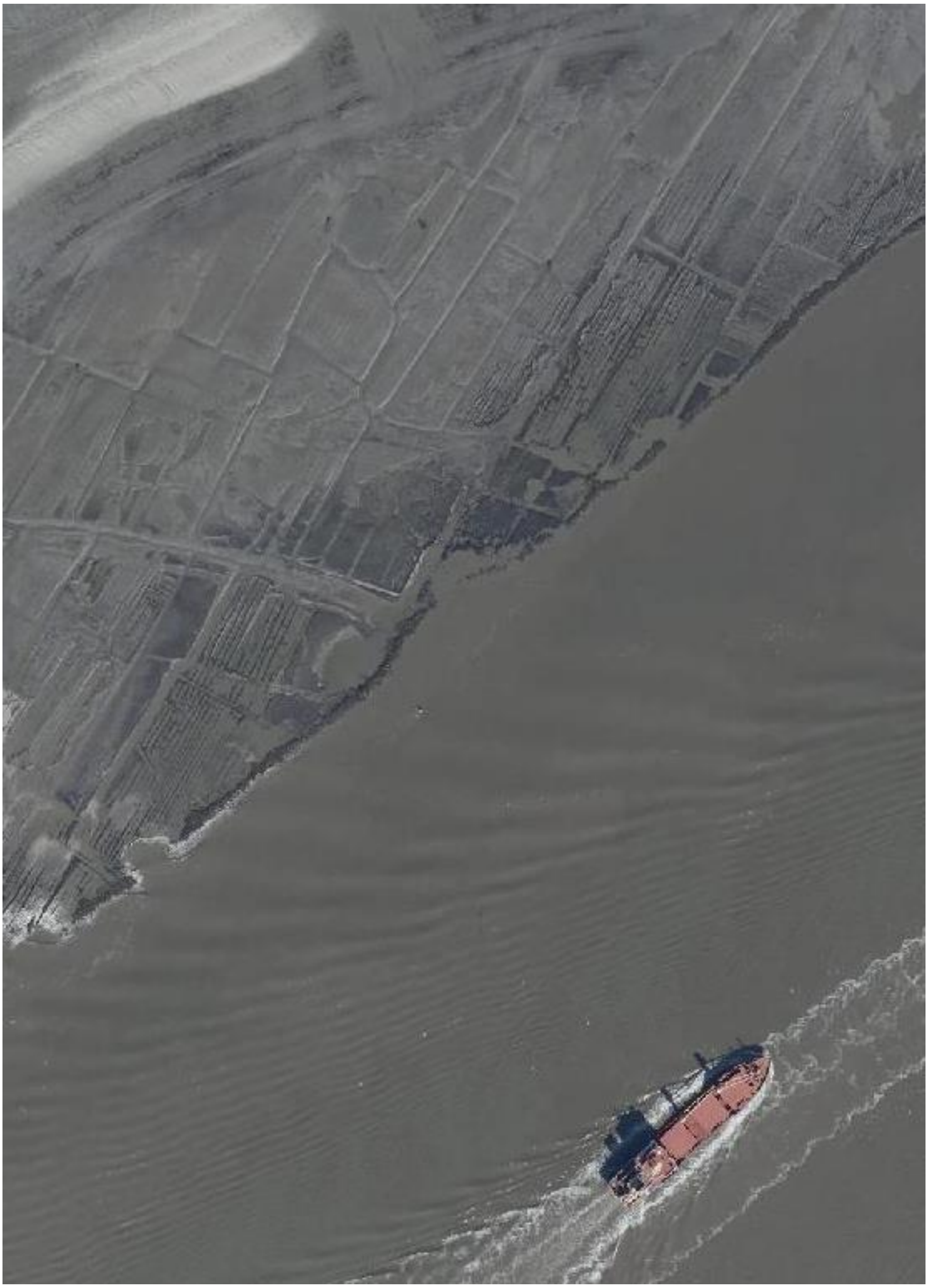
Holocene Heritage Quest: Possibilities for Citizen Science Research of Archaeological Heritage in the Dutch Province of Zeeland

Willemstein, Jacobus Johannes

Holocene Heritage Quest

Possibilities for Citizen Science Research of Archaeological Heritage in the Dutch Province of Zeeland



Remko Willemstein

Cover Image: The remains of the drowned village of Oud-Rilland in 2018 (Image by R. Willemstein, PDOK).

Holocene Heritage Quest

Possibilities for Citizen Science Research of Archaeological Heritage in the Dutch Province of Zeeland

MSc Archaeological Science

Author: Remko Willemstein – S2699605

Supervisor: Dr Karsten Lambers

Leiden University – Faculty of Archaeology

Driewegen, 15-06-2023

Table of Contents

Chapter 1: Introduction

For over a century aerial photography has been used in archaeology to detect traces of the past in the landscape. With the emergence of citizen science projects and vast amounts of remotely sensed data, Leiden University in collaboration with regional partners has developed a successful citizen science project called ‘Erfgoed Gezocht’, or ‘Heritage Quest’, in which citizen scientists can participate in identifying heritage in the central Netherlands through remotely sensed LIDAR data. Because of the success of Heritage Quest, its widespread use by citizen scientists and the resulting archaeological dataset containing hundreds of new archaeological sightings, other actors such as the Province of Zeeland have shown interest in- and have approached Leiden University to implement their own citizen science project. There are however a couple of hurdles to overcome when setting up a similar project in the west of the Netherlands; the nature of its mostly flat Holocene landscape is not as suitable for the use of LiDAR data from the Actueel Hoogtebestand Nederland (AHN) to detect archaeological heritage, as its Pleistocene, forested and ‘rugged’ counterpart of the Veluwe is. Furthermore, there are only a few areas with extensive burial-mounds and other prehistoric traces in the west of the Netherlands, especially compared to the Veluwe (and the broader East). Therefore, a shift in setup and focus is necessary if the successful concept of a citizen science project on remote sensing of archaeological features is to be transferred to the west of the Netherlands. The Holocene landscape is different from the landscape of the original heritage quest, the archaeological heritage mostly stems from different time periods and the visibility of this archaeological heritage in remotely sensed datasets needs to be evaluated.

To set up a citizen science project similar to ‘Erfgoed Gezocht’ for the Province of Zeeland a new remote-sensing, citizen science approach must be developed; one that also uses open-source remotely sensed datasets in which citizen scientists can easily recognize and interpret archaeological data, but also one which is more suitable for the local archaeological heritage of Zeeland. This thesis will therefore explore if satellite imagery from different years is suitable for remotely sensing heritage in the province of Zeeland, what the ‘major types’ of heritage in the province of Zeeland are, and what types of archaeological heritage can be identified in the research area with the available satellite imagery.

1.1 Theory

The original idea for a citizen science project in the Netherlands concerning archaeological heritage on the Veluwe and Utrechtse Heuvelrug was contrived because of the need for a large dataset which contained both known archaeological objects and archaeological objects that were still unknown, but which could be validated within the dataset (Lambers, 2019, 7). This need stemmed from the fact that a proof-of-concept deep learning-based workflow called WODAN (Workflow for Object Detection of Archaeology in The Netherlands), which was being developed to automate archaeological prospection, relied upon automated object detection using an image classifier that 'learns' to generalize shapes from examples presented to it (Verschoof-van der Vaart & Lambers, 2019). However, without any labeled datasets that were available from the outset, such a dataset needed to be created manually. This process is both labor-intensive and susceptible to errors, inaccuracies and bias. With these challenges in mind, a citizen-science approach to the creation of this dataset was considered (Lambers, 2019, 7). Because of the global pandemic that prevented fieldwork, the integration of WODAN and Heritage Quest has not yet materialized in practice. Nonetheless, the citizen science project was launched and at this moment has been completed. The innovative approach of using citizen science to create a comprehensive dataset of archaeological heritage led to a drastic increase in the amount of known burial mounds, charcoal kilns, Celtic fields and cart tracks across the Veluwe and Utrechtse Heuvelrug. Furthermore, the Heritage Quest project led to a broad participation of volunteers engaging with their local heritage (Erfgoed Gelderland, 2023). Because of this success, the question arose if a project like heritage quest could be successfully reproduced in other areas of the Netherlands, specifically the western part of the country. However, to be able to start a citizen science project in the Holocene landscape of the west, a whole new set of challenges arose; what types of archaeological heritage can be remotely sensed in this vastly different landscape, and by which sensors? And what are other similarities and differences between the original Heritage Quest and a citizen science project in the west of the country? Therefore, this thesis' main focus will be to see if a citizen science project like heritage quest is viable for the province of Zeeland, and by extension, the rest of the western Netherlands.

1.2 Research questions

The types of heritage that can be found in Zeeland differ wildly from those that can be found on the Veluwe because of the nature of its landscape and history, and although LiDAR data has been considered for remotely sensing archaeological heritage in Zeeland, satellite imagery probably has a lot more potential in visually identifying archaeological traces in the Holocene, agricultural landscape of Zeeland. Furthermore, the province of Zeeland has, apart from some areas in the south of Zeeuws-Vlaanderen, little to no prehistoric archaeological traces which are visible on the surface. A new heritage quest in Zeeland will thus have to shift its main goals and focus from prehistoric archaeological heritage to post-Roman archaeological heritage. In this context the following main research question has been formulated:
What correlations can be found, tested and evaluated, in the context of a Citizen Science project, between existing open-source, satellite-based remote sensing datasets and visible archaeological traces within these datasets for the province of Zeeland?

To answer the main research-question the following sub-questions will also need to be answered:

1. *What archaeological object classes are suitable for the identification of archaeological heritage through remote sensing in the research area?*

To be able to identify archaeological heritage in remote sensing datasets, an overview of some of the (major) types of archaeological heritage that can be found in the province of Zeeland should be established in the form of a set of object classes. These object classes can then be evaluated for their visibility in the available remote sensing datasets.

2. *How viable is the usage of satellite imagery for identifying archaeological heritage in Zeeland?*

Because of the nature of the landscape in Zeeland and its habitational history not all remote sensing datasets are as viable to identify certain types of heritage. Through the usage of remote sensed satellite data on a few selected case-studies, these datasets can be evaluated for their usage in identifying archaeological heritage and their usability in remote sensing archaeological features by untrained volunteers.

3. *What satellite imagery (i.e., from what year) yields the best results for the identification of archaeological heritage per case study?*

There are many factors which could influence the usability of remote sensed satellite imagery in the identification of archaeological heritage, such as rainfall, drought, the types of crops sown (or lack thereof), the growth stage of said crops, ground-resolution of the imagery, distortions caused by orthorectification such as differences in color or artifacts caused by overlapping pictures, faulty georeferencing, etc. When all results have been evaluated on their visibility the most viable satellite imagery for remote sensing archaeological heritage can be defined per case-study and for all case studies as a whole.

4. *What are the differences and similarities between the original 'Erfgoed Gezocht' project and a potential similar citizen science project in the province of Zeeland?*

If a project like 'Erfgoed Gezocht' is to be adapted in the province of Zeeland, a comparison of the goals, data, methods and results of the original project and a potential project in Zeeland will need to be evaluated to show which elements can be maintained and which ones need to be adapted or replaced. To this end, a review of the original 'Erfgoed Gezocht' project is included in sub-chapter 2.2 and the implementation of a citizen science project in Zeeland will be discussed in chapter 6.1.4.

5. *What time period(s) will be the main focus of a citizen science remote sensing project in Zeeland?*
6. *What types of spatial shapes can be roughly defined in the case-studies?*
7. *How easy or hard is it for someone with little to no prior knowledge of archaeology and remote sensing to use the data for identifying archaeological heritage?*

1.3 Reading Guide

After the introductory chapter one, chapter two will focus on the background of the thesis research. Here, the research area will be explored through its geology and history of human habitation, after which the original Heritage Quest project and three other citizen science projects are described. Chapter three will define the different object classes which will be used in this research to test if satellite imagery is viable for usage in a citizen science project in the province of Zeeland. In chapter four the different data which is used in this research is described, followed by the methodology which was used for this research. In chapter five the results of the research are presented per different object class. Chapter six features a discussion concerning the results per object class and a discussion concerning the implementation of a citizen science project similar to Heritage Quest in the province of Zeeland. Chapter seven goes into the conclusions and subsequent recommendations of this research.

Chapter 2: Background

2.1 Research Area

The research area will encompass the entire province of Zeeland, the most south-western province of the Netherlands (see figure 1). To establish a comprehensive overview of the research area, both the geological formation and its history of human habitation will be briefly discussed here.

Figure 1: Research area. (Figure by R. Willemstein, PDOK).

2.1.1 Geology

The oldest parts of Zeeland were formed during the last ice-age in the late-Pleistocene (127.000 BC – 8000 BC) and consist of aeolian sands. This sandy soil was transported to Zeeland on the north-western winds blowing from Doggerland, which would later become the North-sea. Nowadays, this Pleistocene soil is only near the surface at the southernmost parts of Zeeuws-Vlaanderen at one meter below Normaal Amsterdams Peil (NAP). Going north, the Pleistocene sands are covered by younger geological formations; in the Borssele Polder on Zuid-Beveland the Pleistocene sands are between four and five meters below NAP, and on Noord-Beveland they can be found approximately ten to thirteen meters below NAP (Ovaa *et al,*1965, 5).

The Holocene deposits show a varied history of flooding and silting up of the landscape. During the beginning of the Holocene (8000 BC), the ice receded and sea levels were rising. Because of this change in climate the groundwater level rose and it became possible for peat to grow. Further sea level rising 'drowned' the layer of peat and formed a layer of clay on top of it called the 'oude zeeklei' (Ovaa *et al,*1965, 5).

The lower sediments of clay contain a lot of sand, whereas the upper sediments contain a lot of reed-roots indicating a lot of reed vegetation in the youngest stage of sedimentation. The softness of the clay indicates it hasn't ripened. The uppermost layer of clay can be close to the surface in certain areas, but there are major differences in height across the province. On Walcheren the top lies between one and a half to four meters below NAP, in the Borssele Polder the top layer lies about three and a half meter below NAP, on Noord-Beveland and Schouwen it can be found one and a half to three and a half meters below NAP (Ovaa *et al,*1965, 5).

During the sedimentation of this 'old sea clay' a spit complex formed along the coastline of the shallow mudflat landscape. This spit complex gradually expanded to form a natural barrier and during the beginning of the subboreal (3660 BC) marine sedimentation was temporarily halted. Stagnation in drainage, a supply of river and rainwater and desalination led to the widespread formation of a layer of peat. The thickness of this peat layer varies from a couple of centimeters in areas where the peat edges out on the sandy layer and in areas of peat-cutting to around two and a half metres on Tholen. In areas where there was no peat-cutting or erosion the thickness of the peat is between 70 centimeters and 1,2 meters (Ovaa *et al,*1965, 5-6).

The youngest marine sedimentation started during the sub-atlanticum (400 BC) and consists of jonge zeeklei, 'young sea clay', of which the formation outside of the dykes still continues to this day. At the beginning of the sub-atlanticum the old dunes along the coast were breached at different places because of rising sea levels. These breaches grew to form an extensive, branching trench system, the smallest of which penetrated deep into the peat landscape and subsequently eroded large parts of the peat. From these creeks young sea clay was deposited upon the remaining peat. In the entire province the older peat layer, for the parts which haven't eroded away, is covered by a layer of this young clay (Ovaa *et al,*1965, 6).

2.1.2 Human habitation

The earliest evidence of human activity in the research area stems from the middle-Paleolithic (until 35000 BC) and consists of some flint flakes and tools, including hand axes. Finds from the late-Paleolithic (35000 BC to 8800 BC) also consist of flakes and tools, including flint spires, scrapers, plugs and an antler axe. Furthermore, when digging the Westerscheldetunnel, animal remains from this time period have been found. Most artefacts from the middle- and late-Paleolithic have been found in secondary contexts; most of them washed ashore, were found during dredging, were loose finds from fields or found in loose context (Kuipers, 2005, 15).

Mesolitic (8800BC – 4900BC) finds in Zeeland are restricted to the area of Zeeuws-Vlaanderen. The rest of Zeeland probably also has Mesolithic sites, but these are very hard to find as they are covered in meters of sedimentation. During this period a more temperate climate would have resulted in an increase in human activity, and the emersion of smaller animals such as boars, beaver, otters and birds, and large game such as primeval cattle, bison and red deer combined with the possibility of gathering nuts and fruits would have resulted in a different subsistence strategies than those which were used during the Paleolithic. No longer was there a need for groups of humans to traverse long distances to find game; the temperate climate and correspondently changing landscape made it possible to stay in certain areas for a longer period of time and to exploit seasonal abundance of certain foodstuffs (Coppens, 2013, 24).

During the Neolithic period (4900BC – 2000BC) habitation in Zeeland was only possible on the beach ridges and a few higher, silted up areas in the tidal area. In this period people abandoned their nomadic way of life for sedentary subsistence strategies, using cattle and agriculture to sustain themselves. Neolithic traces of human activity in Zeeland are scarce; a couple of sherds from the Michelsberg culture have been found in Saeftinghe, but the first traces of actual settlements date from around 4500 BP and can be found on the beach ridges of Haamstede (Coppens, 2013, 24-25).

As was the case with the Neolithic period, finds from the Bronze age (2000BC – 800BC) are scarce. The steadily rising sea levels and the inaccessibility of the landscape would have provided little opportunities for permanent habitation. Nonetheless scarce finds do indicate habitation in Zeeland during this time period; A dredged heel axe from the coast of Westkapelle, some metal finds from the old dunes near Schouwen-Duiveland and two urns from the quarry of Nieuw-Namen are rare finds from the province but point towards sparse human activity (Kuipers, 2005, 17-18).

Even though Zeeland is characterized by an extensive peat landscape during the Iron Age (800BC – 12BC), evidence can be found of intensive habitation. Settlements and finds from this period stem mostly from Walcheren, Tholen and Schouwen. In the village of Grijpskerke, a pit was uncovered during archaeological excavation which contained over 800 kilos of pottery. During the Iron Age agriculture was the primary subsistence strategy. Evidence of the cultivation of barley, rye and flax and livestock farming of cattle, sheep, goats and pigs has been found. Settlements consisted of a few

farms which were probably inhabited by a small group of extended family. There is little to no evidence of central governance or extensive contact with other regions (Kuipers, 2005, 19-20).
Around 50 BC the Romans arrived in the province of Zeeland. For the first time in history the region is described in historical sources, such as Julius Caesars ‘De Bello Gallico’. The Dutch Roman era properly begins in 2012 BP, when the Roman general Drusus subjugates all tribes in the Netherlands. From the middle of the first century AD the Rhine river becomes the northern border of the Roman Empire in continental North-Western Europe, and Zeeland becomes a part of the Gallia Belgica province. In the Roman period, as in the Iron Age before, Zeeland largely consists of a peat landscape. Although the majority of habitation centers around the dunes and the banks of the Scheldt estuary, recent finds also show intensive habitation of the peat landscape. Known Roman settlements are in Haamstede, Zierikzee, Colijnsplaat, Kats, Domburg, Aardenburg and Ellewoutsdijk. Aardenburg was part of the Roman coastal defense network, and a castellum was built there between 175 and 280 AD. During the Roman period trade becomes an important activity in the province, and salt and fish-sauce become important trade goods. Several shrines devoted to the goddess Nehalennia contain the names of the traders shipping these wares. Temple complexes devoted to Nehalennia were erected near Domburg and Colijnsplaat. During the Roman period improved drainage dehydrates the peat landscape, leading to settling of the peat and lower ground levels. These lower ground levels, in combination with the drainage ditches, consequently allow the sea to get access to the land again (Kuipers, 2005, 20-28).
After 250 AD Zeeland gradually sinks beneath the waves again, because of the adverse effects of drainage and a continual rise in sea-levels. For a long period of time the province is uninhabitable, and as of yet there is no proof of habitational continuity after the Roman period. The peat-landscape is ravaged by multiple storm surges which erode deep tidal channels into the landscape, flood the surrounding areas and depose thick layers of clay and sand. After 700 AD most of these channels are silted up and the landscape becomes inhabitable once more. At the end of the 8th century AD the first signs of human habitation can be found again. Gradually the area is Christianized by missionaries hailing from England and Flanders, and the saint Willibrord presumably visited the ‘Villam Walichurm’, the crown-domain of Walcheren, in 695. During the 9th century AD the entire coastal area is plagued by Viking incursions, and as a defensive measure against their raids ‘ringwalburgen’ are erected in multiple locations. These large, round defensive works with earthen walls, palisades and a moat have been found in Domburg, Middelburg, Oostburg, Oost-Souburg and Burgh-Haamstede. Around 1000 AD most parts of Zeeland are inhabited again. Creek ridges which are higher up in the landscape are suitable for the foundation of settlements and for the construction of roads to connect them. Churches are founded by local liege-lords (ambachtsheren), and large swaths of the landscape get their distinctive, contemporary looks during the late Medieval period when dykes and embankments are constructed on a large scale, the construction of which is spearheaded by Flemish

