlaub und Reisen (FUR), Reiseanalyse 2014

Renes, H. (2018). The Wadden Sea region as a cultural landscape. In L. Egberts & M. Schroor (Eds.), Waddenland Outstanding (S. 45–64). Amsterdam University Press.

Rindfuss, R. R., Walsh, S. J., Turner, B. L., Fox, J. & Mishra, V. (2004). Developing a science of land change: challenges and methodological issues. Proceedings of the National Academy of Sciences of the United States of America, 101(39), 13976–13981.

Scheller, R. M. (2020). Managing Landscapes for Change (Bd. 27). Springer International Publishing.

SH Ministerium für Wirtschaft, Arbeit, Verkehr und Technologie. (2012). Tourismusstrategie Schleswig-Holstein 2025. Accessed 14 October 2021. Retrieved from: https://www.schleswig-holstein.de/DE/Fachinhalte/T/tourismus/Downloads/tourismustrategie_schleswigholstein_2025_lang.pdf;jses

Schroor, M., Kühn, J., Brown, N., Enemark, J., Vollmer, M. (2009). Landscape and Culture. Thematic Report No. 2. In: Marencic, H. & Vlas, J. de (Eds), 2009. Quality Status Report 2009. WaddenSea Ecosystem No. 26. Common Wadden Sea Secretariat, Trilateral Monitoring and Assessment Group, Wilhelmshaven, Germany.

Schroor M., Enemark J., Fischer L. & Guldberg M. (2017). *Landscape and culture.* In: Wadden Sea Quality Status Report 2017. Eds.: Kloepper S. et al., Common Wadden Sea Secretariat, Wilhelmshaven, Germany. Last updated 21.12.2017. retrieved: 21.09.2021. from: qsr.waddensea-worldheritage.org/reports/landscape-and-culture

Sparkassen-Tourismusbarometer Schleswig-Holstein (2018). Jahresbericht 2018. Accessed 14 October 2021. Retrieved from http://www.sgvsh.de/Tourismus/Publikationen/Jahresberichte/Jahresberichte/TB-SH-2018_Jahresbericht-Online_270818.aspx

Statistisches Amt für Hamburg und Schleswig-Holstein. (2017). Beherbergung im Reiseverkehr in Schleswig-Holstein 2017. Accessed 14 October 2021. Retrieved from: https://www.statistik-nord.de/fileadmin/Dokumente/Statistische_Berichte/industrie__ handel_und_dienstl/G_IV_1_j_S/G_IV_1-j17-SH.pdf

Statistische Ämter der Länder. (2018). Volkswirtschaftliche Gesamtrechnungen der Länder – Bruttoinlandsprodukt, Bruttowertschöpfung in den Ländern der Bundesrepublik Deutschland 1991-2017. Accessed 14. October 2021. Retrieved from: https://www.statistik-bw.de/VGRdL/ (Zugriff 14.5.2018)

Stiftung Offshore Windenergie. 2017. Offshore-Windenergie – Sauberer Strom vom Meer. Accessed on 25 October 2021. Retrieved from https://www.offshore-stiftung.de/offshore-windenergie.

Tourismusverband Nordsee (2018). Nordsee – Niedersachsen erzielt 2016 weiteren Übernachtungsrekord. Accessed 15 October 2021. Retrieved from: http://tourismusverband-nordsee.de/wp-content/uploads/2017/04/Jahresbooklet_2016_final.pdf. Tress, B. & Tress, G. (2001). Capitalising on multiplicity: a transdisciplinary systems approach to landscape research. Landscape and Urban Planning, 57(3-4), 143–157.

UNESCO. (2019). 2019 Operational Guidelines. Retrieved from https://whc.unesco.org/en/guidelines/. Accessed on September 20, 2021.

Vollmer, M., Guldberg, M., Maluck, M., Marrewijk, D. & Schlicksbier, G. (2001). Landscape and Cultural Heritage in the Wadden Sea Region – Project Report. Wadden Sea Ecosystem No. 12. Common Wadden Sea Secretariat. Wilhelmshaven, Germany.

Walsh, C. (2018). Metageographies of coastal management: Negotiating spaces of nature and culture at the Wadden Sea. Area, 50(2), 177–185.

Weith, T., Barkmann, T., Gaasch, N., Rogga, S., Strauß, C. & Zscheischler, J. (Eds.). (2021). Human-Environment Interactions. Sustainable Land Management in a European Context. Springer International Publishing.