monasteries. These developments ensure an expansion of the population and pave the way for the development of the first cities (Coppens, 2013, 26).
Because of the dykes, floodwater could no longer spread across the extensive salt-marshes and instead was being pushed ever higher against the flood-defenses. Behind the dykes the landscape was slowly but surely ‘sinking’, due to artificial drainage and subsequent (peat) settlement. When the dykes broke, because they were insufficiently raised or poorly maintained, it had catastrophic consequences for the landscape. The water which was pushed up against the dykes spilled into the low-lying polders with great force and eroded large gullies, and because the polders were now beneath the water level at high tides these gullies were nearly impossible to close-off again. During each tidal change the water would flood into them. Although there were many breaches of the dykes and storm surges during the early-modern period (1500 AD – now) there was no net-loss of land across the province. Salt marshes which were sufficiently silted up were continuously enclosed by dykes and thus added to the land (Coppens, 2013, 27). During the early-modern period the province of Zeeland is characterized by war, economic prosperity and subsequent economic decline. Shorty after the capture of the provincial capital of Middelburg by William of Orange in 1574, no more fighting in the province between Dutch and Spanish troops took place north of the Scheldt. Zeeuws-Vlaanderen however remained a warzone up until the Peace of Munster was signed in 1648 (Kuipers, 2005, 91-106). In the 17th century, the province played an integral role in the establishment and activities of the VOC and WIC trading companies. During the same period, whaling and the grain trade with Northern-Europe were also important sources of income for the province (Kuipers, 2005, 108-116). Economic prosperity kept increasing up until the surrender of the province in 1795 to the French Empire under Napoleon. During the period between 1795 and 1814 both trading companies were dismantled, relations with Flanders decreased, flooding caused huge damages in 1808 and the English invaded in 1809 (Kuipers, 2005, 137-138). The first half of the 19th century in Zeeland was characterized by a slow decline. Houses within the cities were demolished, city gates were demolished and the walls of important cities such as Middelburg, Zierikzee and Goes were either demolished or transformed into public parks. The separation of Belgium in 1830 brought war back to the Scheldt and Zeeuws-Vlaanderen, and it was not until the second half of the 19th century that modest modernization and growth would return to the province. Between 1860 and 1873 the railroad line which still connects Brabant to Zeeland was constructed between Bergen op Zoom and Flushing, and not until around 1900 some modest industrialization took place. Because of better connections to the rest of the country, a phenomenon which still characterizes Zeeland to this day developed in the province in the late 19th century; coastal tourism (Kuipers, 2005, 152-159). During the first World War, Zeeland remained unscathed because of Dutch neutrality. The second World War however, brought devastating consequences to the province. The province refused to capitulate to Germany after the Dutch surrender on the 15th of May, to provide French troops with a corridor to retreat, which led to the destructive bombardment of Middelburg two days later. French troops tried to slow the German

advance by blowing up bridges and ferries across the province. Zeeuws-Vlaanderen, the last remaining free part of the Netherlands, was eventually captured by the Germans on the 30th of May, concluding the conquest of Zeeland and the Netherlands. Zeeland was designated a *Sperrgebiet* due to its strategic importance, and in 1942 the construction of the *Atlantikwall* commenced. Two years later in 1944, considering a potential allied invasion, large parts of Zeeland were inundated by German troops. To be able to capture the province, the allies commenced with the inundation of Walcheren in the fall of the same year, bombing the dykes near Ritthem, Veere, Flushing and Westkapelle. Nearly the entire island was flooded, and the salt water killed all crops. Intense fighting commenced, and at the end of November Zeeland was liberated. On the 28th that month, the first big allied convoy could enter the important port of Antwerp through the Scheldt (Kuipers, 2005, 176-182).
Before the great flood of 1953 the islands of Zeeland were not yet connected to the mainland by hydrological works, although it was already apparent in 1937 that the coastal defenses were insufficient to withhold a large flood. On the first of February 1953 a heavy northwestern storm combined with hurricane level winds and spring tide ravaged the province, breaking the dykes in 89 places and flooding 137.000 hectares of land. Directly after the disaster a commission was established to make plans for new hydrological works, and in 1958 building of the 'Deltaplan' started. Multiple gullies were closed, and a flood-surge barrier was built to protect the Oosterschelde, whilst heavier and bigger dykes were constructed to protect the Westerschelde (Coppens, 2013, 27-28).

2.2 Heritage Quest – goals, data, methods and results

To be able to compare and show which elements of the original Heritage Quest can be adapted or should be replaced for a Heritage Quest project in Zeeland, the original Heritage Quest project will be explored here. This will touch upon the goals, data, methods and results of the original project. When these are sufficiently established, and case-studies for a potential project in Zeeland have been tested with a remote sensing dataset, it will become clear which elements of the original heritage quest can be maintained and which ones will need to be adapted or replaced. This will be discussed in chapter 6.1.4.

2.2.1 Goals

According to the Heritage Quest website by Leiden University, the goals of the original Heritage Quest project were two pronged, focusing on both components of the term 'citizen science'.
The first goal was to make as many people as possible aware of the archaeological heritage of the Netherlands. When people hear the term archaeology too many people think of the pyramids or Stonehenge, unaware of the plethora of archaeological heritage that exists in their own region.

Participation by citizens leads to a sense of ownership and increased awareness of archaeological sites, which in turn results in better protection of fragile heritage from the distant past.
The second goal was to discover archaeological sites, often hidden under dense vegetation cover, that were as of yet unknown. This especially includes prehistoric burial mounds and field systems (Heritage Quest, 2020). The citizen science approach makes it possible to gather big data; this includes more representative samples and a study of a much larger area than that which would be possible by (a small team) of professional archaeologists alone (Universiteit Leiden, 2020).

2.2.2 Data

For the original Heritage Quest project high resolution altitude data created by airborne LiDAR (Light Detection And Ranging) was used to investigate large (forested) areas which were often inaccessible. The LiDAR data used in the project was made available for public use by the 'Actueel Hoogtebestand Nederland' (AHN), a cooperation between the national government, provinces and water boards of the Netherlands (Heritage Quest, 2020).
Participants in the Heritage Quest project used cutouts of the AHN data measuring 300 by 300 meters and had the option to switch between two different visualizations of the AHN data; a 'shaded relief' and a 'Simple Local Relief' visualization (Lambers et al, 2019).

2.2.3 Methodology

For citizen scientists to be able to analyze the LiDAR data provided by the AHN a web-based platform called Zooniverse was used; Zooniverse is the world's largest and most popular platform that offers opportunities for 'people-powered research' and citizen science. Their goal is to enable over a million people around the world to assist in research which would otherwise be impossible or impractical (Zooniverse, 2023). An important concept of the Heritage Quest project is that citizen scientists do not need any prior training, expertise or specialized background to be able to participate in the research project, i.e. a low-threshold approach. To allow international researchers to participate in the data collection a bi-lingual user interface was chosen. In the heritage quest project citizen scientists are tasked with marking all potential burial mounds, Celtic fields, cart tracks and charcoal kilns within a small section of LiDAR data of 300 by 300 meters. When marking the imagery, participants can choose between two different LiDAR visualizations to assist them in their classification: A Simple Local Relief model and a Shaded Relief model. To guarantee minimal inter-analyst variability and present possibilities of inter-rater agreement every LiDAR cutout was classified by a maximum of 15 users for the Veluwe and 60 users for the Utrechtse Heuvelrug respectively. Online support, provision of feedback and user engagement was monitored by a staff member at ‘Erfgoed Gelderland’ who has first-hand experience with the region (Universiteit Leiden, 2020).

2.2.4 Results

When the original heritage quest project on the Veluwe in the central Netherlands commenced in May 2019, engagement by citizen scientists was much higher than expected. Within the short time-span of four and a half months the entire area of the Veluwe, a research area which encompasses 2000km2, had been researched. In total, 2064 citizen scientists participated in the project, scanning 396.552 cutouts of AHN height maps and identifying hundreds of potential new burial mounds, Celtic fields and charcoal piles (Universiteit Leiden, 2020).
The follow-up heritage quest project on the Utrechtse Heuvelrug saw even more engagement from citizen scientists. A total of 4572 participants took part in the research. Within a mere four weeks the entire research area, encompassing 350km2, had been thoroughly investigated. For this project a total of 300.971 cutouts of height maps had been scanned by citizen scientists. The heritage quest project for the Utrechtse Heuvelrug also yielded hundreds of potential new burial mounds, Celtic fields and cart-tracks (Universiteit Leiden, 2020).
After the online research by citizen scientists had been completed, a sampling coring-campaign by archaeologists, students from Leiden University and volunteers was initiated to verify if the online identifications were correct. Over 300 mounds were investigated, with 80 of them being verified as burial mounds. These results were then used to estimate how many mounds which have not yet been researched through coring are actual burial mounds, indicating that another 949 mounds are probably burial mounds. In practice, this means that the number of burial mounds on the Veluwe and Utrechtse Heuvelrug has been doubled by the research efforts of citizen scientists. Furthermore, countless examples of old cart-tracks, around 900 charcoal piles and 36km2 of Celtic fields have been identified. As a cherry on top, in 2022 the heritage quest project won the European Heritage Award/Europa Nostra Award in the category ‘science’ for proving that citizens can play an active role in protecting cultural heritage (Erfgoed Gelderland, 2023).

2.3 Other approaches to citizen science in cultural heritage and archaeology

2.3.1 Atlas of Hillforts, hillfort documentation in Great Britain and Ireland.

Another example of a successful citizen science project concerning archaeological heritage has been carried out in Great-Britain and Ireland. With the help of around one-hundred citizen scientists, researchers from the universities of Oxford, Edinburgh and the University College Cork have created an online map database of all hillforts in Britain and Ireland. In total, 4.147 hillforts dating between 1000BC and 700AD have been discovered throughout the Isles during the nearly five years of the project's duration (https://www.ox.ac.uk/news/2017-06-23-online-hillforts-atlas-maps-all-4147-britain-and-ireland-first-time). The Atlas of Hillforts project had three major aims: Providing information for the Atlas database on hillforts, to encourage people who visit hillforts to critically assess the earthworks in an informed way and to gather information on the current condition of hillforts. Instead of being computer-based, the Atlas project was kept low-tech and paper based to attract and appeal to a larger number of people. Citizen scientists had to visit the hillforts and record their findings in a ten-page survey form. To be able to efficiently do this, a seven-page guidance note on hillfort surveys had to be read by the citizen scientists. Furthermore, the researchers provided the participants with many additional sources if they wanted to read more information on the subject. The surveys were of mixed quality, with many participants providing additional materials such as photographs, LiDAR imagery, drawings, etc. These results then had to be analyzed by the research team to be implemented in the Atlas Hillforts database map (Hillforts, 2017).

In comparison with the Heritage Quest project in the central Netherlands, there are five major differences between Heritage Quest and Atlas of Hillforts. First, the number of citizen scientists participating in the Atlas of Hillforts project was way lower than the number of participants in Heritage Quest; one hundred citizen scientists participated in gathering data for Atlas compared to over 6600 citizen scientists for Heritage Quest. Secondly, participants in the Atlas project needed prior training to be able to participate in the project, instead of the low-threshold approach by Heritage Quest. This was done by providing the citizen scientists with a guidance on hillfort surveys and additional sources. Thirdly, instead of being web-based, the Atlas project was based around using low-tech paper survey forms. The fourth major difference is that citizen scientists had to actually visit the hillforts to be able to fill out their survey forms. The fifth and last major difference is the scope of the Atlas project; the research area in which hillforts were to be described encompassed all the British Isles, and the project lasted for nearly five years.

2.3.2 GlobalXplorer°, crowdsourced mapping of archaeological sites in Peru

The GlobalXplorer citizen science project was launched on the 30th of January 2017, with the aim of identifying new archaeological features and sites of looting in an area stretching from the Pacific coast to the Sacred Valley in Peru. A global project, GlobalXplorer's goal is to create a tool which can help humanity protect and preserve cultural heritage. The research area covered roughly 150.000km2, and since the project was launched over 70.000 citizen scientists from over 100 different countries participated in the project. Apart from some simple instructions on how to identify areas of looting, the GlobalXplorer project required very little prior knowledge from its participants. Together, the participants scanned 14.620.932 high-resolution satellite images with a ground resolution between 50 and 70 centimeters provided by the projects partner DigitalGlobe. Over the course of the project, participants have identified 19.084 features of archaeological interest dating between 3200BC and 1572AD. These were then sorted into categories by the research team, who identified 342 sites of very high interest in the data. Following the digital and citizen science aspect of the project, 40 sites were visited and mapped in detail using drones, providing the researchers with detailed 3d-models, photos and videos of the archaeological sites. This data was then handed over to the Peruvian authorities, who could use it to setup protection boundaries and register the sites archaeological properties under the protection of the state. Furthermore, the data can be used by future researchers for non-intrusive research. Data collection and the identification of archaeological heritage were not the only goals of the GlobalXplorer project; an important aspect of the project was to create a sense of stewardship for archaeological heritage in local communities, incentivizing them to protect their local heritage while increasing their income (GlobalXplorer, 2018).

Although more similar to the Heritage Quest project than Atlas, there are still some differences between Heritage Quest and GlobalXplorer which need to be examined further. The first major difference is the international aspect of GlobalXplorer in comparison to Heritage Quest. Even though Heritage Quest allowed international researchers to participate through a bi-lingual interface, GlobalXplorer was specifically aimed at participation by an international crowd. This is reflected in their ambition to create a global platform for the protection and preservation of cultural heritage, and in their participants hailing from over 100 different countries. This international approach led to the second major difference; the scope of GlobalXplorer is much bigger than that of Heritage Quest, with over fourteen-million images in which heritage was to be identified compared to nearly 700.000 images respectively. Furthermore, the number of users participating in GlobalXplorer was more than tenfold that of Heritage Quest. Over 70.000 citizen scientists participated in the project, compared to 6.636 participants in the Heritage Quest project. Thirdly, due to the gigantic scope of the research area, the number of participants and enormous image dataset, a staggering amount of over 19.000 potential archaeological sites have been identified. On the flip side, only a very small number of sites have been verified by the researchers, of which only 40 sites have been investigated through fieldwork. This illustrates an interesting fourth difference; even though the Heritage Quest project had a much smaller scope, the amount of verified archaeological sites resulting from the citizen science project was much higher. Furthermore, whilst Heritage Quest actively involved citizen scientists in the verification process, verification in the GlobalXplorer project was carried out by a small team of professional researchers.

2.3.3 The CitPres app, participatory site stewardship in Bodie, California

The ghost town of Bodie is a former gold-rush town and popular tourist attraction in the state of California, attracting more than 100.000 visitors on a yearly basis. Because of this popularity, the preservation of the site is quickly deteriorating. Visitors remove artefacts from their original contexts to be kept as souvenirs or to bring them to park staff, removing important pieces of the sites history and limiting the understanding of the site and its former community in the process. To combat this, researchers have developed the CitPres app in which citizen scientists, visitors, park managers and archaeologists can photograph and describe artefacts *in-situ*, which can then be visualized spatially through the CitPres Map desktop application. Beta testing was conducted in 2018 and in 2019 an on-site preservation and awareness program was developed. Ten volunteers were then randomly recruited to test the app and collect data on the Bodie site. The volunteers were trained in person and on site, and further video training was available for reference in the field. The training focused on the importance of *in-situ* object collection, the identification of different archaeological materials such as ceramics, metal, glass, etc., and the importance of dimensional reference. Participants were also instructed to carry multiple plastic scales while taking pictures on site. The results of the study were that the CitPres app has the potential to increase awareness of the archaeology and history of the site and could engage casual visitors in the preservation of the site and the protection and stewardship of its material culture (Lercari and Jaffke, 2020).

Although the nature of the research for the implementation of an app to document and protect archaeological heritage is quite different from the Heritage Quest project, there are some similarities and differences which should be discussed. Even though the CitPres app works on an artefact scale instead of focusing on different archaeological sites, both projects have shown that the usage of digital applications can increase the engagement of people in their (local) heritage. The biggest difference between both projects is the amount of training which is required prior to using the application made to identify archaeological heritage. The CitPres app requires a lot of user training to work effectively, but the study has shown that if done correctly a small number of citizen scientists with little prior knowledge can be trained to document archaeological heritage on a very professional level. This not only increases their understanding of the past, but also increases their awareness of the importance of protecting cultural heritage and lets citizen scientists act as stewards of said heritage. However, the amount of necessary training creates a high threshold for citizens to participate in the project, and participation is also limited to people visiting the Bodie site and willing to go through said training. With over 100.000 visitors per year, it is also questionable if local archaeologists and park staff have the time to train enough volunteers for the project to have the desired impact of creating a sense of stewardship in the visitors of the Bodie site. Furthermore, artefacts which have already been moved by past tourists could be wrongfully identified as *in-situ* and artefacts which have been registered through the app can still be removed by tourists despite their documentation. Nonetheless, the usage of field-apps on mobile devices can be a powerful tool for the documentation of archaeological heritage in the field by citizen scientists.

Chapter 3: Object Classes

To establish the different case studies that will be further explored in this research three major themes of the Provincial Research agenda Archaeology Zeeland 2017-2020 have been evaluated with local professionals from ‘Stichting Cultureel Erfgoed Zeeland’ (SCEZ) and chosen for their potential viability (Provincie Zeeland, 2017). The themes all touch upon current knowledge gaps in the archaeological record of the province and are on the surface seemingly suitable for research through a citizen science project using remote sensed satellite data. The themes that are established through the POAZ and that will be used to establish object classes for this research are, in order of magnitude and potential suitability, as follows:

- Defense works in Zeeland
- Drowned land and villages
- The rural landscape and infrastructure

Otherwise potential classes of archaeological objects could be focused on prehistoric heritage, Roman heritage, early medieval heritage or the 2nd World War. However, due to the nature and formation of the landscape of Zeeland, there are only very few areas in the south of Zeeuws-Vlaanderen in which prehistoric and Roman heritage can be found on the surface. During the early medieval period Zeeland was mostly uninhabited, so this class is also unsuitable for an extensive citizen science project. The 2nd World War could be a potentially suitable class of archaeological heritage which can be researched through citizen science, but its traces in the landscape are few and spatially confined to some small regions. Because of the amount of potential heritage from the medieval and early-modern period from around 1000AD to 1800AD, the object classes which have been chosen are focused on this time period.

In the following sub-chapters, each object class will be explored further. The amount of features that will be considered in this research will vary for each object class, as some object classes (such as drowned land and villages) are quite comprehensive, whilst others (such as defense works) have a wider variety in occurrence and time-period. Conservation of all object classes should be relatively good, considering all object classes date to the time period after the construction of the first dykes after which the surface of the landscape saw relatively few geomorphological changes.

3.1 Defensive works in Zeeland

Due to its location at sea and the estuary of the Scheldt and Rhine rivers, the Province of Zeeland has been a strategic location throughout its history. This strategic position is attested to by the many different types of fortifications that have been built in the province from the Roman period onwards. Dating to the Roman period the castellum at Aardenburg attests to the strategic importance of the region, whilst in the early medieval period we see relatively unique ring fortresses being constructed. Names like Middelburg, Souburg, Domburg and Oostburg are all connected to the construction of these burghs. At the turn of the early to the late-Medieval period, motte-and-bailey castles are constructed throughout the region, and during the renaissance 'proper' medieval castles are being built. Extensive fortified lines and 'modern' fortifications were being built during the eighty years' war, at roughly the same time when medieval city walls make way for the typical star fortifications of the period. For some cities such as Vlissingen and Veere these fortifications are expanded upon during the Napoleonic wars, and more recently the province of Zeeland became part of the '*atlantikwall*' during German occupation in World War 2 (Provincie Zeeland, 2017).

With such a diverse assemblage of fortifications dating from the Roman period to the second World War, there is much potential for identifying these sturdily built, defensive structures in remote sensing datasets. For this research two major types of fortifications in the province will be expanded upon in case-studies; the medieval motte-and-bailey castles and the extensive fortifications and fortified lines from the eighty years' war called the 'Staats-Spaanse Linies'.

3.1.1 Motte-and-Bailey castles and castle grounds

The small medieval (11th to early 13th century) mounds that are dotted around the province of Zeeland have appealed to the imagination and interest of chroniclers, historians and archaeologists for nearly four centuries. First described in 1634 by the chronicler Jan Reygersbergh, the mounds were interpreted as temporary places of refuge during the construction of the first dykes in the eleventh century. This early description is still reflected in the local name for these mounds; *vliedbergen*, which roughly translates to 'flood-mounds'. Later interpretations are diverse, and range from places of permanent habitation by Smallegange (1696), burial mounds by Speeleveldt (1808), refuge mounds from the time period *before* the construction of dykes by de Kanter and Dresselhuis (1824) and places for signaling or ritual sacrifice by Dresselhuis (1845) and Macare (1859) (de Klerk et al, 1969, 4-8). Dr. Jan Cornelis de Man wrote two extensive articles on the mounds in 1887 and 1897 which were more descriptive in nature. He was the first to establish a connection between the locations of the mounds and small local lordships called *ambachtsheerlijkheden*. He also noted that in close proximity to each mound there had presumably been a farm or stable, the mounds were constructed nearby roads, waterways or banks and they were oftentimes the foundational point of villages. Although he still believed the mounds could have been places of ritual sacrifice, unintentionally he was the first who suggested the mounds could have had a military function by describing the distances between the mounds surrounding Middelburg as 'likewise, as to how these days outposts and fortifications are built at a certain range from fortresses.' During the 1920s, excavations by van Giffen (1922), Remouchamps (1927) and Hubregtse (1927) showed that some mounds were constructed in two phases (de Klerk et al, 1969, 8, 35, 37).

In 2007 an extensive catalogue was published detailing all 38 (known) mounds that are still in existence, listing spatial, morphological and metric data about the structures and subsequently ordering them into five different categories. The 38 mounds are approximately 20% of the original number of mounds in existence, putting the original number of mounds at a little under 200. The catalogue confirms the usage of the mounds as defensive structures or mottes, but also clearly states that the popular view that the mounds were all motte-and-bailey castles with lower castle-grounds and a surrounding moat is too generalized. This popular image stems from a reconstruction drawing of the mound near Borsele that was published in 1961 (see Figure 2), but only 18% of inventoried mounds show concrete evidence of castle grounds. These specific mounds are possibly testament to later stadia of castle-development. For three of the mounds a surrounding moat was also not found. For seven of the mounds, all with a diameter of around 50 meters, their groundwork plans are more squared than round. These are interpreted as being rudimentary late 12th or early 13th century predecessors of the late 13th century castles with a square layout (van Heeringen et al, 2007). The data indicates that most mounds from the 11th century may well have solely been a rounded mound with a wooden tower and moat. Later developments in castle-building led to some of the wealthier motte-owners modernizing to square buildings, with renovation or rebuilding in the 13th century in natural stone or brick (van Heeringen et al, 2007).

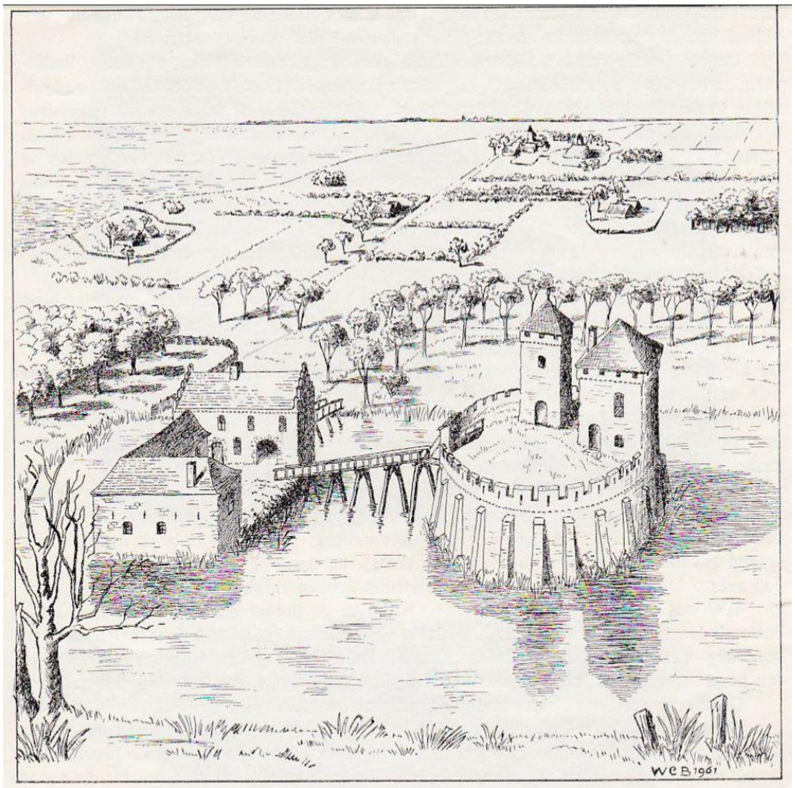


Figure 2: Reconstruction of the mound near Borsele (W.C. Braat, 1961).

3.1.2 'Staats-Spaanse Linies', defensive works and lines from the 16th up to the 18th century.

During the second half of the 16th century a process started in which the provinces of the Low-Countries gradually started to claim more independence from the Spanish king Philips II. This culminated in an armed conflict between the Spanish crown and the Dutch republic, led by William of Orange, in 1568. Due to war exhaustion on both sides, an uneasy peace was signed in 1609, but the conflict re-ignited after twelve years in 1621 when Spanish forces took the city of Breda. The Dutch republic settled on an offensive strategy of consolidation of its core territories by capturing territories on its eastern and southern borders, to which the most southern part of the province of Zeeland, Zeeuws-Vlaanderen (Zeeuwish-Flanders) also belonged. During the 1640s the necessity of war became debatable; Spanish troops and military capacity was weakened, but on the other hand the southern border and buffer-zone of the republic remained unsecure. With the capture of Sas van Gent in 1644 and Hulst in 1655, Zeeland was deemed secure, which led to peace under the treaty of Munster in 1648 (Sijmons et al, 2003, 33).
During the revolt which is popularly known in the Netherlands as the Eighty years' war, both parties participating in the conflict constructed over a hundred fortifications in Zeeuws-Vlaanderen. Dutch fortifications of this period were based upon Italian designs which were imported during the first half of the 16th century. The fortress Rammekens near Flushing, designed by Donati de Boni and constructed between 1547 and 1557, is the only fortress in Zeeland dating to this period which is still in existence today (see Figure 3). An important strategical advantage of these 'modern' fortresses was the ability to cover each rampart with musketry fire from two sides. From the second half of the 16th century the '*oud-Nederlandse vestingstelsel'* (old-Dutch fortress system) was introduced, which was based upon Italian principles but differentiated from the Italian counterparts through the usage of wet- instead of dry moats, ninety-degree angles between the curtain walls and the outer ramparts, and the usage of earthen ramparts instead of ramparts covered with- or fully constructed in stone. Small fortresses were usually manned by a half or full company, consisting of thirty or sixty men. Larger fortresses could be garrisoned by up to two hundred men. At the start of the 17th century defensive line-dykes were being constructed in Zeeuws-Vlaanderen to connect fortified towns with chains of fortresses in an east-west direction. The fortresses were constructed at locations of strategic importance from which main waterways and creeks, and thus trade and troop-transportation by ship, could be controlled. On the inside of these lines of fortifications roads were constructed for transporting troops and supplies, while the outside of the lines was often inundated to hamper Spanish attackers. Although inundations were successfully used by both sides participating in the conflict, for instance during the Spanish siege of Leiden in 1573 or the Dutch siege of 's-Hertogenbosch in 1629, the strategy had by far the most destructive consequences in Zeeuws-Vlaanderen. Inundations could not be properly controlled because of tidal action, and large swathes of cultural landscape became uninhabitable and were lost to the sea causing depopulation, social disintegration and severe

economic recession. The defensive lines remained in use and were being maintained and expanded upon until the start of the 19th century, when the southern border of Zeeuws-Vlaanderen was no longer of any military or strategic importance as the Netherlands became part of the French Empire. During the Belgian Revolt of 1830-1831 the defensive lines saw only minor military activity. Their last use was during World War two, when allied forces inundated the waterline between Axel and Hulst and mounted an offensive from the old fortresses of Ferdinandus, St. Nicolaas, St. Livinius, St. Jacob and St. Jozeph. This offensive concluded a period of military usage of the fortifications which had lasted for nearly four hundred years (Sijmons *et al*, 2003, 35-37, 53-54).

Figure 3: Satellite imagery of fortress Rammekens in 2022 (Figure by R. Willemstein, PDOK)

An inventory of the fortresses and defensive lines was undertaken in 2003, in which (known) fortresses were inventoried and qualitatively evaluated based upon their current visibility, ranging from good visibility to decent-, mediocre-, poor visibility and lastly invisible. The inventory was based upon topographical maps, aerial photographs, fieldwork, and earlier studies by Acke (2001) and Stockman and Everaers (1999). Out of 75 fortresses that were described, 46 fortifications were deemed invisible and lost over time. In other words, a little over 60% of all inventoried fortresses were no longer visible in the datasets used. Although no clear indication is given as to how many kilometers of defensive line-dykes were inventoried, most of the lines range in visibility from decent to poor, with some outliers of clearly visible lines and no inventoried lines which are invisible (Sijmons et al, 2003, p. 55, 74-75, 78-79).

3.2 Drowned land and villages

Throughout its history, the province of Zeeland has been known for its struggle against the water. Whether it was due to natural flooding, inundation, or poor maintenance of dykes, there is no other place in Europe where so much land and settlements have been lost to the sea; some parts of which were later reclaimed, and some that still lie beneath the waves. The study of drowned villages and lost lands in Zeeland can be roughly divided into two time periods, the period before and the period after 1000AD. This division has a multiplicity of reasons. First of all, there are very few written sources before the millennial divide and no maps. Furthermore, there is very little archaeological evidence from this period because its landscapes were drowned and covered in (thick) layers of sediment. The archaeological evidence we have mostly dates to the late Iron and Roman periods. A spectacular group of artefacts from the latter period are around 300 Roman altars to the goddess Nehalennia which were fished or otherwise surfaced from the Oosterschelde off the coast at Colijnsplaat (Kuipers et al, 2004, 11). These altars most likely came from the Roman settlement of Ganuenta which was lost to the sea at some unknown point in time. After the Roman period Zeeland seems almost completely uninhabited. This seems to be mostly due to human factors; during the Roman period channels and ditches were dug to dewater the land, which lead to widespread settling of the peat after which the sea swallowed huge swaths of land. This made most of the province uninhabitable save for the dunes and the south of Zeeuws-Vlaanderen. It would not be until the beginning of the 9th century when people would once again start inhabiting the hinterlands of the province (Kuipers et al, 2004, 11, 17, 20-24). To protect themselves from the incoming tides, the inhabitants of Zeeland started damming of streams and building ‘embankment-like’ dykes around the turn of the millennium. The first polders were created by constructing large ring-dykes around silted up salt marshes. These dykes are considered ‘defensive’ in nature, as their primary function was to protect from the sea. ‘Offensive’ dykes were constructed in areas where sediment accrued next to existing dykes or by constructing dykes around shoals which were sufficiently raised by sedimentation. These offensive embankments resulted in land won from the sea, and the oldest examples are found near Cadzand dating to the early 12th century. Unfortunately, these land gains did not come without cost. Between 1134 and 1530 more than 45 major storm surges tore through the newly gained lands, nearly always resulting in flooding and damages throughout the province. Not all lands were permanently lost after they were flooded or reclaimed by the sea; in 1598 the island of Noord-Beveland (1738 hectare) was diked once again, after being lost to flooding six decades earlier. Human inundations during the Eighty years’ war led to major flooding and loss of land in the western parts of Zeeuws-Vlaanderen, but these lands were reclaimed as the 'Generale Prins Willempolder (3255 hectare) in the 1650s. Except for some small creeks that came into existence after the disastrous flood of 1953, no land was lost to the sea after 1682 (Kuipers *et al,* 2004, 27-36).

When Jan Kuipers published his book 'Sluimerend in Slik' in 2004, his comprehensive overview rooted in literature research listed a total of 117 drowned villages and cities that had a church. The inclusion of the church appendix might seem quite random, but during the Medieval and early Modern periods almost every small hamlet in Zeeland had its own church. In this context the choice to list villages with churches is logical as it precludes the smallest of settlements which could barely be considered villages. The author states that the list is dynamic in nature and represents an inventory of drowned villages based upon the (then) latest state of science which can and should be expanded upon. The villages are ordered into three separate classes. Those lost due to natural disasters, those lost due to inundation and those lost due to a combination of natural disaster and inundation. It should be noted here that inundation is the deliberate act of flooding the land, opposed to natural disaster. Inundation can lead to further flooding of areas which were not meant to be inundated. By a large margin, most settlements were lost to the sea by natural disasters. These 99 settlements represent 85% of all villages lost to the sea. The second largest group is that of settlements lost to inundation, with eleven settlements (9% of the total) lost in this manner. Subsequently, the smallest group consists of seven settlements (6%) which were lost due to a combination of natural disaster and inundation. All settlements that were lost due to inundation or a combination of inundation and natural disaster are located in Zeeuws-Vlaanderen, which is perhaps unsurprising considering the widespread use of uncontrolled inundation tactics by both Dutch and Spanish forces during the Eighty years' war in this 'frontline' region. When reading about drowned villages it is often tempting to assume these settlements have all sunk beneath the waves. One has to keep in mind that great swathes of land, as mentioned above, were reclaimed from the sea after being lost. The remains of many of these drowned villages are therefore now on land. According to the map published by Kuipers, 46 out of 117 listed villages lay outside of current dykes. This means that over half (60%) of all drowned villages listed are currently situated on land. It is however prudent to remember that even villages that were under the sea for only a short while can be covered in a thick layer of sedimentation (Kuipers *et al,* 2004, 48-49).

3.3 The rural landscape and infrastructure

When the construction of extensive dykes in the province of Zeeland had commenced there was a difference between functionality of defensive dykes which were used to consolidate silted up salt marshes and provide protection from the tides, and offensive dykes which were used to gain land from the sea. Generally speaking, the land which was (and still is) enclosed by defensive dykes is called *oudland*, meaning ‘old land’. The land which was gained from the sea and enclosed by offensive dykes is called *nieuwland,* meaning ‘new land’. Whilst there is a difference in name between the two types of enclosed land, the differences do not end there. Because of its nature the old land had silted up over time with slow currents, resulting in finer sediments being deposited and more clayey soils. Because new lands were gained from building dykes around silted up shoals where currents were higher, their soils are generally more sandy (Vervloet, 1986, 87-88).

The differences between old- and new land are also expressed in different forms of habitation and allotment patterns. Villages in the old land, called *ringdorpen*, are characteristically built as a circular or square central space which is surrounded by a road. On the outside of this road houses were built with the front side facing the center of the village. The central space is usually occupied by a church and accompanying graveyard, and is separated from the rest of the village by a wall or a ditch which is constructed on the inside of the road. The central placement of the church suggest that these could have played an important role in the establishment of these villages. However, the proximity of mounds to a majority of old land villages might indicate that the ringdorpen have a secondary instead of a primary nature (Vervloet, 1986, 93-94).

Settlement patterns in the new land tend to be more diffuse, with individual farmsteads spread around the polders. Houses are also oftentimes built upon the less steep sides of dykes which used to face towards the sea. When construction of houses on dykes became more dense the steeper side of the dyke would also be used for construction, resulting in characteristic dyke-villages called *dijkdorpen.* Another common type of village in the new land is the Flakkee type; these villages were constructed by building a road perpendicular to a dyke called a *voorstraat* which led towards a church and graveyard. Further expansions and roads were built parallel to the voorstraat instead of being constructed around the church. In the new land, villages were almost always constructed near or on dykes. If a new land village is situated in a polder, this usually indicates that the village has been built on the location of an older drowned village (Vervloet, 1986, 97-98).

The last major difference between old and new land can be seen in the parceling of the landscape. In the old land polders, the natural reliefs of old silted up creek systems were guiding factors in the arrangement of parcels to minimize labor. The parcels were often irregular and could be arranged in both blocks or strips. The irregularities in the layout of the cultural landscape is also reflected in the roads, which are often winding and usually also follow the course of silted up creeks. Contrastingly, roads in the new land are usually straight, with large rectangular fields lying in between. This regular division of the landscape is a testament to the planned division of newly gained lands (Vervloet, 1986, 98-99). Because of extensive reparceling works initiated after the second World War, which were deemed necessary to increase the size of agricultural companies, improve connections between villages and to create space for new housing and other construction projects, large parts of the original layout of the landscape were destroyed. The fragmented character of much of the old land was lost in favor of the creation of large rectangular parcels (Kavelruilbureau Zeeland, 2023).

A final aspect of the cultural landscape which should be mentioned are the scars that are left in the landscape by (large scale) peat digging activities for the production of salt. The sandy or clayey top soil was removed and the underlying peat excavated. Because the peat had often been underwater for centuries, dating back to the Roman period, it was saturated with salt. The excavated peat was dried and burned in ovens, after which the ashes were mixed with seawater and heated until all the water was evaporated after which the raw salt was refined. Especially old land polders were extensively dug up for peat and the negative impact of these excavation activities soon became apparent. The land settled, increasing the risks of flooding, and the irregularity of the activities could leave the landscape in ruins; the pits that were often randomly dug could make entire swaths of land unsuitable for farming (Vervloet, 1986, 100-101).

As might have become apparent from the case-studies which are explored in this chapter, infrastructural works such as dykes and roads played a major role in the construction and shaping of the landscape of Zeeland. Because of their formative characteristics and inherent nature to show (historical) interconnectedness or lack thereof, and their potential to indicate chronology in land reclamation these infrastructural works are also considered within this thesis. Furthermore, volunteers of the archaeological workgroup of the Netherlands (AWN) are creating a database of all interior dykes in Zeeland. The national government also has plans to create a database which contains all Dutch dykes (Provincie Zeeland, 2017). An eventual inventory of historical dykes which are no longer visible to the naked eye could help datasets such as these become more versatile in their usage and help to indicate and establish broader trends in dyke construction over a large period of time.

Chapter 4: Data and methodology

4.1 Data

4.1.1 Remotely sensed data

The dataset that will be used in this research for remotely sensing archaeological features consists of satellite photographs from the *Publieke Dienstverlening Op de Kaart* (PDOK), which are disclosed as open data through online WMS/WMTS GIS services (www.pdok.nl). These contain ortho-rectified imagery of the entire Netherlands which are consistently updated on a yearly basis. The satellite imagery can thus be specified to a certain year, and this provides a good opportunity to sense archaeological traces which are only exposed irregularly (e.g. cropmarks when and where there are suitable crops on fields or archaeological traces along the coast which are sometimes covered in sand). From 2016 to 2022 nationwide orthorectified satellite imagery which has been remotely sensed during the summer months has been published through PDOK. The 2021 nationwide orthorectified satellite imagery which has been remotely sensed during the summer months is missing from this dataset. The imagery which has been collected during the summer months has a ground-resolution of 25 centimeters. From 2021 onwards a nationwide orthorectified satellite image which has been remotely sensed in spring has also been published. These 'spring' datasets have a ground-resolution of 8 centimeters. Because the 2021 summer dataset is non-existent, for this year only the spring dataset has been used (https://www.pdok.nl/introductie/-/article/luchtfoto-pdok).
For this research the datasets which are remotely sensed during the summer months are potentially viable for the identification of crop-marks, and thus, archaeological heritage. Because there are no crops on the fields during the spring months, it will be interesting to see if there is a marked difference in visibility of potential heritage between the 'spring' and 'summer' datasets. All remotely sensed orthorectified satellite imagery used for this research is listed in the table below (see Table 1), and can be accessed in GIS through the following WMS link.

Year of acquisition	**Spatial resolution**	**Temporal resolution**	**Spectral resolution**
2016	25 cm	Summer	RGB
2017	25 cm	Summer	RGB
2018	25 cm	Summer	RGB
2019	25 cm	Summer	RGB
2020	25 cm	Summer	RGB
2021	8 cm	Spring	RGB
2022	8 cm	Spring	RGB
2022	25 cm	Summer	RGB

Table 1: Satellite imagery used.

The usage of satellite imagery disclosed as open data by ESA through the Copernicus program has also been considered. Remotely sensed by their Sentinel-2 satellites (Sentinel-2A and Sentinel-2B) ESA has published a cloudless background map of Europe for both 2016 and 2018. However, because of its low ground-resolution of 10 meters, compared to the satellite imagery disclosed by PDOK with a resolution of 8 or 25 centimeters, the imagery released by ESA does not seem very suitable for the detection of archaeological heritage and thus has not been used in this research (https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/overview).

4.1.2 Other GIS datasets

To be able to find suitable examples for each case study in the remote-sensing datasets, several open-access GIS layers which are disclosed online through Web Map Services (WMS) have been used. The first WMS layer that has been used is the 'map of drowned villages of Zeeland' which was published by the province of Zeeland in 2018 after being revised with new archival and archaeological research data. Secondly, a WMS layer containing the locations of known fortified lines from the State-Spanish Lines dating to the Eighty years' war and up to the French period (1794) has been used. The layer is published by the province of Zeeland and consists of lines indicating the location of line-dykes but does not contain the location of fortresses and fortifications. Another WMS layer published by the province of Zeeland containing points which indicate known fortifications and fortresses has also been used to complement the line data. This combination of datasets provides a powerful tool for usage in remote sensing of defensive structures from the State-Spanish Lines. A WMS layer of the *Archeologische Monumenten Kaart* (AMK, Archaeological monuments map) has also been used to supplement the other datasets. The AMK contains an overview of important archaeological terrains in the Netherlands, which have all been evaluated and classified by their archaeological importance. In this instance, the layer only contains a cutout of the province of Zeeland. Furthermore, the geomorphological map scale 1:50000 and soil map scale 1:50000 of the Netherlands which have been published by Wageningen University have also been used. Lastly, RD coordinates of all known mounds/mottes in the province of Zeeland as described by R.M. van Heeringen *et al* in the appendixes of the catalogue 'Monumenten van aarde – Beeldcatalogus van de Zeeuwse bergjes' have been used to easily locate known mounds and inspect them in the remote sensing datasets. All GIS data apart from the remotely sensed satellite imagery used is listed in the table below (see Table 2).

Subject	**Published by**	**Type**	**Hyperlink to WMS layer**
Drowned villages of Zeeland	Province of Zeeland	Point	WMS
State Spanish Lines	Province of Zeeland	Line	WMS
State Spanish Lines	Province of Zeeland	Point	WMS

Archeological Monuments Map (AMK)	Province of Zeeland	Polygon	WMS
Geomorphological Map of the Netherlands	Wageningen University	Polygon	WMS
Soil Map of the Netherlands	Wageningen University	Polygon	WMS
RD Coordinates of Mounds in Zeeland	R.M. van Heeringen *et al*	Point (coordinates)	-

Table 2: Other GIS data used.

4.2 Methodology

To answer the main research question and sub-questions all data will be reviewed through spatial analysis using a geographic information system (GIS) using QGIS 3.28.2. For each different case-study a combination of remote sensed satellite imagery from the years 2016 - 2022 and WMS layers concerning the relevant information for the case-study (or spatial data in the form of RD coordinates of mounds/mottes for the case-study of mounds) will be used to see if archaeological features which are relevant to the corresponding case study can be identified in the satellite imagery described in chapter 4.1.1.

If archaeological features that are potentially relevant to the case study can be identified in satellite imagery from a certain year, the satellite imagery from other years will also be inspected in the same location to see if the archaeological traces manifest themselves differently. If traces are suspected in one satellite image, they could be localized disturbances due to plowing, machinery driving over the land, recent excavations, shadows, mowing, harvesting, drainage or other processes which could make interpretation of the traces as archaeological features problematic. If features appear on satellite data from different years, there is a very high possibility that they are not localized distortions due to external factors.