Wolff, W. J. (1992). The End of a Tradition: 1000 Years of Embankment and Reclamation of Wetlands in the Netherlands. Ambio, 21(4), 287–291. http://www.jstor.org/stable/4313944

Wu, J. (2013). Landscape Ecology. In R. Leemans (Eds.), Ecological Systems (S. 179–200). Springer New York.

Wu, J. (2013). Landscape sustainability science: ecosystem services and human well-being in changing landscapes. Landscape Ecology, 28(6), 999–1023.

Annex

Annex 1: Landscape types and dominant soil types in the Wadden Sea Region

Vollmer et al., 2001, 15:

	Calcareous gley soils (sandy clay)	Predominantly non-calcareous gley-soils (heavy clay)	Peat-soils	Podzols & brown soils (sand and loam)
Dunes & moraine islands	(Embanked) salt marshes			
Shoreline landscape	Salt marshes Halligen			(Sandbanks)
Embanked coastal marshes & tidal river marshes	Younger coastal marshes Tidal riverine landscape	Older coastal marshes Tidal-river marshes (Riverbanks)	(River Back swamps)	
4. Polder lands & drained lakes	Younger polders Former salt marshes Recent sea polders	Older polders	Drained lakes Drained broad lands & meres	
5. Fenlands & cut-over raised bogs		Reclaimed fenland marshes	Wet fenlands Black fens (Squatter colonies)	Reclaimed fenland Moors Cut-over raised bogs
6. Upland moors		(Brook valleys) (Marshland meadows)		Moraine plateaus Sandy plains Moraine hillocks Squatter settlements (Reclaimed brecklands)

Annex 2: Typical Landscape Examples

Photos: Adobe Stock

From Nessmersiel to the Island Borkum

On the left there is the village of Nessmersiel with the harbor, the fairway and tideways.

Island of Texel

In the center, we see the dikes, the land in between and in the background we can see the typical polders, ponds, forests. Typical coastal Wadden Sea landscape.

Wadden Sea National Park Schleswig-Holstein aerial view

Hallig Oland

North Frisian Island Pellworm

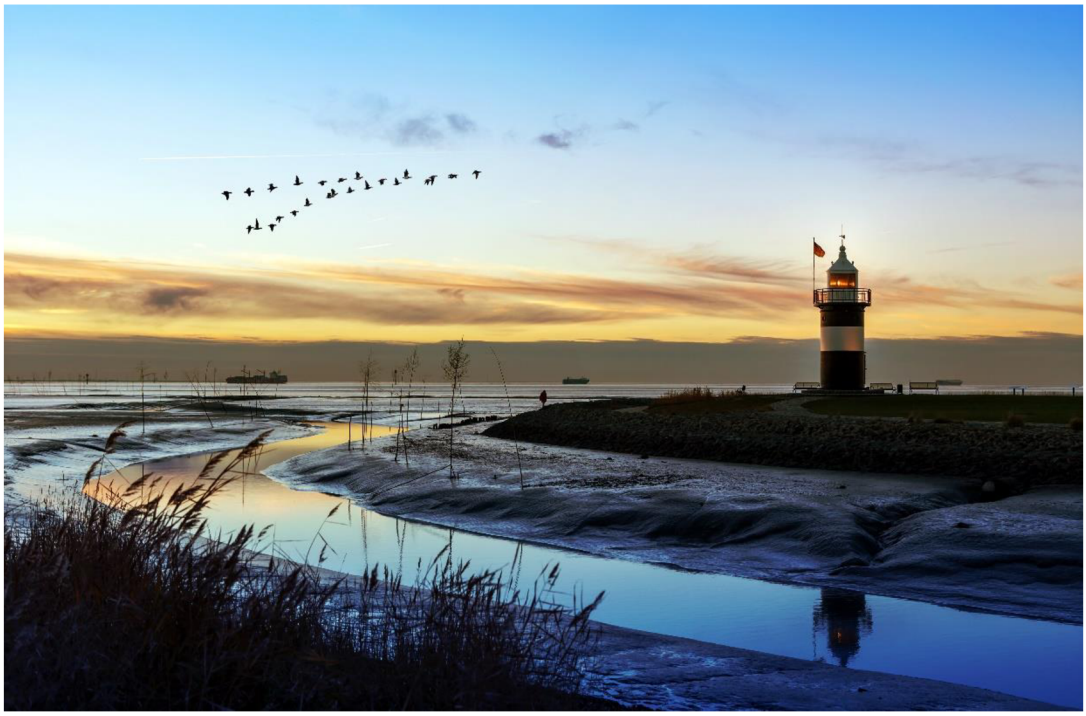
Annex 3: Landscape Evolution and Human Impact