If archaeological features are identified they will be evaluated on their visibility in all different satellite imagery datasets. This will be done in both the geodatabase and the results according to a ranking system ranging from 1 to 5, where 1 represents invisibility and 5 represents extremely clear visibility (see Table 3).

Visibility rating	1	2	3	4	5
Ranking	Invisible	Slightly visible	Moderately visible	Clearly visible	Very clearly visible

Table 3: Visibility ratings and rankings.

After their visibility has been evaluated, the general shape and size of the features will be described based upon the imagery with the highest visibility rating. The features will then be interpreted and, wherever possible, identified historically using the information stored in the WMS layers or separately sourced information. Some features might be hitherto unknown archaeological traces, and as such these can probably not be identified historically. Furthermore, each archaeological feature will include a central RD coordinate and toponym for (future) spatial localization.

When archaeological features have been identified and described, they will be mapped in QGIS. Maps of archeological features will be made with the satellite imagery from the year which yields the highest visibility per feature. The visibility rating beneath the year from which the satellite imagery was used will be written down in bold text, so readers can instantly see which imagery was used for the creation of the map.

When enough data has been inspected per case study, the resulting information about the spatial features such as quantity, shape, size, visibility and historical relevance will be used to evaluate the potential of each case study for a remote sensing project using citizen scientists in Zeeland. This will then be compared to the original Heritage Quest to see what aspects can be adapted and what aspects could or should be reconsidered, modified or replaced/removed completely.

All inventoried remote sensing datasets and visible archaeological traces will be catalogued accompanied by a database linked to GIS which compiles spatial data with accompanying discrete data such as time-period, visibility, etc. The GIS workspace will use the RD coordinate system. The GIS workspace and database will be published together with this thesis.

Chapter 5: Results

In this chapter the results of this study will be described in order of appearance of the case-studies described in chapter 3. Although the number of results vary between each case-study, all results will be described according to the same nominators as mentioned in chapter 4.2. These are: visibility per year of satellite imagery (ranging from 1, invisible, to 5, extremely clear visibility), general shape and size on the imagery that has the highest visibility rating, interpretation and (if possible) historical identification. A table with a complete overview of all results, their visibility, interpretation, historical identification, toponym and their respective central RD coordinate is included as an appendix (see Appendix A). Furthermore, all visibility ratings in the satellite imagery from different years for the different features will also be included as an appendix (see Appendix B). A map listing all features which have been explored in this research is added below.

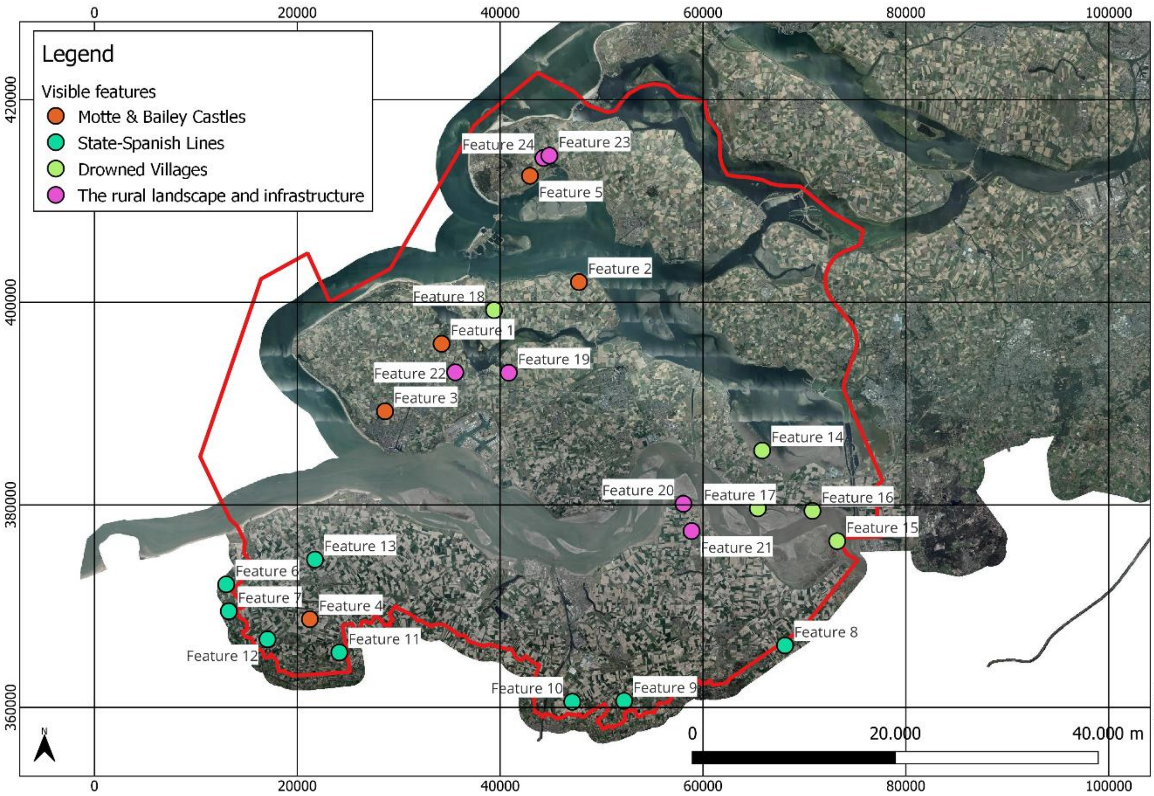


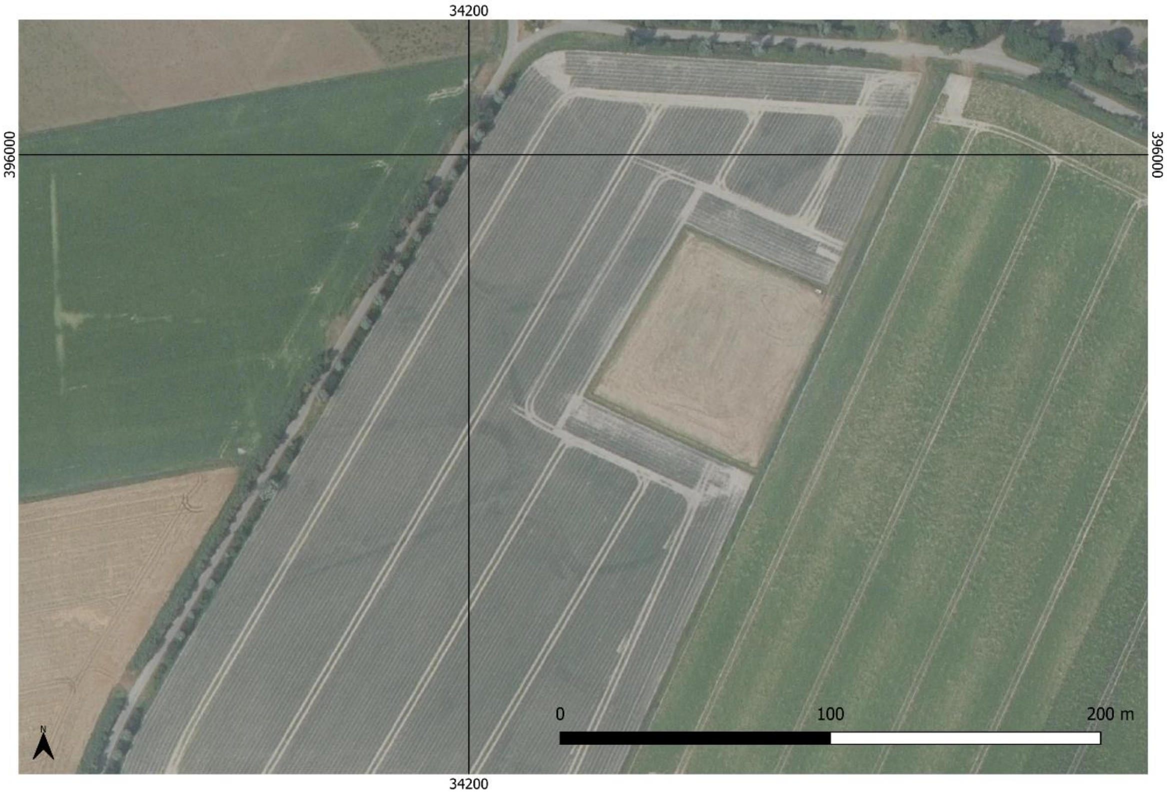
Figure 4: Map of all features described in this research. (Figure by R. Willemstein, PDOK)

5.1 Defensive works in Zeeland

In this sub-chapter, all defensive works that have been identified in the dataset will be listed and described according to the descriptors as mentioned in chapter 4.2.

5.1.1 Motte-and-Bailey castles and castle grounds

Feature 1



Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022, 8cm**	**2022, 25cm**
Visibility	2	1	1	**4**	3	2	2	1

Shape: More or less straight lines with curved edges at the ends

Size: The entire shape covers an area of approximately 260 by 140 meters. The interior of the feature measures approximately 100 by 70 meters.

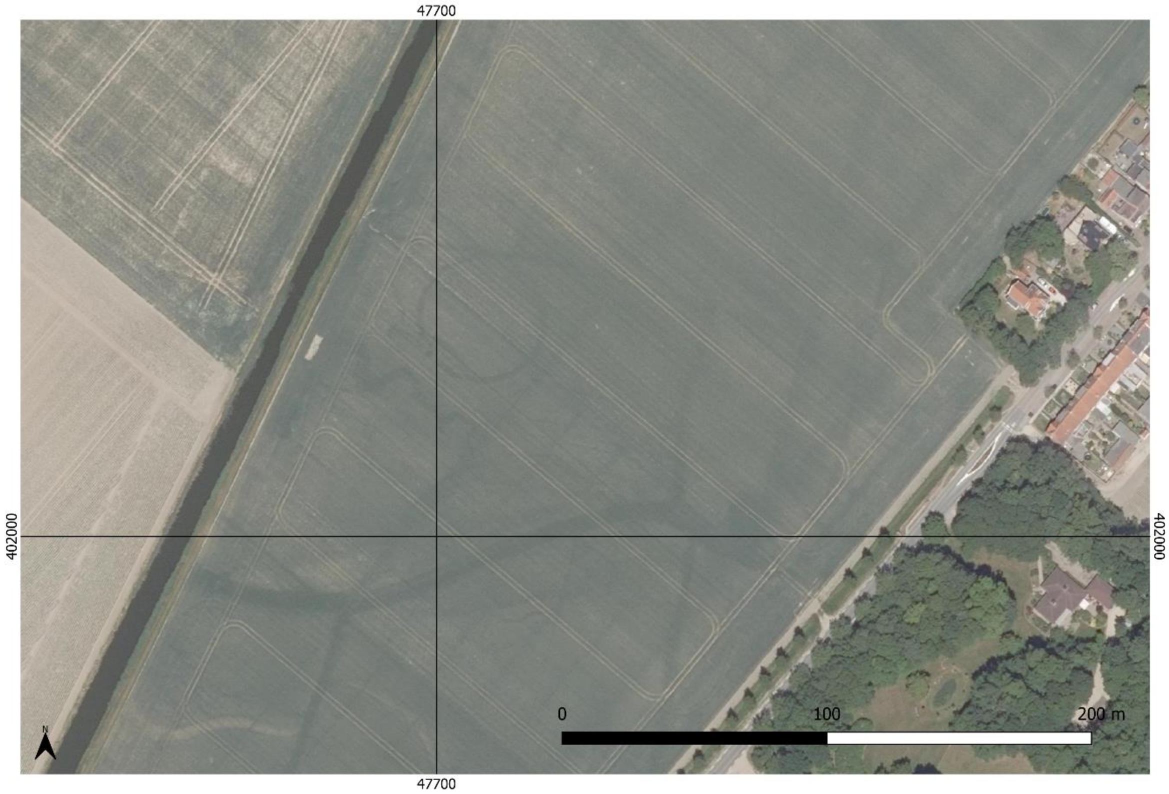
Interpretation: The traces are those of a castle terrain belonging to the mound which is located in the yellow squared patch.

Historical identification: Castle terrain of the mound 'Zandweg-Bieweg'.

RD: 34235, 395900

Toponym: Zandweg-Bieweg

Feature 2



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	1	1	1	**4**	1	2	3

Shape: Curved and straight lines with a circular shape in the western part of the features.

Size: The curved line in the bottom-centre is approximately 250 meters long and 5 meters wide. The circular feature has a diameter of approximately 45 meters.

Interpretation: The curved line is likely an old creek to which man-made ditches are connected for drainage. The irregular pattern of the parcels in between the ditches and the presence of a creek suggest that this was once ‘old land’. The circular feature might be the remains of a mound, its size is too big to be a drinking well for animals but fits in with the size of other mounds.

Historical identification: -

RD: 47715, 402080

Toponym: Colijnsplaat West

Feature 3

Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	**5**	3	2	3	2	1	2

Shape: A circular or slightly oval form with irregular lines across the parcel.

Size: The oval form measures 58 meters at its widest and 48 meters at its smallest diameter. The irregular 'line' which runs from a south-west to north-east direction is approximately 170 meters long and 10 to 15 meters wide.

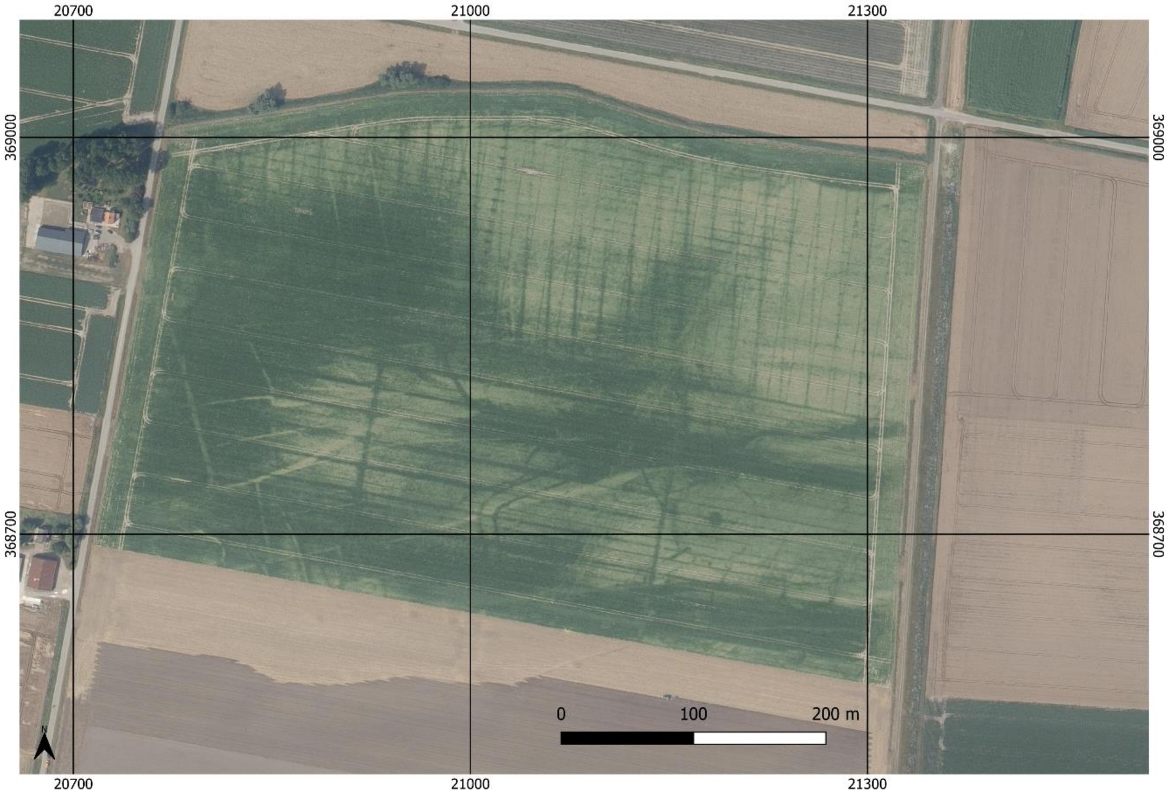
Interpretation: Although relatively large, the circular shape could be the remains of a mound. The irregular line could be interpreted as a moat, creek or being compromised of different soil.

Historical identification: -

RD: 28600, 389250

Toponym: Koudekerke East

Feature 4



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	2	1	**5**	3	1	1	1

Shape: Dark lines following a regular square pattern and light lines following an irregular pattern. Two curved lines running from the south to the east in the bottom-center with a circular shape to their east.

Size: The entire parcel is roughly 590 by 400 meters. The longest irregular light line is 145 meters long and 3 meters wide. The two curved lines (together) are roughly 115 meters long and 12 meters wide. The circular feature has a diameter of roughly 60 meters.

Interpretation: The dark lines are modern drainage pipes. The light lines look like 'old land' parcels. The two curved lines running to the west from the bottom centre could be the remains of a road, moat or dyke, but it is unlikely they are the remains of a creek for these are usually uniform in color. The circular structure could be the remains of a large mound.

Historical identification: -

RD: 21050, 369020

Toponym: Bonte Kof

Feature 5

Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	3	**4**	3	1	2	1	1

Shape: A circular feature in the bottom-center next to a wide creek. A light straight line in the center which bends towards the north and a curved line at the top of the parcel. A wide, straight line running from the southwest corner of the map towards the center left, where it bends in a north-north-western direction. Multiple dark lines running across the creek.

Size: The circular feature has a diameter of roughly 30 meters. The creek runs for approximately 260 meters from the south west before splitting off in a eastern and northern direction. At its widest point the creek is 36 meters wide. The curved line at the top of the parcel is approximately 340 meters long and is between 4 and 10 meters wide. The straight light line in the center probably starts at the western edge of the parcel and is 240 meters long and 3 meters wide. The wide straight line which starts at the southwest corner of the map is approximately 17 meters wide.

Interpretation: The curved line at the top is an old road which led to the 'Luchtenburg' farmstead, with the more or less straight lines being ditches which resemble 'old land' parceling. Because the road cuts through the creek, they are most likely not contemporary. It is unclear what the wide straight line coming in from the southwest is, but it could possibly be a dyke or moat. The dark lines running through the creek might be ditches which are also younger than the creek itself. The circular feature is possibly a mound which is on the smaller end of the spectrum. Its location next to a creek without much indication for the construction of a moat which clearly belongs to it could indicate a very early form of motte with just a small tower on a hill.

Historical identification: The motte could be an earlier iteration of the 'Luchtenburgh', which is the name of the farmstead on the northern edge of the parcel. *Burgh*, an old-fashioned way of writing *burcht*, translates to castle, stronghold or fortified tower.

RD: 43040, 412450

Toponym: Luchtenburghseweg

5.1.2 Summary of results for Motte-and-Bailey castles and castle grounds

The 'Motte-and-Bailey castles and castle grounds' object class has yielded some potentially interesting results. Apart from the identification of the location of the castle grounds for feature 1, an already known mound, four potential new Motte-and-Bailey castles or mounds have been discovered in the remotely sensed data. All features have been discovered in parcels which have crops on them, with the clearest examples in 'greener' crops. Unsurprisingly, most potential new mounds (features 2, 4 and 5) have been found in parcels which show traces of old-land parceling. Features 2 and 5 also show traces of old creeks. Spatially, two of the features were discovered on Walcheren, one feature was discovered in Zeeuws-Vlaanderen, one feature in Noord-Beveland and one in Schouwen-Duiveland.

From an image source perspective this object class was most clearly visible in the 2019 and 2020 satellite imagery, with a respective average visibility score of 3 and 2,8. The 2019 imagery also yielded the clearest picture for two of the features, whereas the 2017, 2018 and 2020 imagery were all used to map one feature.

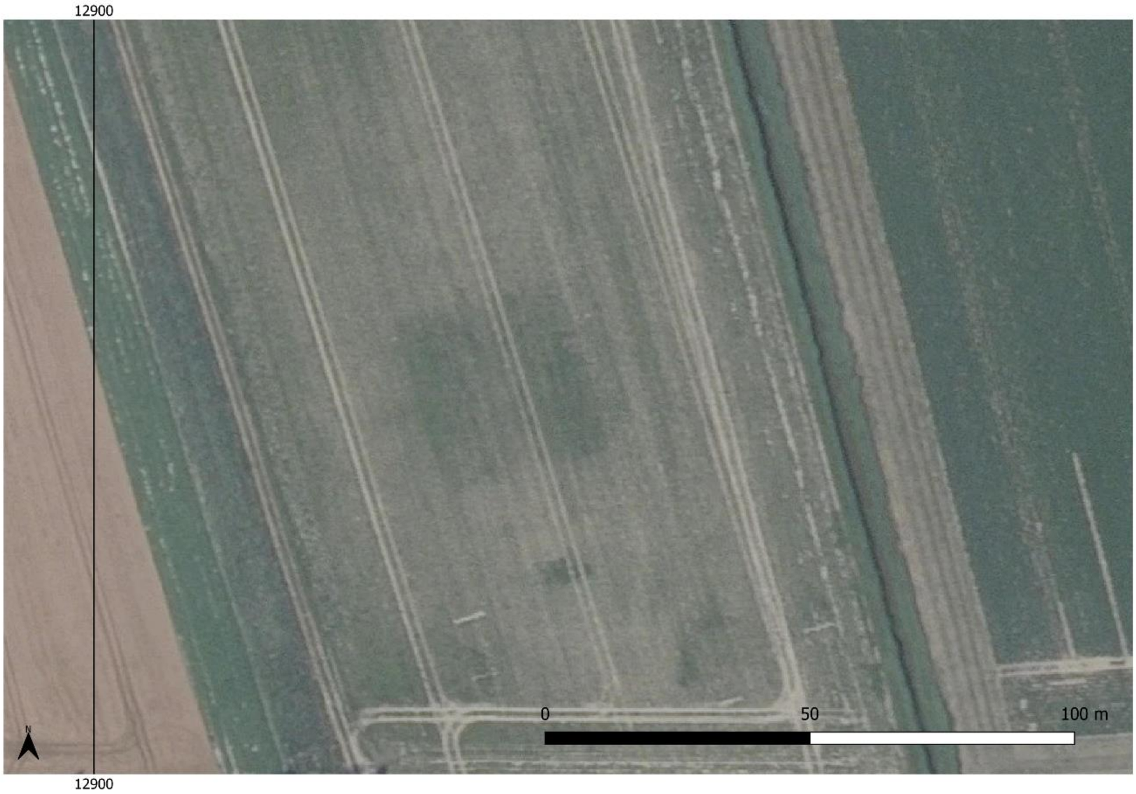
Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022, 8cm**	**2022, 25cm**
Visibility Feature 1	2	1	1	**4**	3	2	2	1
Visibility Feature 2	1	1	1	1	**4**	1	2	3
Visibility Feature 3	1	**5**	3	2	3	2	1	2
Visibility Feature 4	1	2	1	**5**	3	1	1	1
Visibility Feature 5	1	3	**4**	3	1	2	1	1
Average Visibility	1,2	2,4	2	**3**	2,8	1,6	1,4	1,6
Times used for mapping	0	1	1	**2**	1	0	0	0

Table 4: Visibility ratings for the 'Motte-and-Bailey castles' object class.

5.1.3 'Staats-Spaanse Linies', defensive works and lines from the 16th up to the 18th century

For the State-Spanish Lines case-study three features (nr. 6, 7 and 8) which are located just across the Belgian border have also been included in the results. This choice was made because they are part of a larger cultural-historical phenomenon which stretches from the north of Zeeuws-Vlaanderen to the city of Antwerp, date to roughly the same time period as other features in this object class, and are situated in a similar landscape compared to the features located in the Netherlands. These features will have "(Belgium)" appended to their toponym.

Feature 6



Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022, 8cm**	**2022, 25cm**
Visibility	1	1	2	**3**	2	1	1	1

Shape: Square feature in the center of the map.

Size: 31 by 31 meters.

Interpretation: Redoubt

Historical identification: A redoubt which was part of the *Linie van Fontaine*. Invisible according to the WMS point data of the State-Spanish Lines.

RD: 12980, 372150

Toponym: Greveningedijk (Belgium)

Feature 7

Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	1	2	1	**5**	1	1	2

Shape: Bastion fortress

Size: Approximately 100 meters from each point of the bastion to the next. Curtain walls of 35 meters wide and 15 meters thick. Interior square measuring 40 by 40 meters.

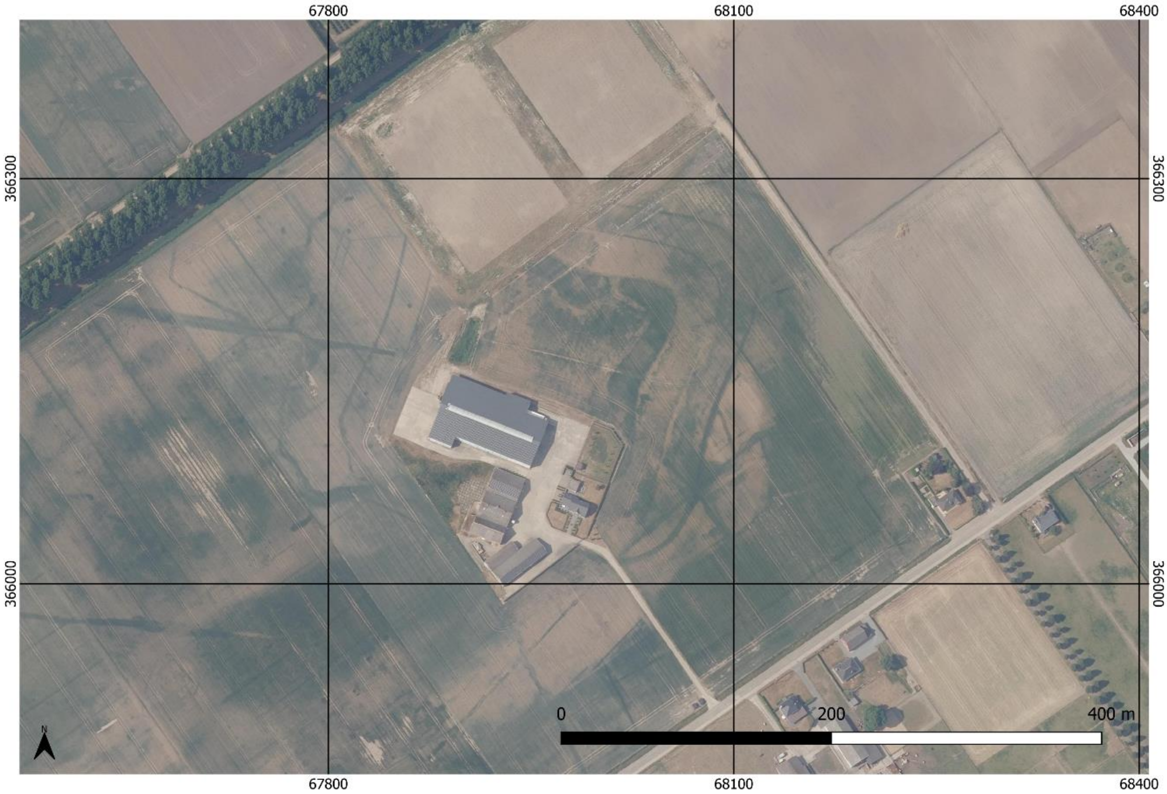
Interpretation: Bastion fortress

Historical identification: Fort Sint-Job, constructed in 1604.

RD: 13160, 369500

Toponym: Fort Sint-Job (Belgium)

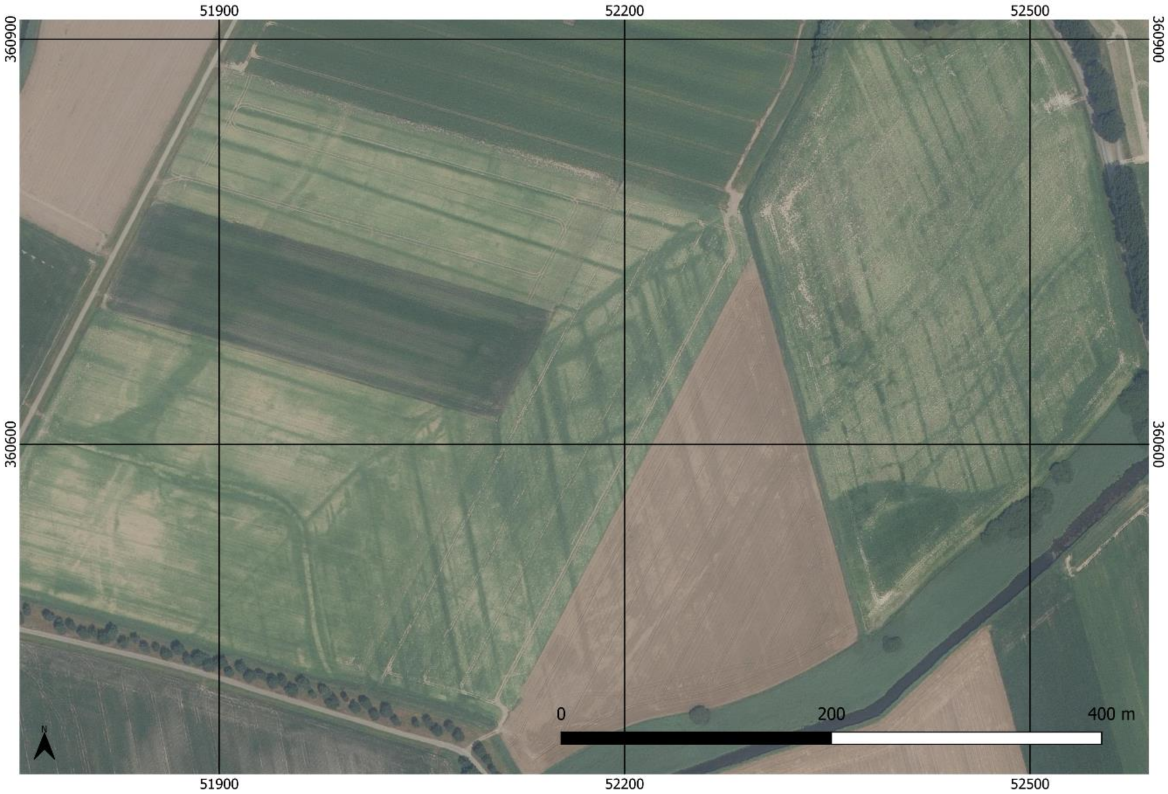
Feature 8



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	2	1	1	4	**5**	1	2	1

Shape: Bastion fortress with multiple dark lines surrounding it. Some of these lines seem connected.
Size: Approximately 115 meters from each point of the bastion to the next. Curtain walls approximately 25 meters wide with a possible thickness of 15 meters. Interior square unmeasurable. The possible trenches surrounding the fortress and going north-west towards the fortified city of Hulst are between 2 and 2,5 meters wide and extend more than 400 meters in the direction of Hulst.
Interpretation: Bastion fortress with potential trenches and (a double?) moat surrounding it with some traces of former creeks.
Historical identification: Fort Fuentes, Fort Spinola after 1626. Constructed shortly after the capture of Hulst by Dutch troops in 1591 and reinforced in 1626. Erected to protect the Waal valley against attacks from Hulst, the fortress played an important part in the re-capture of Hulst by the Spanish in 1596. Headquarters of governor Albrecht of Austria. The fortress was captured by the Dutch in 1645 in preparation of the siege of Hulst (Staats-Spaanse Linies, 2023).
RD: 67970, 366166
Toponym: Fort Fuentes/Spinola (Belgium)

Feature 9



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	3	2	**5**	2	1	1	1

Shape: Dark square/diamond shape with straight lines next to it and a curved light line in the southwestern corner. The straight lines become more erratic towards the northeast corner of the map.

Size: The square shape is approximately 70 meters wide on the northern and southern sides and 65 meters wide on the western and eastern sides. It is ten meters thick. The straight dark lines vary between 350 and 110 meters.

Interpretation: A redoubt situated next to what looks like a creek from which perpendicular ditches lead towards the south and west. These ditches seem too irregularly placed to be modern day drainage and could potentially be the remains of former parceling. A road is situated in the southwestern corner of the map which is likely constructed on an old creek-bed.

Historical identification: Although the location is marked in the State-Spanish Lines WMS layer, there is no additional information as to when the redoubt was constructed or what its name was. According to the WMS data the redoubt is invisible to the naked eye.

RD: 52180, 360635

Toponym: Zijpstraat

Feature 10

Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	**4**	2	2	1	1	1	1

Shape: A rectangular/trapezoid shape in the center of the map with curved lines to the southwest and a thick line running parallel to the road in the northwestern corner. Erratic lighter areas in the northeastern part of the map.

Size: The trapezoid shape is roughly 45 meters long on the eastern side, 75 meters long on the northern side, 55 meters long on the western side and 65 meters long on the southern side. Its thickness varies between 12 meters on the southern side and 8 meters on the northern side. The thick line running parallel to the road in the northwestern corner is 20 meters thick, and the curved line varies between 10 and 20 meters thick.

Interpretation: The thick line in the northwestern corner is possibly a dyke. The curved line is most probably the remains of a creek. The trapezoid shape could perhaps be a hitherto unknown redoubt.

Historical identification: -

RD: 47110, 360560

Toponym: Molenstraat

Feature 11

Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	3	3	3	2	2	**4**	1	1

Shape: Square with rounded corners.

Size: Roughly 165 by 165 meters on the outside of the square and 100 by 100 meters on the inside of the square with a thickness between 30 and 35 meters.

Interpretation: Compared to the other fortresses and redoubts that have been analyzed in these results this structure is quite large with extremely thick walls. It might therefore be possible that the lighter square is a moat and the darker inner square is the actual fortress. This would put the size at roughly 115 by 115 meters with 8-meter-thick walls. Although this seems more plausible size-wise, it doesn't explain the dark outer layer of the 'fort', which would by the same logic also be an 8-meter-thick wall separated from the inner wall by a moat. This seems quite inconvenient defensive-wise. Due to its location and shape it probably has something to do with the State-Spanish Lines, but it is difficult to give a definitive answer on its functionality.

Historical identification: This potential fortress is not listed in either WMS dataset on the State-Spanish lines.

RD: 24030, 365420

Toponym: Zuidweg

Feature 12

Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	2	3	4	**5**	3	2	3	1

Shape: Two dark diamonds within each other on the northwestern corner of the parcel, with the outer diamond slightly curved on the southern side. Straight dark lines on the northeastern corner and two straight light lines running down the center flanked by two squiggly light lines.

Size: The outer diamond is roughly 150 meters long on the northern sides, 135 meters long on the eastern side and 100 meters long on the southern side. The inner diamond is 105 meters long on the northern sides, 90 meters long on the eastern side and 75 meters long on the southern side. The inner diamonds thickness ranges from 10 to 15 meters, whilst the outer diamonds thickness is only about 7,5 meters. The dark straight lines are approximately 2 meters thick, whilst the light squiggly lines are about 3,5 meters thick. The light straight lines are 25 meters thick together, and about 7,5 meters thick on their own.

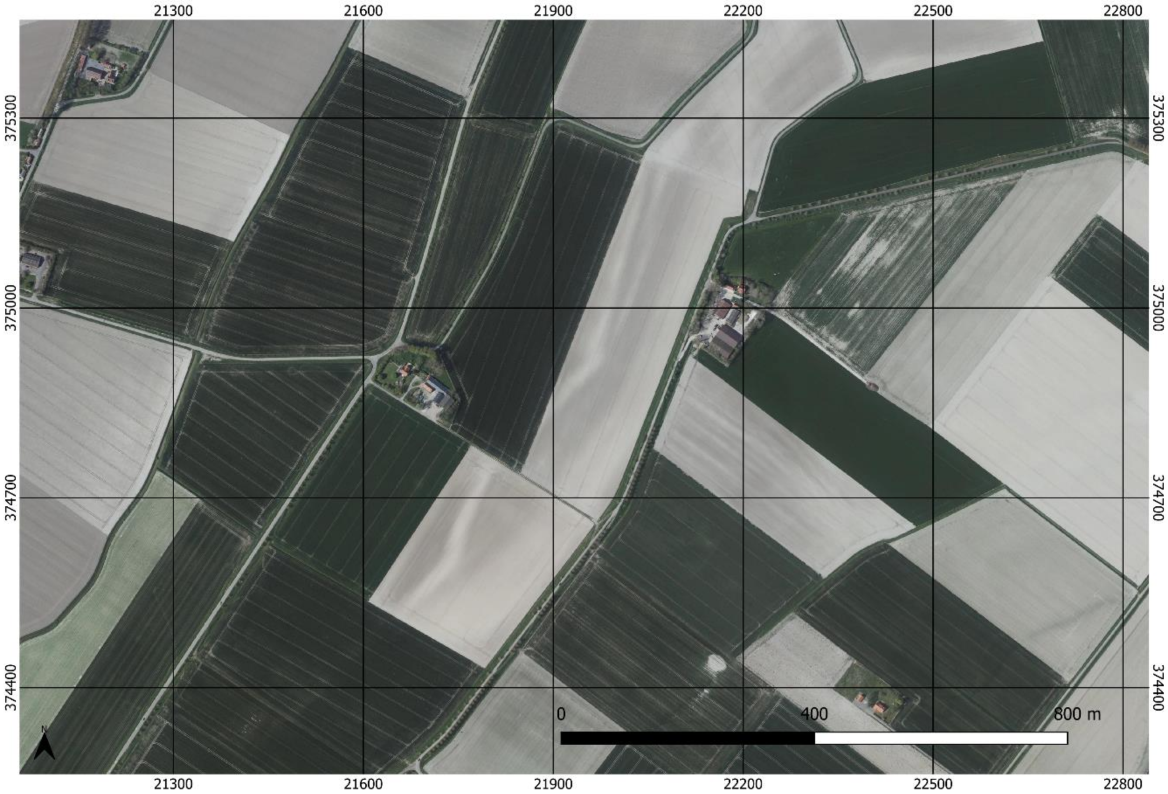
Interpretation: The squiggly lines are most definitely creeks, and the dark straight lines are probably traces of ditches revealing former parceling. The straight light lines could be part of a dyke or canal, although the latter seems more plausible because they head straight for a creek. The diamond structure is probably a redoubt to guard the city of Aardenburg, which is two kilometers to the east, from anyone approaching from the west using the waterway. This could also explain why the walls of the inner diamond are thicker in the north and west.

Historical identification: On the map from 1900 (topotijdreis.nl) the diamond structure is referred to as *'t Kraaijennest*, a common Dutch name for a lookout post (usually in the mast of a ship). This most likely confirms its function as a redoubt to guard and watch over the western flank of Aardenburg. The redoubt is not listed in either WMS dataset about the State-Spanish lines.

RD: 17070, 366699

Toponym: 't Kraaijennest

Feature 13



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	**4**	1	3	1	2	2	4	3

Shape: A clearly visible light line with 150 degree angles every 200 to 300 meters.

Size: The thickness of the feature is 22 meters. The part that is visible in the data is at least 1400 meters long.

Interpretation: A line-dyke which is part of the defensive works of the State-Spanish Lines; usually regular dykes and canals aren't constructed with angles every couple of hundred meters.

Historical identification: The line-dyke isn't attested to in the WMS data, but the former existence of redoubts at both its traceable ends also indicates this was a hitherto unknown line-dyke.
RD: 21730, 374600
Toponym: Henricusdijk

5.1.4 Summary of results for 'Staats-Spaanse Linies', defensive works and lines from the 16th up to the 18th century

The State-Spanish lines object class has yielded the most visible features (apart from former parceling, which can be found throughout the research area in great quantities) of all object classes touched upon in this research. Three potential new fortresses or redoubts, features 10, 11 and 12, have been identified in the imagery. Furthermore, feature 13 could be interpreted as a large stretch of hitherto unknown line-dyke because of its size and shape with angles at regular intervals. Features six, seven, eight and nine are all fortresses or redoubts which were already known and listed in the WMS datasets on the State-Spanish lines, but which were listed as invisible or poorly visible to the naked eye. Both features seven and eight clearly show the layout of the former fortresses which once stood there. All features apart from feature 13 have been identified on parcels with crop growth. It looks like parcels which seemingly have experienced more drought, such as those of features seven and eight, show better visibility of features than parcels on which the crops are seemingly growing more uniform, such as those of features 11 and 12. Logically, all features of this object class have been identified in Zeeuws-Vlaanderen or Vlaanderen.
From an image source perspective, the 2019 imagery yielded the highest average visibility and was also used most in mapping, with three features being mapped with this data source. In contrast to the Motte-and-Bailey object class, the average visibility of the State-Spanish lines features is higher and more similar throughout the imagery. This could be due to the larger size of the features which were identified in the imagery but there is also a possibility that this is a random result which stems from the type of crops sown on the parcels throughout the years.

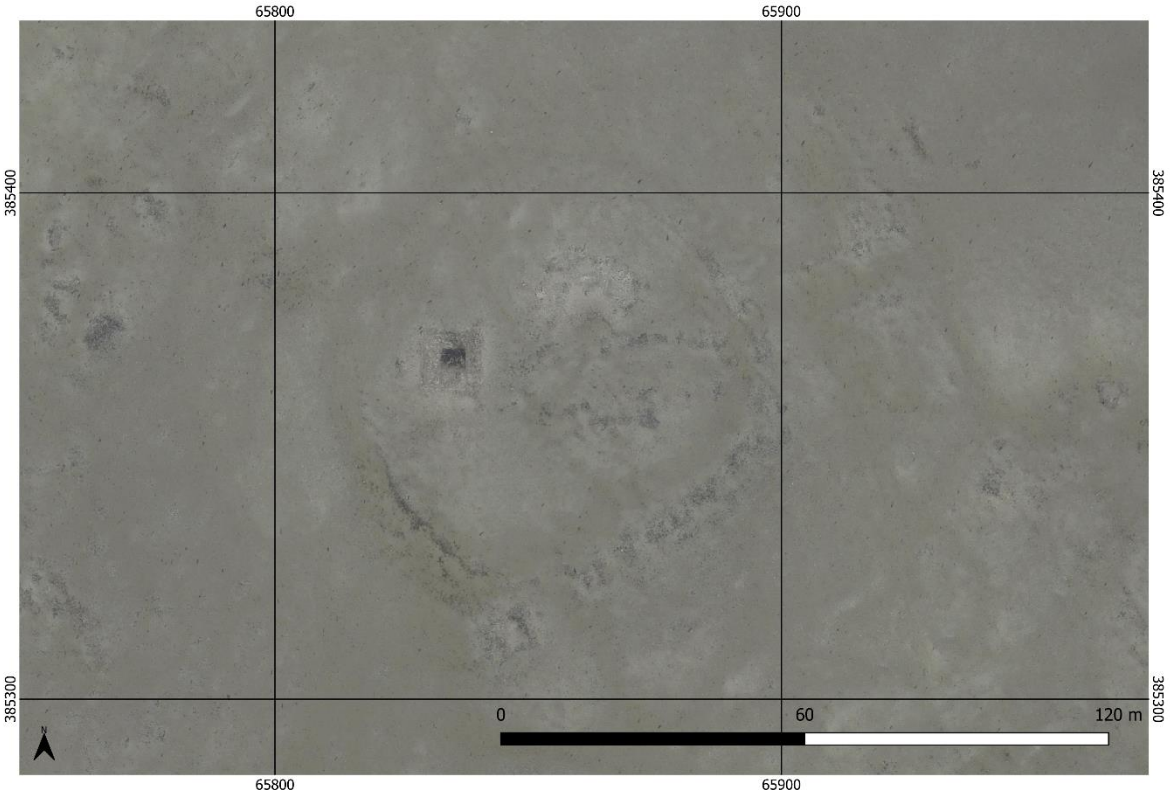
Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022, 8cm**	**2022, 25cm**
Visibility Feature 6	1	1	2	**3**	2	1	1	1
Visibility Feature 7	1	1	2	1	**5**	1	1	2
Visibility Feature 8	2	1	1	4	**5**	1	2	1
Visibility Feature 9	1	3	2	**5**	2	1	1	1
Visibility Feature 10	1	**4**	2	2	1	1	1	1

Visibility Feature 11	3	3	3	2	2	**4**	1	1
Visibility Feature 12	2	3	4	**5**	3	2	3	1
Visibility Feature 13	**4**	1	3	1	2	2	4	3
Average Visibility	1,875	2,125	2,375	**2,875**	2,75	1,625	1,75	1,375
Times used for mapping	1	1	0	**3**	2	1	0	0

Table 5: Visibility ratings for the 'Staats-Spaanse linies' object class.