			Human Impact			
Time	**Cultural Period**	**Economy**	**Exploitation**	**Habitat change**	**Other impacts**	**Ecological changes**
40000 – 10000 BP	**Paleolithic**					
	Ice age					
8000 – 4900 BC	**Mesolithic**	**Hunter-gatherer**	**Subsistence**			**Gradual decrease**
	Sparse Mesolithic occupation, Wadden Sea creation ca. 5500 BC		Hunting (game, birds, seals), fishing (fish, shellfish), gathering (eggs, feathers, plants)			Large terrestrial game (e.g., aurochs, elk, bear)
4900 – 800 BC	**Neolithic / Bronze Age**	**Agriculture**	**Artisan**	**Adaption**		**Gradual decrease**
	Neolithic time introduced ca. 4200-2800 BC, Bronze Age (2100-800 BC)	Cattle grazing, arable farming				Large terrestrial game (e.g., aurochs, elk, bear)
800 BC – AD 1050	**Roman / Early Medieval**	**Trade**	**Artisan**	**Modification**		**Disappearance**
	Pre-Roman and Roman Iron Age (800 BC – AD 400), Early Medieval and Viking Age (AD 400- 1050)	Long-distance trade, Frisian commerce, agriculture, basic technology same as previous				Large terrestrial game (e.g., elk, bear), perhaps some large birds (pelican, flamingo)
AD 1050 – 1500	**High / Late Medieval**	**Market**	**Commercial**	**Transformation**	**River pollution**	**Decline**
	Society, Middle Ages	Exponential expansion of exchange sector, Hanseatic power, agricultural technique and extent increased	Commercialization of fishing (herring, oyster), bird hunting, whaling, seagrass harvest for dike building	Systematic embankment and drainage of coastal marshes and inland mires, low dikes, dams, and ditches, peat exploitation	Sewage, sedimentation, siltation	Large diadromous fish, large birds, wetlands; disappearance of grey seals, aurochs

			Human Impact			
Time	**Cultural Period**	**Economy**	**Exploitation**	**Habitat change**	**Other impacts**	**Ecological changes**
AD 1500 – 1800	**Early Modern**	**Modern**	**Intensification**	**Separation**	**River pollution**	**Decline**
	Modernization	Integration into modern world economy, agriculture and maritime trade greatly intensified, islanders involved in shipping, trading, whaling	Intensified fishing, whaling, hunting of birds, seals, porpoise, collection of eggs, feathers, regulations imposed on declining resources	Separation and homogenization of landscape, modern dikes, many forelands embanked, river damming, harbor building	Sewage, wastewater, sedimentation, siltation	Large groundfish, birds, wetlands; disappearance of large whales
AD 1800 – 1900	**Late Modern**	**Industrial**	**Peak and decline**	**Construction**	**Estuarine pollution**	**Decline & Loss**
	Industrialization, Urbanization	High days of large-scale modern agriculture and coastal shipping, industries grew	Traditional fisheries peaked and declined, new fisheries developed, bird exploitation peaked, whaling ceased	Large embankments, canalization of estuaries, river damming, transportation routes	Sewage, wastewater, sedimentation, siltation	Most birds, diadromous fish, large groundfish, oysters, wetlands
AD 1900 – 1970	**Early global**	**Global**	**Industrial**	**Destruction**	**Coastal pollution**	**Loss**
	Mechanization, warfare	Large-scale mechanization of agriculture and fishing	Industrial-scale fisheries, trawling	Agricultural landscape stripped to essentials, large loss of brackish waters (Zuiderzee), seafloor trawling, shoreline petrification	Sewage, wastewater, artificial fertilizer, pesticides, DDT, heavy metals, sedimentation, siltation	Loss of large predators (many birds, mammals, fish at low levels), habitat-building species, wetlands
AD 1970 – 2000	**Late global**	**Tourism**	**Collapse and conservation**	**Protection**	**Multiple impacts**	**Invasion and recovery**
	Globalization	Increased activities, boat traffic, infrastructure	Artisan inshore fishery, shellfish cultures, industrial offshore fishery collapse, species protection	Coastal defense, habitat protection, restoration efforts, National parks	Artificial fertilizer, heavy metals, pesticides, PCBs, TBT, climate change, exotic invasions	Impacts of invaders, harmful algal blooms, algal masses, diseases; recovery of some birds and seals