5.2 Drowned land and villages

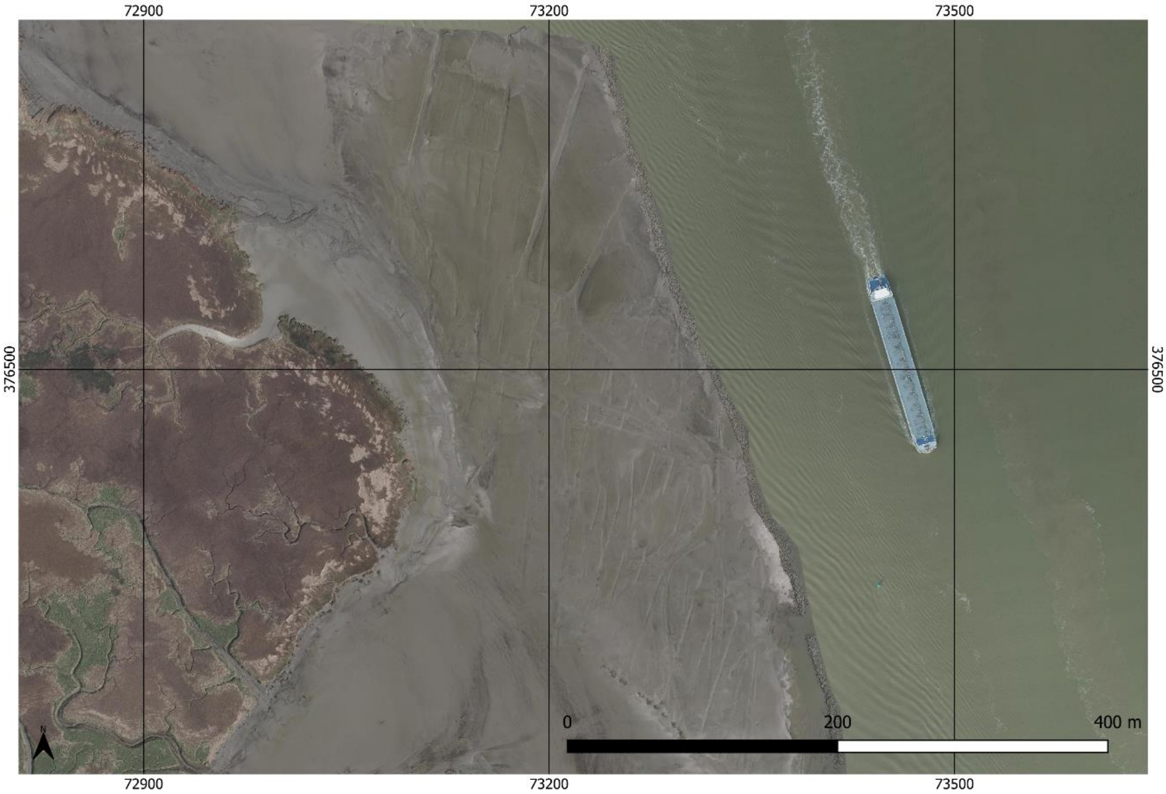
Feature 14



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	2	3	3	3	**5**	1	3

Shape: A circular feature with a square hollow shape on the left of its center.
Size: The circular feature has a diameter of roughly 78 meters. The outside of the square feature is approximately 11 by 11 meters. The inside of the square feature is roughly 4,5 by 4,5 meters.
Interpretation: The drowned remains of the center of a *ringdorp*, with the foundations of the former church tower. The nave of the church has been eroded away by the waves, but the positioning of the tower to the left of the ring indicates that it was situated, together with the chancel, towards the east in traditional fashion.
Historical identification: The drowned village of Nieuwlande which was lost to the sea after the St. Felix flood of 1530 and the *Allerheiligen* flood of 1532.
RD: 65850, 385370
Toponym: Nieuwlande

Feature 15



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	4	4	2	4	**5**	1	2

Shape: More or less rectangular traces with a curving line on the southern half of the feature.

Size: The width of the rectangular traces varies between <1 meters and 5 meters. The length varies between 10 meters and 170 meters.

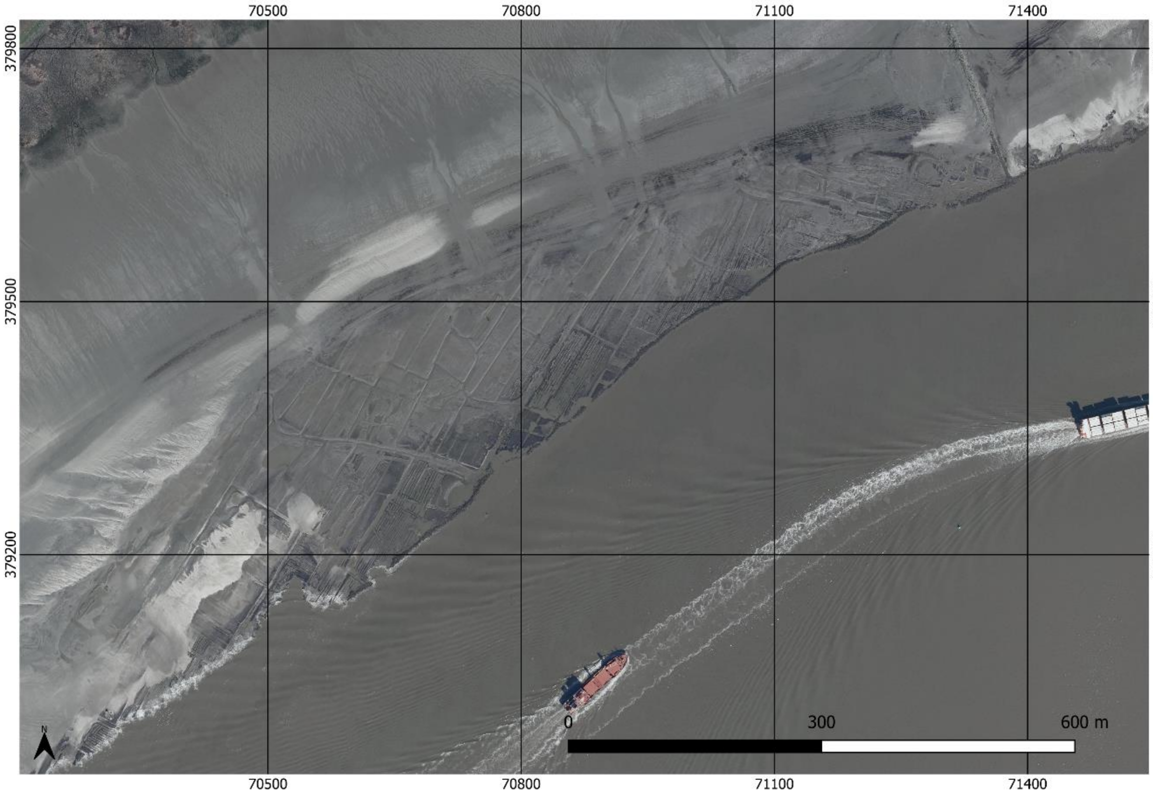
Interpretation: The remains of a drowned landscape which shows 'old land' parceling.

Historical identification: The remains of the (parceling of the) drowned village of Saeftinge, located on the eastern banks of the drowned land of Saeftinghe.

RD: 73200, 376500

Toponym: Saeftinghe.

Feature 16



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	3	**5**	1	2	1	1	1

Shape: A lot of rectangular shapes with small rectangular shapes near the waterline.

Size: The ‘small’ rectangular shapes are all more or less 2 meters wide and vary in length from 4 meters long to 70 meters long. The larger rectangular shapes vary in width from roughly 12 meters wide to roughly 40 meters wide and from about 30 meters long to roughly 320 meters long.

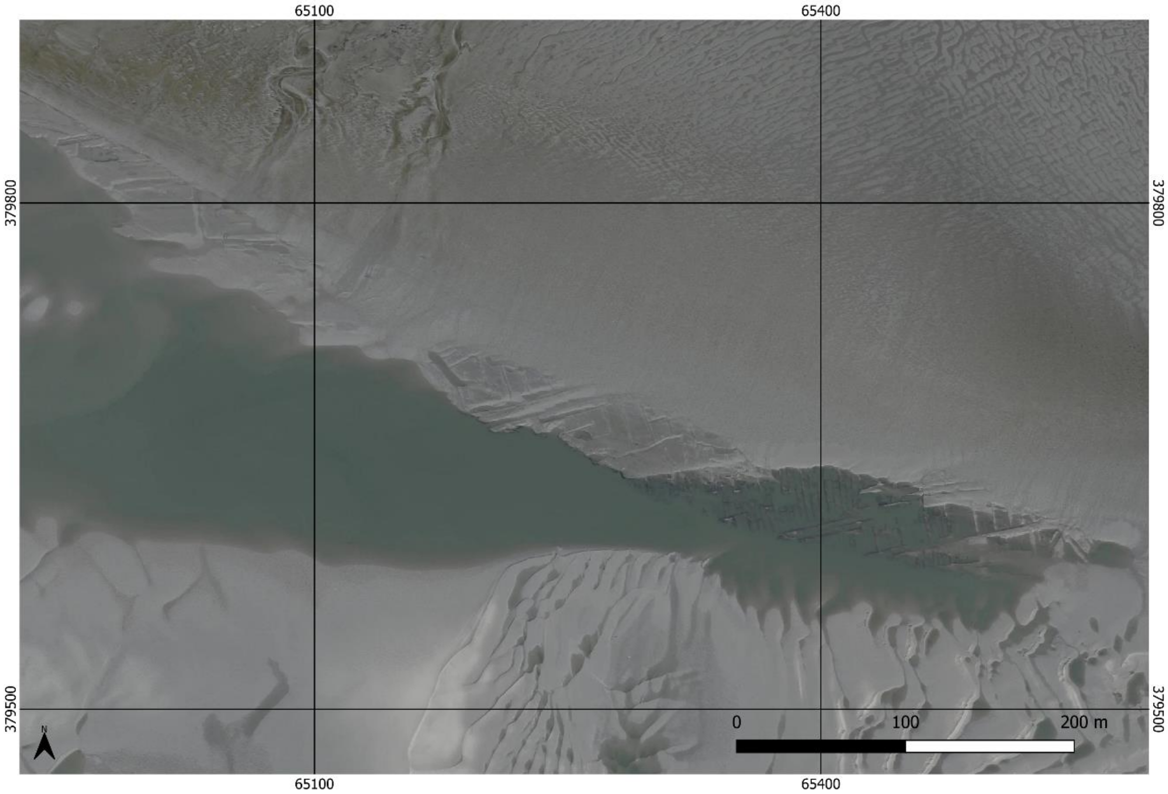
Interpretation: The irregularity of the larger rectangular features indicates drowned ‘old land’ parceling. The smaller rectangular features are the result of extensive peat digging.

Historical identification: The remains of the (parceling of the) drowned village of Oud Rilland.

RD: 70750, 379400

Toponym: Oud Rilland

Feature 17



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	2	**4**	1	3	3	1	3

Shape: Roughly rectangular shapes with smaller rectangular shapes near the southeast of the features.

Size: The larger rectangular shapes vary in width from roughly 4 to 20 meters and in length from roughly 10 meters to roughly 70 meters. The smaller rectangular shapes are all about three meters wide and vary in length from 3 to 35 meters.

Interpretation: A drowned 'old land' parceling pattern with traces of peat digging towards the southeast of the features.

Historical identification: The remains of the (parceling of the) drowned village of Valkenisse.

RD: 65370, 379620

Toponym: Valkenisse

Feature 18

Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	3	**5**	2	2	1	1	1

Shape: Roughly rectangular features next to a house, with linear features which overlap into the field to the east and a lot of squiggly lines. The field also contains a relatively wide linear feature which stretches from the south to the north.

Size: The largest rectangular feature is roughly 7 by 12 meters, whilst the smallest is roughly 5 by 8 meters. The longest of the straight lines are roughly 120 meters. The wider linear feature is about 14 meters wide and 120 meters long.

Interpretation: The regular patterning of the parcels and straight road or dike indicate 'new land' parceling, which would indicate that the rectangular features near the modern-day road are the remains of houses of a dyke village.

Historical identification: The drowned village of Oud Campen, which was lost to the waves during the Saint Felix flood of 1530 and the *Allerheiligen* flood of 1532. The land was reclaimed from 1598 onwards, and in 1699 the village of Kamperland was constructed near the remains of drowned Campen.

RD: 39400, 399150

Toponym: Oud Campen

5.2.1 Summary of results for Drowned land and villages

In comparison to the other object classes touched upon in this research and considering the high number of drowned villages listed in the WMS layer, this object class has yielded very few results. Only one feature, the former houses of the drowned village of Oud Campen in feature 18, could be identified on land. Features 15, 16 and 17 were all identified along the coast. Feature 14 was identified underwater. Thus, the identification of drowned land and villages in satellite imagery is highly reliant on a temporal aspect; sea and water levels need to be low enough to identify these features. This is also reflected in the average visibility of the imagery from different years. High visibility indicates low water levels, whilst low visibility indicates high water levels. All results for this object class are sites which are already known, and no hitherto unknown drowned villages or have been discovered through this research. It is however unclear if the parceling of the drowned land in features 15, 16 and 17 have already been mapped in detail. Spatially, three features of this object class have been identified in the drowned land of Zuid-Beveland, one feature has been identified in the drowned land of Saeftinghe and one feature has been identified in Noord-Beveland.
From the perspective of the image sources, the 2017, 2018 and 2021 imagery is most suitable for the identification (or inspection) of drowned land and villages, with the 2018 imagery having a very high average visibility compared to all other data. Most imagery was, due to the temporal nature of the visibility of features, poorly suitable for clear identification of features. Only the 2018 and 2021 data has been used to respectively map three and two features.

Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022, 8cm**	**2022, 25cm**
Visibility Feature 14	1	2	3	3	3	**5**	1	3
Visibility Feature 15	1	4	4	2	4	**5**	1	2
Visibility Feature 16	1	3	**5**	1	2	1	1	1
Visibility Feature 17	1	2	**4**	1	3	3	1	3
Visibility Feature 18	1	3	**5**	2	2	1	1	1
Average Visibility	1	2,8	**4,2**	1,8	2,8	3	1	2
Times used for mapping	0	0	3	0	0	2	0	0

Table 6: Visibility ratings for the ‘Drowned land and villages’ object class.

5.3 The rural landscape and infrastructure

Feature 19

Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022, 8cm**	**2022, 25cm**
Visibility	1	4	2	4	**5**	2	2	1

Shape: Thick curved lines going from the north-west towards the south with a circular feature in the upper-middle.

Size: The lighter colored western part of the curved line is roughly 30 meters thick. The dark part running down the center is between 16 and 33 meters thick. The lighter colored eastern part is between 11 and 13 meters thick. Combined the lines are between 60 and 80 meters thick. The middle linear feature is roughly 560 meters long. The circular feature is roughly 40 meters wide.

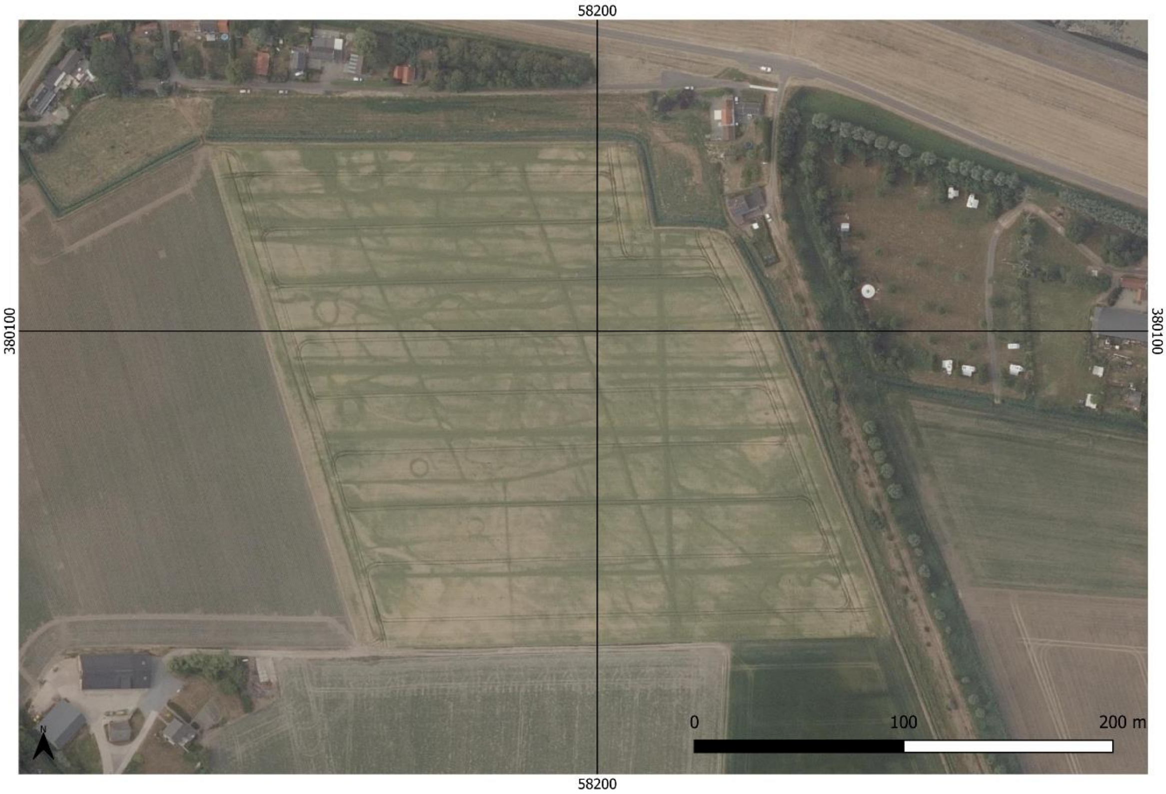
Interpretation: Due to the thickness and length of the feature this is likely a former dyke.

Historical identification: The dyke of the most eastern part of the former island of Calandspolder.

RD: 40800, 393000

Toponym: Calandweg

Feature 20



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	1	2	1	**5**	1	1	2

Shape: Straight horizontal and vertical lines and a lot of meandering lines, with circles concentrated on the left part of the parcel.

Size: The circles are roughly between 8 and 13 meters in diameter. The longest straight lines are roughly 250 meters long and all lines are between one and three meters thick. The meandering lines vary greatly in both length and width.

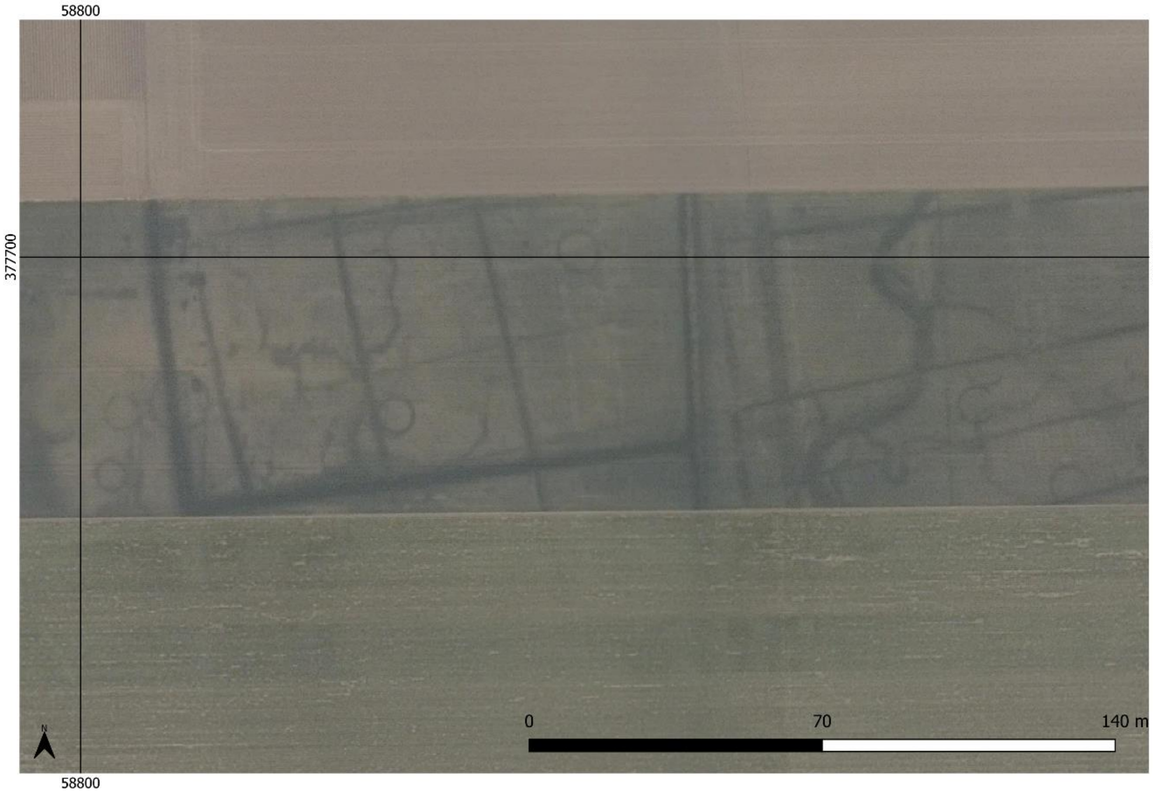
Interpretation: The meandering lines are most likely the remains of old creeks which can still be seen in the landscape. The thicker straight lines are most likely the result of agricultural drainage, while the thinner lines could possibly be the remains of old parceling. The circles are hard to interpret but could be anything from ditches to drinking wells.

Historical identification: First identified from aerial pictures by Arie de Kraker, one of the circles has been excavated by the *Rijksdienst voor Cultureel Erfgoed* (RCE) in 2011. The circles were interpreted as drainage-ditches and were dated between the 12th and 14th century. This means they were constructed shortly after the construction of the first polders. The insides of the circles were used for the storage of hay, grains or reed. Further research by Karel-Jan Kerckhaert from *Erfgoed Zeeland* led to the discovery of a total of 68 circles spread out in 9 different zones (Kerckhaert, 2022).

RD: 58200, 380100

Toponym: Molenweg

Feature 21



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	3	2	2	**5**	1	1	1

Shape: Straight and curved lines with circles dotted across the middle parcel.

Size: The straight lines vary in size from about 20 to 120 meters long and are between one and three meters wide. The curved line is about 120 meters long and between two and five meters wide. The circular shapes vary in diameter between roughly seven and eleven meters.

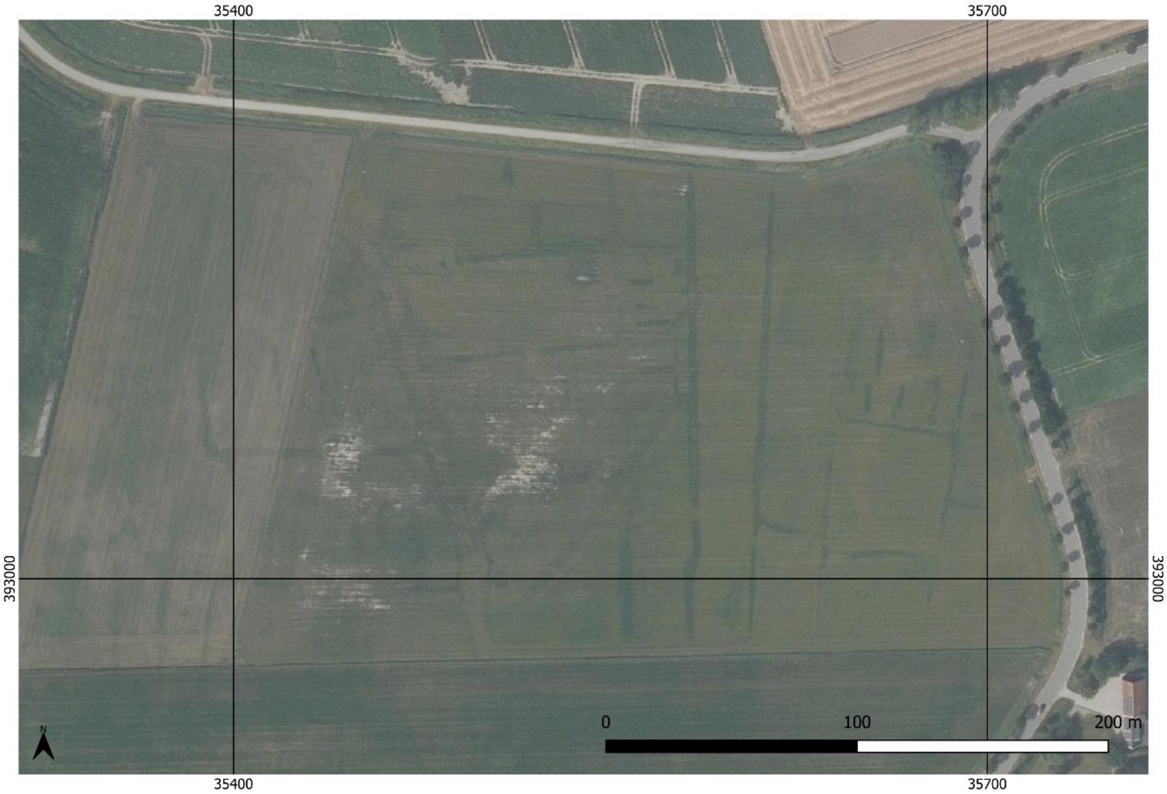
Interpretation: The straight lines are probably ditches indicating former parceling. The curved line is most likely an old creek. The circular features are ditches for storing hay, reed and grains as described in feature 20.

Historical identification: See feature 20.

RD: 58800, 377700

Toponym: Stuiverstraat

Feature 22



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	1	1	**4**	1	1	1	1

Shape: Multiple curved and straight lines running across the entire parcel.

Size: The longest lines are about 180 meters long, while the shortest lines are roughly ten meters long. The lines vary in width between 1 and 3 meters.

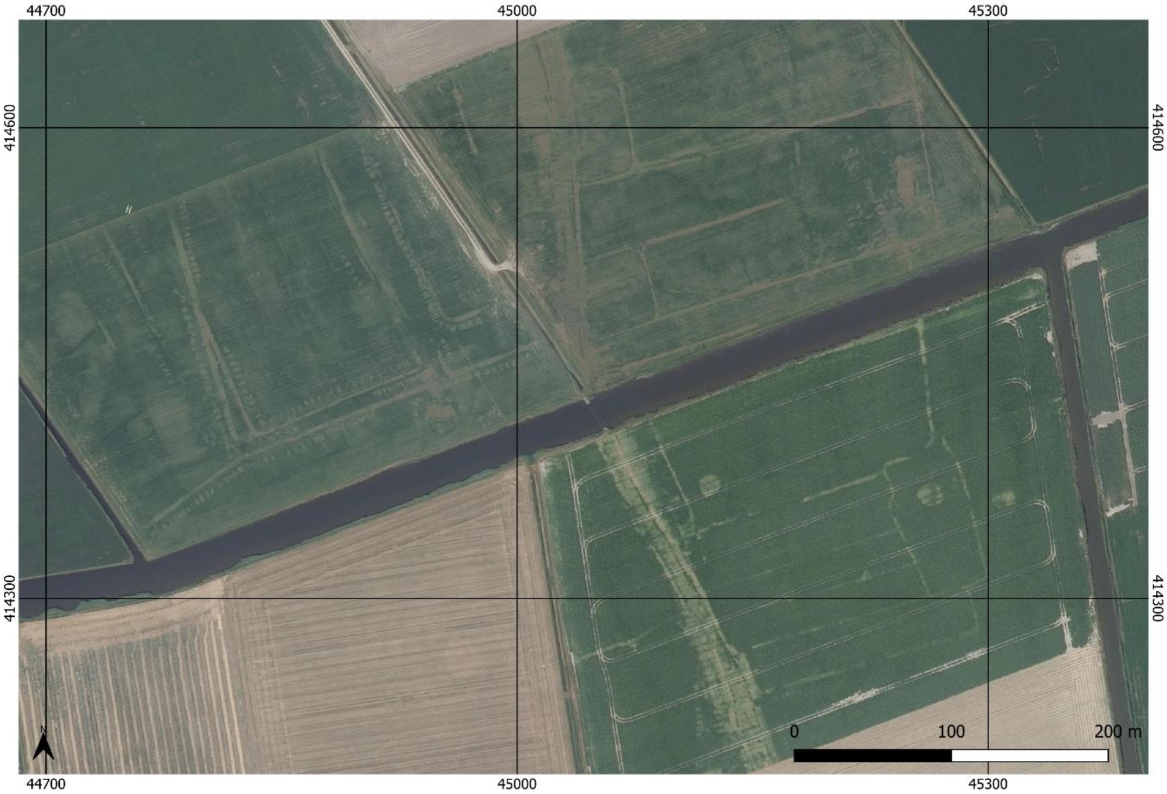
Interpretation: Old-land parceling with a road running from the north-west towards the south.

Historical identification: Old-land parceling.

RD: 35400, 393000

Toponym: Derringmoerweg

Feature 23



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	1	3	**5**	4	1	1	1

Shape: Multiple linear features which have parallel dots running alongside them in the north-western parcel. A lighter, thicker linear feature in the southern parcel, with two light circles to its east.

Size: The linear features in most parcels are between 50 and 290 meters long and between one and three meters wide. The dots which run alongside the linear features in the north western parcel are roughly 1,5 meters in diameter. The thick linear feature in the southern parcel is roughly 230 meters long and 17 meters wide. The circular features in the southern parcel have a diameter of 12 and 14 meters.

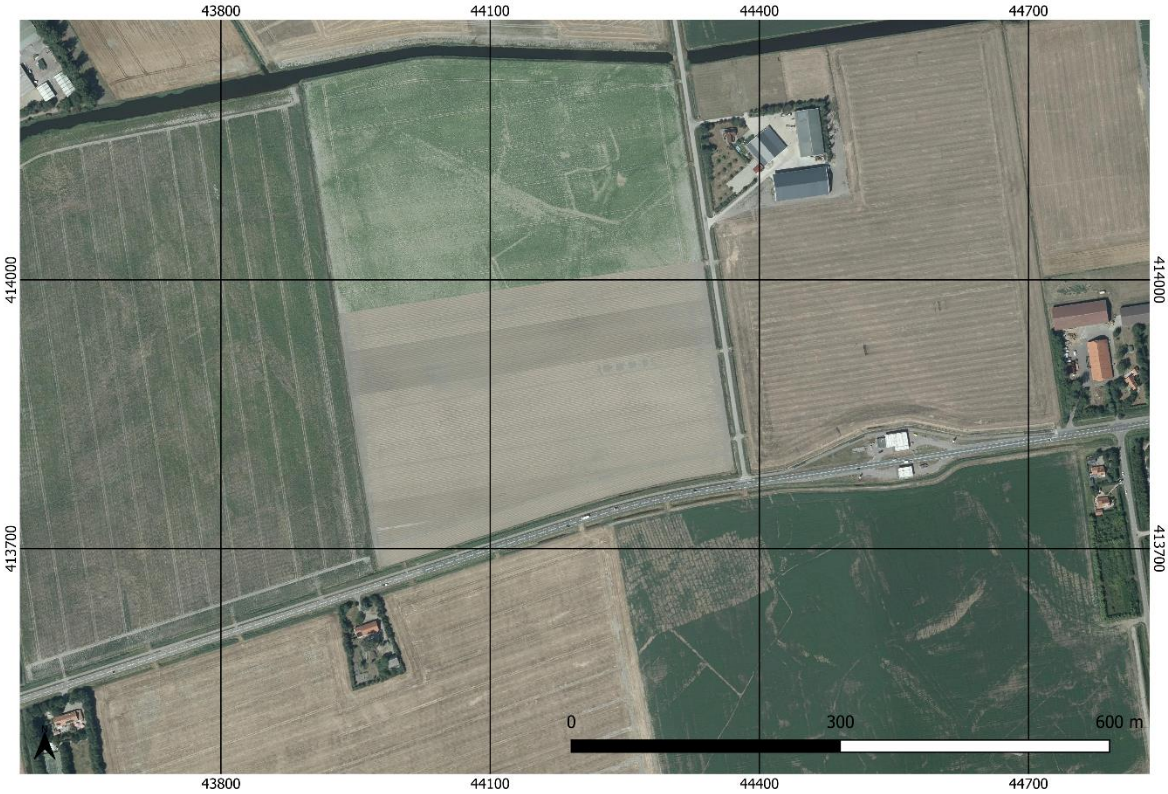
Interpretation: Most linear features seem to be old-land parceling, but the linear features which have parallel dots are most likely old roads which were flanked by trees. The thick, light linear feature could possibly be a dyke or the remains of a ‘modern’ road. The circular features are most likely drinking wells for livestock.

Historical identification: -

RD: 45000, 414400

Toponym: Trekvlot Serooskerke

Feature 24



Year	2016	2017	2018	2019	2020	2021	2022, 8cm	2022, 25cm
Visibility	1	3	**4**	2	2	1	1	1

Shape: A diverse assemblage of linear features which run across multiple parcels, with two roughly circular shapes in the northern parcel. The south-eastern parcel has thick light lines running in a north-south direction in the top left corner.

Size: The linear features vary in length between 30 and 400 meters. Their width varies from roughly one to four meters. The circular shapes are eight and eleven meters in diameter. The thick light lines in the south-eastern parcel are between 37 and 75 meters long and are three to four meters wide.

Interpretation: The thinner linear features are most likely ditches which show old-land parceling. The linear feature which runs roughly from the south-east to the north-west in the upper parcel could potentially be an old road. The circular features are most likely drinking wells for livestock. The thick linear features in the south-eastern parcel could, due to their consistent size and shape, be remains of medieval peat digging.

Historical identification: -

RD: 44100, 414000

Toponym: Koetenisseweg

5.3.1 Summary of results for The rural landscape and infrastructure

The identification of features for this object class has yielded a very large amount of results, of which only a handful have been selected and mapped to be used as examples for this research. Some imagery, such as shown in feature 23 from 2019, reveals a complete former (medieval?) cultural landscape in the research area. If imagery from different years would be combined, features 5, 23, 24 and the parcels in between them reveal an area of former cultural landscape which is nearly four kilometers wide in which individual plots, drinking wells, potential mounds, roads and dykes can be identified. Although only a couple of infrastructural works such as roads and dykes have been selected as features for this object class, there is a lot of by-catch in other object classes that could also be listed here. Eleven out of eighteen features (61%) in other object classes show traces of former parceling, roads or dykes. As stated before, traces of former parceling can easily be found across the entire research area. However, the identification and mapping of all these elements of past cultural landscapes as features would go beyond the scope of this research. Except for the dyke identified in feature 19 and the circles in features 20 and 21, the features in this object class show hitherto unknown rural or infrastructural elements of the landscape. Spatially, this object class can be identified throughout the research area.

From an image source perspective, the 2019 and 2020 imagery yielded the highest average visibility of features and have been used to map six out of seven features listed in this object class. Instead of an even spread in average visibility, the imagery from 2017-2020 shows high averages compared to very low averages for the imagery from 2016, 2021 and 2022.

Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022, 8cm**	**2022, 25cm**
Visibility Feature 19	1	4	2	4	**5**	2	2	1
Visibility Feature 20	1	1	2	1	**5**	1	1	2
Visibility Feature 21	1	3	2	2	**5**	1	1	1
Visibility Feature 22	1	1	1	**4**	1	1	1	1
Visibility Feature 23	1	1	3	**5**	4	1	1	1
Visibility Feature 24	1	3	**4**	2	2	1	1	1
Average Visibility	1	2,2	2,3	3	**3,7**	1,2	1,2	1,2
Times used for mapping	0	0	1	3	3	0	0	0

Table 6: Visibility ratings for the ‘Rural landscape and infrastructure’ object class.

Chapter 6: Discussion

6.1 Discussion

6.1.1 Defensive works in Zeeland

This research has touched upon two different types of fortifications which are to some extent still present in the province of Zeeland; Motte-and-Bailey castles and castle grounds (otherwise known as Zeeuwse mounds) from the medieval period and the State-Spanish lines in Zeeuws-Vlaanderen (and Belgium) from the early modern period.

Currently, only 38 mounds are still visible throughout the province, but the estimated 200 mounds that were once present made this an interesting object class to include in this research. Furthermore, the Zeeuwse mounds are a well known cultural-historical phenomenon amongst the inhabitants of Zeeland and have been described for hundreds of years. These were the two main reasons this object class was included in this research; the potential to find large numbers of 'new' mounds and an already established (local) public interest in their history.

The research into this object class has yielded some interesting results, which are two-pronged for the research into Zeeuwse mounds. Firstly, the identification of the castle grounds in feature 1 has shown that satellite imagery has the potential to complement current knowledge about Zeeuwse mounds. It was already established this mound probably had accompanying castle grounds, but through this research the boundaries of these grounds can be clearly established. This provides new opportunities for non-intrusive archaeological research into Zeeuwse mounds, which can now be focused upon a clear spatially defined research area around the original mound. Furthermore, its discovery and visibility indicate that other castle-grounds could be discovered through a citizen-science project. Secondly, the discovery of four potential new mounds in the satellite imagery make this object class suitable for a potential citizen-science project. However interesting infrastructural works and medieval parceling may be for archaeologists, the possibility to discover new mounds probably sounds more enticing to the average person living in Zeeland (and beyond) that would consider participating in a Heritage Quest project. Because there are only 38 mounds still in existence, the discovery and verification of new mounds could greatly complement our archaeological and historical understanding of medieval Zeeland.

From an image source perspective this object class was most clearly visible in the 2019 and 2020 satellite imagery, especially if green crops were present on the parcels. This indicates that it is perhaps not the image source which is most important for the discovery of new mounds, but the presence of green crops on the parcels which are being investigated. Therefore, even though the visibility is highest in the 2019 and 2020 data, satellite imagery from other years should not be dismissed outright in its suitability for usage in a citizen science project.

The second object class which was investigated in this research under the theme 'Defensive works in Zeeland' were the State-Spanish lines. An elaborate network of defensive structures which were first constructed and heavily used during the Dutch revolt, but which saw usage up until the second World War.

This object class has surprisingly yielded a lot of results. Surprisingly, because it is often assumed that these early-modern defensive works are all well-known and described. Nonetheless, three potential new fortresses or redoubts have been discovered through this research, alongside a large stretch of hitherto unknown line-dyke. This indicates that through a citizen-science project even more unknown parts of these defensive works, which played an important role during the Dutch revolt, could be discovered. Investigating and inventorying fortifications and defensive structures and the potential discovery of hitherto unknown fortresses, ramparts, redoubts and line-dykes, could complement current knowledge on the spatial layout of- and relationships between defensive structures in Zeeuws-Vlaanderen from the 16th, 17th and 18th century. A turbulent yet formative period for both the local region, Zeeland, and the Netherlands as a whole. The identification and exact localization of four former fortresses which were considered invisible or poorly visible to the naked eye indicates that current knowledge on the State-Spanish lines could be complemented through citizen science with the localization and exact layout of 'lost' structures. Identification of hitherto unknown defensive structures and the complementation of established knowledge on the State-Spanish lines make this object class an interesting subject for a citizen science project in Zeeland. Furthermore, a CS project could further the protection of these archaeological monuments, as well as informing on local details in modern reconstructions without the need for intrusive research.

As with the object class of Zeeuwse mounds, the State-Spanish lines were most clearly visible in the satellite imagery from 2019. Average visibility throughout all imagery used in this research was higher for all different years compared to the mounds, and again very much reliant on the presence of green crops on the investigated parcels. Therefore, even though the 2019 data yielded the best results, the other data used in this research should not be dismissed outright.

6.1.2 Drowned land and villages

At the onset of this research, and as stated at the beginning of chapter three, the research into the drowned land and villages object class was considered to have high potential for a CS project. With over a hundred known drowned villages in the province, and half of them currently situated on land, this object class could have yielded a lot of results. However, after extensively going through all satellite imagery at all locations listed in the WMS layer of drowned villages, only one example of (a part of) a drowned village has been discovered in the form of a street of Oud-Campen. The archaeological sites of Nieuwlande, Saeftinghe, Oud-Rilland and Valkenisse (features 14, 15, 16 and 17, respectively) were already well known before the research for this thesis commenced, and although the possibility to be able to remotely sense drowned villages with the use of satellite imagery proves that such datasets can be versatile tools in archaeologically mapping coastal regions that are constantly under the influence of geomorphological changes, it was a tedious process to inspect the large amount of drowned villages on land and further away from the coastline without getting any results. I would therefore propose that while the usage of satellite imagery can be very useful to map archaeological sites which are situated on the flood line or directly below it, the case study of drowned villages in general is not very suitable for the identification of archaeological heritage by means of remote sensing through citizen science in Zeeland. However, the usage of satellite imagery may well prove to be a powerful tool for heritage experts to assess the conservation of these sites.

6.1.3 The rural landscape and infrastructure

The research into the rural landscape and infrastructure object class has yielded a large amount of results. By using remotely sensed imagery, large swaths of former cultural landscape have been identified. These include former creeks, parceling, drinking wells, roads, lanes, dykes and evidence of former peat digging activities. Features that could belong in this object class have not only been identified as isolated examples, but 61% of features in other object classes also contain elements of the former rural landscape and infrastructure as by-catch. Identifying former cultural landscapes through citizen science with satellite imagery from different years could potentially lead to large swaths of Zeeland in which the original (medieval) cultural landscape can be reconstructed. Furthermore, this object class is very suitable for combination with other object classes in a potential CS project; the Zeeuwse mounds also stem from the medieval period, and the discovery of new mounds in combination with the identification of the original cultural landscape could prove to be valuable for our knowledge of medieval Zeeland.