Annex 4: Tidal range examples

Wremen, Lower Saxony, Germany (Adobe Stock photos)

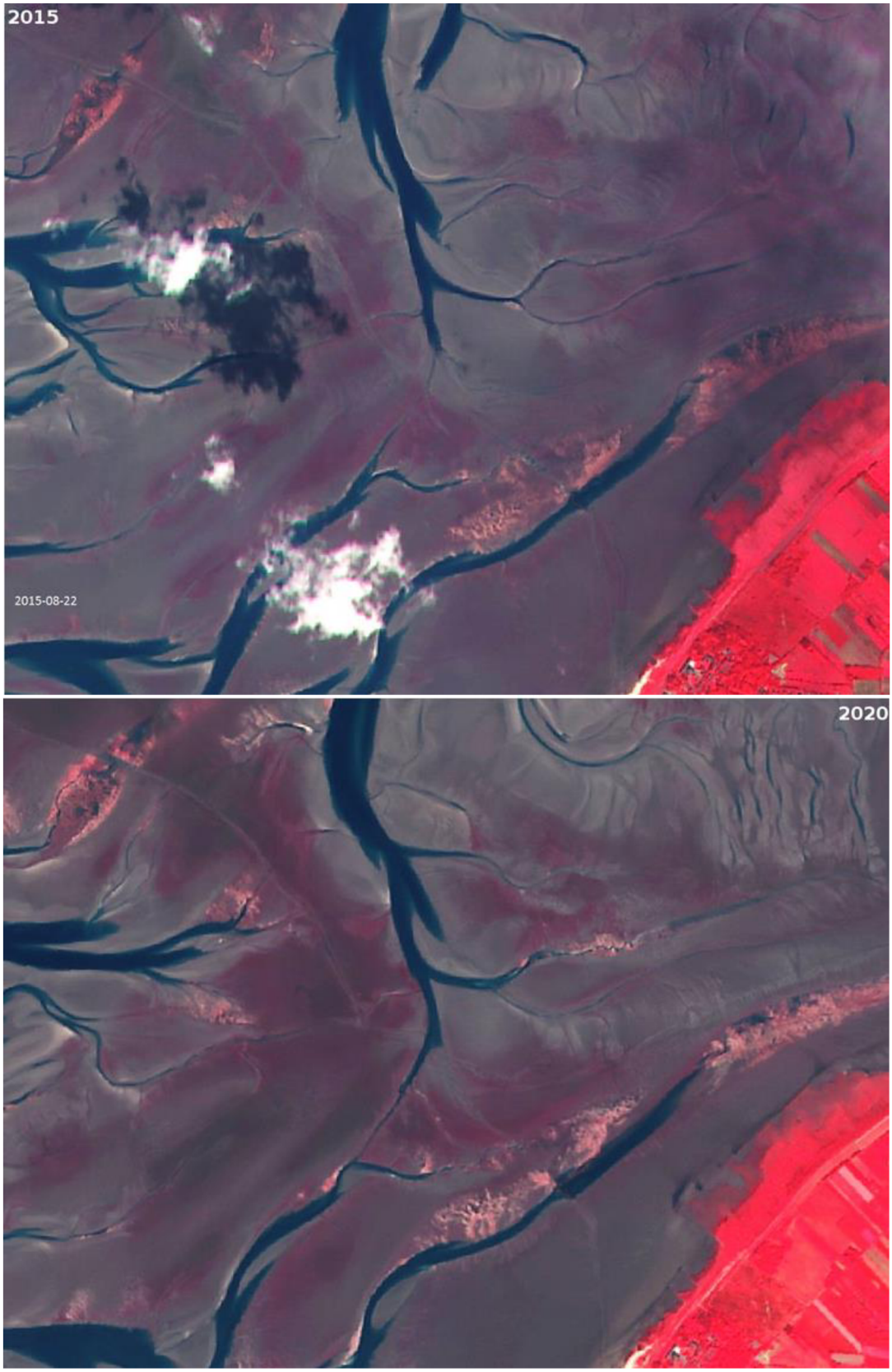


Annex 5: Dogger Land Map by National Geographic Society

A map showing Doggerland, a region of northwest Europe home to Mesolithic people before sea level rose to inundate this area and create the Europe we are familiar with today. https://www.nationalgeographic.org/maps/doggerland/

Annex 6: "Duhner Loch": Changes from 2015-2020.

Retrieved from https://wasserundeis.com/



Annex 7 Schematized cross-sectional reconstruction of the Dollard area between 1000 and 2000 AD

Vos & Knol, 2015