From a data perspective former land layout can be seen throughout the province and throughout the data. Again, as with other object classes, the presence of green crops on the investigated parcels seems to be more important for the identification of archaeological heritage than inherent aspects of the data. The temporal nature of the satellite imagery used, covering multiple years during the summer months, might prove valuable for researching past rural landscapes and infrastructure. Whereas one parcel could yield results in a specific year with little results on neighboring parcels, the neighboring parcels might yield results when data from another year is used. The large number of potential participants in a citizen science project makes it possible to look at all parcels with imagery from different years.

When it has been established which parcels show results in which imagery, the imagery from different years could be combined to form a comprehensive map of large, interconnected swaths of former cultural landscapes.
Furthermore, the identification of former dykes has proven to be possible with the satellite imagery used in this research and could complement current knowledge on the chronology of the impoldering of the province. Because dykes have played a major role in the construction and shaping of the landscape of Zeeland, their inclusion in a citizen science project (together with other features of the rural landscape) could give such a project a distinctly 'Zeeuws' character.

6.1.4 The implementation of a Citizen Science project (like Heritage Quest) in Zeeland

In chapter 2.2 and 2.3, the methods and results of the original Heritage Quest projects have been established, together with alternative approaches to citizen science projects. In combination with the results yielded by this research, an assessment can be made on which aspects of the original heritage quest 'formula' can be maintained and adapted and which aspects should be changed. In this way a suitable method for a Heritage Quest or similar citizen science project concerning archaeological heritage in Zeeland can be established.
One of the key aspects of the original Heritage Quest project was its low threshold for citizen scientists to participate. This was partly possible because of the clearly defined object classes which could be identified in the AHN data which was used. This low threshold yielded a large amount of positive results; hundreds of hitherto unknown burial mounds, charcoal kilns, cart tracks and a lot of Celtic fields were identified *and* could be verified. A similar low-threshold approach was used in the GlobalXplorer project, which used satellite imagery similar to the imagery used in this research. Although the GlobalXplorer project had a much larger scope in participants, research area and amount of imagery used, it has yielded fewer tangible results than the Heritage Quest project. The enormous number of 19.084 identifications of all sorts of potential heritage 'only' led to the archaeological mapping of 40 different sites. Contrastingly, the Atlas project which took nearly five years to complete with around 100 citizen scientists successfully catalogued 4.147 hillforts. Their higher-threshold approach thus proved valuable in achieving the goals set out by the researchers. When considering a citizen science project for the province of Zeeland, which would use the same type of data as the GlobalXplorer project, it is important to evaluate how much data will be gathered when there is no prior knowledge required and participants are 'let loose' on the satellite imagery. Without clear boundaries, there could potentially be so much identification of potential heritage that it will prove very hard or perhaps even impossible to verify all data through a team of heritage experts. Therefore, to successfully implement a citizen science project in Zeeland which would yield tangible results, a choice must be made to either limit the amount of object classes citizen scientists will be

identifying or to provide participants with (modest) prior training before they start identifying heritage through satellite imagery. A combination of both these aspects, with a focus on certain object classes *and* prior training for participants could also be considered, but this might raise the threshold to participate to a level where not all data can be investigated because of a lack of participants. A scenario such as with the CitPres app, where a lot of prior training is required, should probably be avoided. In conclusion, the threshold for a successful CS project in Zeeland could potentially be somewhere in between that of the original Heritage Quest project and the Atlas project, where users would be encouraged to look through some information beforehand but in which the types of heritage which should be identified are also (more or less) clearly defined.

Another important aspect of Heritage Quest are the goals which had been set out to achieve. Similarly to the other CS projects discussed, a recurring goal of citizen science projects concerning heritage is to engage (local) participants in their cultural heritage and creating a sense of stewardship. This could lead to better protection of archaeological heritage and the active involvement of local communities with archaeological sites. For a citizen science project in Zeeland participation by locals could be promoted by initially focusing on aspects which are quintessentially 'Zeeuws' such as the Zeeuwse mounds and dykes. When people are engaged through these topics, short instructions on the types of heritage which can be identified throughout the province could then increase the scope of research whilst simultaneously increasing the knowledge of participants on the cultural heritage of the province. This could then in turn lead to a broader awareness of archaeological heritage, and a sense of stewardship and ownership over said heritage which will lead to better protection. Another goal of Heritage Quest was the possibility of the creation of 'big data' through citizen science. As has been shown through the study of different object classes in this research, there is a lot of potential for the province of Zeeland to gather a lot of new information on its medieval and early-modern heritage. The scope of a potential citizen science project should be considered here; it could for instance only be focused on identifying new Zeeuwse mounds but could also be used to map out entire cultural landscapes of the past.

When evaluating the data which should be used for CS in Zeeland a combination between the Heritage Quest project and the GlobalXplorer project should be considered. Instead of focusing on one satellite image per area which is being researched, it would probably work best to combine multiple different images (from different years) per spatially defined unit. This is similar to Heritage Quest, where two different visualizations could be used by participants. The chance that parcels in the imagery have green crops on them and are thus viable for the identification of archaeological heritage, increases if data from different years is considered.

Chapter 7: Conclusions and recommendations

In this chapter the research questions will be answered according to the findings that have been made in chapter 5: Results and chapter 6: Discussion. First, the sub-questions will be addressed before answering the main research question. When all research questions have been answered a few recommendations will be given on the possibilities of implementing a citizen science project in Zeeland in chapter 7.2.

7.1 Conclusions

1. What archaeological object classes are suitable for the identification of archaeological heritage through remote sensing in the research area?

From the object classes evaluated in this research, the ‘Motte-and-Bailey castles and castle-grounds’, ‘State-Spanish lines’ and ‘Rural landscape and infrastructure’ object classes are most suitable for the identification of archaeological heritage through remote sensing in the research area. All these object classes yielded hitherto unknown results or yielded results which complements current knowledge on archaeological heritage in the research area.

2. How viable is the usage of satellite imagery for identifying archaeological heritage in Zeeland?

The usage of satellite imagery for identifying archaeological heritage in Zeeland seems quite viable; especially if satellite imagery from different years is combined to increase the chances of finding heritage per parcel. The highest visibility was seen in the imagery captured between 2017 and 2020, with an average visibility across all object classes of 2.3 for 2017, 2.7 for 2018 and 2019 and an average visibility of 3 for the 2020 satellite imagery.

3. What satellite imagery (i.e., from what year) yields the best results for the identification of archaeological heritage per object class?

For the ‘Defensive works in Zeeland’ object classes the 2019 satellite imagery yielded the best results, with an average visibility score of 3 for ‘Motte-and-Bailey castles’ and an average visibility score of 2.9 for ‘State-Spanish lines’. For the ‘Drowned villages’ object class the 2018 satellite imagery yielded the best results with an average visibility score of 4.2. For the ‘Rural landscape and infrastructure’ object class the 2020 satellite imagery yielded the best results, with an average visibility score of 3.7.

4. What are the similarities and differences between the original Heritage Quest project and a potential similar citizen science project in the province of Zeeland?

The similarities between the original Heritage Quest project and a potential CS project in Zeeland are mostly to be found in its goals; the ability to generate 'big data' using citizen scientists and the potential to increase historical awareness, engagement with archaeology, creating a sense of stewardship and subsequently increase the protection of- and engagement with the archaeological heritage of the province. Furthermore, from a data perspective, it would be valuable if every 'tile' which is to be researched would be looked at by multiple different citizen scientists, to guarantee minimal inter-analyst variability. There should also be a focus on identifying object classes which have been defined *a priori*, such as burial mounds in the original Heritage Quest, because of the scope of the data which could be used (satellite imagery from multiple years) and the possibility of generating too much data.
A major difference between the original Heritage Quest project and a potential CS project in Zeeland is that some prior training for participants should be considered, increasing the threshold for participation but also decreasing the number of false positives. Another difference is that a CS project in Zeeland should probably use more images per tile which is being investigated than the two different images used in the Heritage Quest project. Instead of using two different visualizations of the same data, a CS project in Zeeland should use satellite imagery from four different years (2017-2020) for the same tile.

5. What time period(s) will be the main focus of a citizen science remote sensing project in Zeeland?

A citizen science remote sensing project in Zeeland should probably be focused on the medieval and early-modern periods, focusing on archaeological heritage from between 1000 and 1800 AD.

6. What types of spatial shapes can be roughly defined in the case-studies?

In general, most spatial shapes that can be identified in the satellite imagery will be lines, circles, squares, trapezoids and fortress-shaped objects.

7. How easy or hard is it for someone with little to no prior knowledge of archaeology and remote sensing to use the data for identifying archaeological heritage?

When looking at the remotely sensed data it can potentially be quite challenging to identify archaeological heritage. Former creeks, agricultural drainage and contemporary disturbances might easily be mis-identified as archaeological heritage. Therefore, it would be wise to present citizen scientists with some prior training in recognizing archaeological heritage and distinguishing between natural or contemporary features and said heritage.

Main research question: What correlations can be found, tested and evaluated, in the context of a Citizen Science project, between existing open-source, satellite-based remote sensing datasets and visible archaeological traces within these datasets for the province of Zeeland?

This research has proven that there are a lot of potential correlations between the archaeological heritage of the province of Zeeland and the satellite-based (open source) remote sensing datasets which were used for this study. Especially satellite imagery from between the years 2017 and 2020 has yielded hitherto-unknown archaeological features for the different object classes which have been explored. Furthermore, the research of different object classes in this study has shown that apart from finding new archaeological features, the results from a citizen science project could also be used to complement existing knowledge.

Using satellite imagery to identify archaeological heritage in the Province of Zeeland by means of a citizen science project can not only provide a lot of new data, but also increase historical awareness and create a sense of stewardship in its participants. This would not only lead to the identification of more archaeological sites, but also further protection efforts in the province. Although there will be some differences from the original Heritage Quest project, a very similar citizen science project for the province of Zeeland which would include some prior training could yield valuable results.

7.2 Recommendations

In this sub-chapter I will give some recommendations for the implementation of a citizen science project like Heritage Quest in the province of Zeeland.

- Perhaps most importantly, a citizen science project in the province of Zeeland should include satellite imagery from multiple years in which archaeological heritage can be identified by the participants. This will increase the chance of suitable crops being present on different parcels for the identification of archaeological features.
- If satellite imagery from different years, such as the data used in this study, is to be used in a CS project in Zeeland, there is a potential to map cultural landscapes on a very large scale. It is therefore not only important to register where features are spatially identified, but also to register in what years' satellite imagery they can be seen.
- If a citizen science project is to be adapted for the province of Zeeland, it would probably be favorable to focus on a certain set of archaeological features which are to be identified such as old parceling, mounds and infrastructure.
- When implementing a citizen science project in Zeeland users should be provided with some prior training to avoid both false-positives and the possibility of too much data which can subsequently not be verified through fieldwork.
- As with the original Heritage Quest project, the engagement of the local community in their heritage will be an important aspect for a CS project in Zeeland. To stimulate engagement, a CS project in Zeeland could lay an initial focus on heritage which is already seen as quintessentially Zeeuws, such as mounds and dykes.
- Because the cultural landscape which is (and was) present in Zeeland does not necessarily stop at the Belgian, Brabant and South-Holland borders, but continues onwards into the clayey areas of Flanders, Brabant and Holland, it could potentially prove to be fruitful to also include (parts of) these regions in a citizen science project. This would be especially true if a citizen science project would focus on the State-Spanish lines. By increasing the research-area archaeological heritage in the province of Zeeland could be put into a broader perspective, and the potential pool of citizen scientists who would participate in such a project might increase.

Abstract

For over a century aerial photography has been used in archaeology to detect traces of the past in the landscape. With the emergence of citizen science projects and vast amounts of remotely sensed data, Leiden University has developed a successful citizen science project in the Veluwe and Utrechtse Heuvelrug called 'Heritage Quest'. Because of its success in both identifying hitherto unknown archaeological heritage and in engaging participants with their local heritage, other actors such as the province of Zeeland have shown interest in adapting the Heritage Quest formula or developing their own citizen science project. However, due to the different nature of the Holocene, agricultural landscape of Zeeland compared to the Pleistocene, forested landscape of the Veluwe and Utrechtse Heuvelrug and differences in the archaeological heritage which can be found in both regions, a different approach to citizen science than the approach of the original Heritage Quest was needed.
This thesis research focusses on the possibilities of a 'Heritage Quest' type citizen science project for the province of Zeeland. Instead of using LiDAR data, which is useful in mapping archaeological objects through the canopy of trees and bushes, orthomosaic satellite imagery disclosed through PDOK has been used to assess the potential viability of a citizen science project in Zeeland. Because of the agricultural nature of most of the province, satellite imagery could potentially be a powerful tool in identifying archaeological heritage. The imagery used in this research was remotely sensed during the summer months of 2016 up to 2022 and has a ground resolution of 25 centimeters. For the year 2021 satellite imagery was only available from the spring months, with a ground resolution of 8 centimeters. For the year 2022 both the summer imagery with a ground resolution of 25 centimeters and spring imagery with a ground resolution of 8 centimeters was used.
To assess the viability of using satellite imagery, three different object classes have been chosen to explore further, resulting in a total of 24 different archaeological features which can be seen in the imagery and have been described in this research. Furthermore, to assess which aspects of the original Heritage Quest project could be adapted or needed to be changed, the original Heritage Quest project and three other international citizen science projects have been described after which they were critically reviewed in the discussion chapter.
This thesis research has resulted in the discovery of multiple hitherto-unknown archaeological features, including potential Zeeuwse mounds, dykes, fortifications from the Dutch revolt and traces of the former cultural landscape of Zeeland. Using satellite imagery to identify archaeological heritage in the Province of Zeeland by means of a citizen science project can not only provide a lot of new archaeological data, but also increase historical awareness and create a sense of stewardship in its participants. This would not only lead to the identification of more archaeological sites, but also further protection efforts of archaeological heritage in Zeeland. Although there will be some

differences from the original Heritage Quest project, a very similar citizen science project for the province of Zeeland which would include some prior training could yield valuable results.

Reference list

Coppens, E. (2013). Artefact! Rapport 45. Zaamslag.

De Klerk, A.P., van der Meulen, T., Vervloet, J.A.J. (1969). *Dde Vliedbergen in het kustgebied van Vlaanderen, Zeeland en Zuid-Holland.* Vrije Universiteit Amsterdam. Amsterdam.

Erfgoed Gelderland. (2023). *Erfgoed Gezocht*. Erfgoed gezocht Gelderland. https://erfgoedgelderland.nl/project/erfgoed-gezocht/

GlobalXplorer. (2018, April). GlobalXplorer° Completes Its First Expedition: What the Crowd Found in Peru. https://medium.com/@globalxplorer/globalxplorer-completes-its-first-expedition-what-the-crowd-found-in-peru-7897ed78ce05

Heritage Quest. (2020). About Heritage Quest. https://www.zooniverse.org/projects/evakap/heritage-quest/about/research

Hillforts. (2017). Citizen Science. https://hillforts.arch.ox.ac.uk/assets/citizen.html

Kavelruilbureau Zeeland. (2023). *Wederopbouw*. Provincie Zeeland. https://www.zeeland.nl/ruimte/kavelruilbureauzeeland/wederopbouw

Kerckhaert, K.J. (2022). Erfgoed van alle Zeeuwen. *Zeeuws Erfgoed, 2022, 1.* 13-15.

Kuipers, J.B., van Dierendonck, R.M., de Klerk, A.P., Goldschmitz-Wielinga, L.C.J., de Koning-Kastelein, D., Hendrikse, H., van der Veeke, A.J. (2004). *Sluimerend in slik – Verdronken dorpen en verdronken land in zuidwest Nederland.* Stichting Cultureel Erfgoed Zeeland.

Kuipers, J.J.B., Swiers, R. J. (2005). *Het verhaal van Zeeland.* Hilversum

Lambers, K., Verschoof-Van der Vaart, W. B., & Bourgeois, Q. P. J. (2019). Integrating Remote Sensing, Machine Learning, and Citizen Science in Dutch Archaeological Prospection. *Remote Sensing*.

Lercari, N., & Jaffke, D. (2020). Implementing Participatory Site Stewardship through Citizen Science and Mobile Apps. *Advances in Archaeological Practice : a Journal of the Society of American Archeaology*, *8*(4), 337–350. https://doi.org/10.1017/aap.2020.29

Ovaa L., van der Sluijs, P., Steur, G.G.L. (1965*). De Bodem Van Zeeland*. Stichting voor Bodemkartering Wageningen.

POAZ Provincie Zeeland. (2017). *Wie wat bewaart, die heeft wat. Provinciale Onderzoeksagenda Archeologie Zeeland 2017-2020*. Provinciale onderzoeksagenda archeologie Zeeland 2017-2020.

Sijmons, D., (2003). *Staats-Spaanse Linies – Valorisering van frontierland Zeeuws-Vlaanderen*. Utrecht.

Staats-Spaanse Linies. (2023). Fort Fuentes/Spinola. https://www.staatsspaanselinies.eu/nl/de-staats-spaanse-linies/lijstweergave/linie:fort-fuentesspinola.htm

Universiteit Leiden. (2020). Erfgoed Gezocht. https://www.universiteitleiden.nl/en/erfgoed-gezocht
van Heeringen, R.M., Jong, A.G., Montforts, M.J.G.T., Penders, A.W.P.M., van Rooijen. (*et al*, 2007). *Monumenten van aarde, Beeldcatalogus van de Zeeuwse bergjes*. Koudekerke.

Verschoof-Van der Vaart, W. ., & Lambers, K. (2019). Learning to Look at LiDAR: The Use of R-CNN in the Automated Detection of Archaeological Objects in LiDAR Data from the Netherlands. Journal of Computer Applications in Archaeology, 2(1), 31–40.

Zooniverse. (2023). What is the Zooniverse? https://www.zooniverse.org/about

Appendices

Appendix A: Overview of results

	Visibility	Interpretation	Historical Identification	Toponym	RD coordinates
Feature 1	4	Castle terrain	Castle terrain of the mound ‘Zandweg-Bieweg’	Zandweg-Bieweg	34235, 395900
Feature 2	4	Mound	-	Colijnsplaat West	47715, 402080
Feature 3	5	Mound	-	Koudekerke East	28600, 389250
Feature 4	5	Mound	-	Bonte Kof	21050, 369020
Feature 5	4	Mound	Luchtenburgh	Luchtenburghseweg	43040, 412450
Feature 6	3	Redoubt	Part of the *Linie van Fontaine*	Greveningedijk (Belgium)	12980, 372150
Feature 7	5	Fortress	Fort Sint-Job	Fort Sint-Job (Belgium)	13160, 369500
Feature 8	5	Fortress	Fort Fuentes/Spinola	Fort Fuentes/Spinola (Belgium)	67970, 366166
Feature 9	5	Redoubt	-	Zijpstraat	52180, 360635
Feature 10	4	Redoubt	-	Molenstraat	47110, 360560
Feature 11	4	Fortress	-	Zuidweg	24030, 365420
Feature 12	5	Redoubt	‘t Kraaijennest	‘t Kraaijennest	17070, 366699
Feature 13	4	Line-dyke	-	Henricusdijk	21730, 374600
Feature 14	5	Drowned village	Nieuwlande	Nieuwlande	65850, 385370
Feature 15	5	Drowned village	Saeftinghe	Saeftinghe	73200, 376500
Feature 16	5	Drowned village	Oud Rilland	Oud Rilland	70750, 379400
Feature 17	4	Drowned village	Valkenisse	Valkenisse	65370, 379620
Feature 18	5	Drowned village	Oud Campen	Oud Campen	39400, 399150
Feature 19	5	Dyke	Former dyke of Calandspolder	Calandweg	40800, 393000
Feature 20	5	Ditches	Grain storage	Molenweg	58200, 380100
Feature 21	5	Ditches	Grain storage	Stuiverstraat	58800, 377700

Feature 22	4	Parceling	-	Derringmoerweg	35400, 393000
Feature 23	5	Parceling	-	Trekvlot Serooskerke	45000, 414400
Feature 24	4	Parceling	-	Koetenisseweg	44100, 414000

Appendix B: Visibility ratings of all features

Year	**2016, 25cm**	**2017, 25cm**	**2018, 25cm**	**2019, 25cm**	**2020, 25cm**	**2021, 8cm**	**2022, 8cm**	**2022, 25cm**
Feature 1	2	1	1	**4**	3	2	2	1
Feature 2	1	1	1	1	**4**	1	2	3
Feature 3	1	**5**	3	2	3	2	1	2
Feature 4	1	2	1	**5**	3	1	1	1
Feature 5	1	3	**4**	3	1	2	1	1
Feature 6	1	1	2	**3**	2	1	1	1
Feature 7	1	1	2	1	**5**	1	1	2
Feature 8	2	1	1	4	**5**	1	2	1
Feature 9	1	3	2	**5**	2	1	1	1
Feature 10	1	**4**	2	2	1	1	1	1
Feature 11	3	3	3	2	2	**4**	1	1
Feature 12	2	3	4	**5**	3	2	3	1
Feature 13	**4**	1	3	1	2	2	4	3
Feature 14	1	2	3	3	3	**5**	1	3
Feature 15	1	4	4	2	4	**5**	1	2
Feature 16	1	3	**5**	1	2	1	1	1
Feature 17	1	2	**4**	1	3	3	1	3
Feature 18	1	3	**5**	2	2	1	1	1
Feature 19	1	4	2	4	**5**	2	2	1
Feature 20	1	1	2	1	**5**	1	1	2
Feature 21	1	3	2	2	**5**	1	1	1
Feature 22	1	1	1	**4**	1	1	1	1
Feature 23	1	1	3	**5**	4	1	1	1
Feature 24	1	3	**4**	2	2	1	1	1
Sum Visibility	32	56	64	65	**72**	43	33	36
Average Visibility	1,3	2,3	2,7	2,7	**3**	1,8	1,4	1,5
Amount of times used for mapping	1	2	5	**7**	6	3	0	0