Journal of Cultural Heritage 53 (2022) 190–205

Contents lists available at ScienceDirect

Journal of Cultural Heritage

journal homepage: www.elsevier.com/locate/culher

# A different view on (world) heritage. The need for multi-perspective data analyses in historical landscape studies: The example of Schokland (NL)

Rowin J. van Lanen[a,b,*], Roy van Beek[a], Menne C. Kosian[b]

[a] Wageningen University & Research, Dept. of Environmental Sciences, Wageningen, the Netherlands
[b] Cultural Heritage Agency of the Netherlands, P.O. Box 1600, 3800 BP, Amersfoort, the Netherlands

ARTICLE INFO

*Article history:*
Received 14 June 2021
Accepted 29 November 2021
Available online 21 December 2021

*Keywords:*
World heritage
Historical landscapes, Heritage management and conservation
Historical geographical information systems (hgis)
Landscape archaeology
Multi-perspective data integration

ABSTRACT

The awareness that cultural heritage plays an influential role in shared identities and in both spatial and environmental development has significantly increased in recent years. International collaboration and treaties, such as the 'FARO-convention' in 2005 emphasize the importance of heritage in relation to aspects of human rights and demography. Furthermore, it is becoming increasingly clear that historical perspectives are essential for making well-informed choices regarding environmental challenges (e.g. spatial planning, sustainable development, climate adaptation). This increased awareness not only emphasizes the importance of cultural heritage for present-day challenges, but equally presents a new set of conditions and standards, and requires the development of new methodologies. Besides conservation, more than ever there is a need for cultural heritage to become contextualized and sustainably accessible.

The organisational pinnacle of cultural-heritage conservation is world heritage: sites that are judged to contain a set of cultural and/or natural values which are of outstanding value to humanity. However, to what extent world heritage meets these newly set criteria is unknown. Nevertheless, these sites often reflect an eminent status, scientifically as well as economically (i.e. through tourism). Consequently, world heritage often enjoys interest from multiple stakeholders including governmental, scientific, public, and commercial parties, all of whom engage in contrasting activities and have different interests and needs. As a result the need for accessibility and integrated overviews of these sites is high but equally challenging.

In this paper we will focus on the world-heritage site of Schokland (NL). This former island in the Dutch *Zuiderzee* both reflects outstanding historical and archaeological importance. We will show that the dynamics surrounding this site require tailormade conservation methodologies, which greatly depend on data integration. We present a new Historical Geographical Information System (HGIS) specifically designed to integrate cultural and geoscientific data and facilitate dynamic heritage management. Results show that such a system greatly adds to the contextualization and (digital) accessibility of the heritage site and is essential for substantiating conservation methodologies. Furthermore, it shows great research potential for diachronological reconstructions of dynamic-lowland development. The system facilitates multidisciplinary scientific analyses, integrated monitoring, and public outreach and shows great application potential for other (world-)heritage sites.



## 1. Research aim

Wetland environments are amongst the most dynamic types of landscapes. Their distinct geomorphological characteristics makes them strongly susceptible for environmental changes (e.g. climate, demography, economy, and politics), but equally provide outstanding preservation conditions (of especially organic materials). As a result these landscapes represent unique and invaluable archives of long-term natural and cultural development. Additionally, recent years have shown the potential of wetlands as valuable ecoservices systems for e.g. carbon sequestration and water management. Consequently, the variety of stakeholders active in these landscapes is high and wetlands worldwide are undergoing rapid change and development. The precise impact of these dynamics on the heritage contained in these complex landscapes remains

* Corresponding author.
*E-mail address:* r.van.lanen@cultureelerfgoed.nl (R.J. van Lanen).

https://doi.org/10.1016/j.culher.2021.11.011
1296-2074/

unclear. This study presents a newly developed methodology (i.e. HGIS) for managing and analysing heritage in dynamic environments such as wetlands. By focusing on world-heritage Schokland, a site renowned for its long-term human-landscape interaction, we show that (world) heritage in dynamic landscapes requires multi-perspective, tailor-made research approaches and preservation strategies. Our outcomes show that: (1) multidisciplinarity is key for long-term (world) heritage preservation and understanding in dynamic landscapes for all stakeholders, and (2) through the HGIS-methodology it is possible to model and analyse environmental dynamics and also determine their impact on heritage.

## 2. Introduction: modern-day challenges, world heritage, and HGIS

Traditionally, cultural heritage always has been associated with the conservation of historical remains ranging from monumental objects and buildings to archaeological sites and cultural landscapes. However, over the last decades the emphasis in heritage studies increasingly has moved away from mere preservation towards its role in community formation, shaping shared identities, and the environment (e.g. [[10],[21],[23],[25],[31],[54]]). This trend is underlined by the increasing ratification in recent years of the 'council of europe (CoE) Framework Convention on the Value of Cultural Heritage for Society'-treaty, the so-called 'FARO-convention' by EU-member states [5]. The definition of heritage has proven dynamic and has increasingly broadened, moving away from being object-orientated to preserving whole landscapes and including intangible heritage [[10],[12],[54]]. Consequently, the set of demands associated with heritage has equally shifted and there is an increasing need for heritage to become more contextualized, integrated, and (digitally) accessible (e.g. [[2],[47]]). This need is further underlined by recent studies that increasingly point to the importance of cultural heritage for meeting environmental (e.g. climate adaptation, soil subsidence) and spatial-planning challenges (e.g. [[11],[25],[48]]). Present-day landscapes generally consist of numerous historical elements, which to a large extent have defined modern layouts such as parcelling, infrastructural networks, and waterways. Modern-day development or adaptation strategies are becoming increasingly important and require knowledge of the past in order to make informed choices for the future (e.g. [48]). As a result cultural heritage as a concept is increasingly transcending its conservation meaning and is becoming an integral part of meeting present-day challenges and designing future approaches. This, however, does present a new set of prerequisites for dealing with heritage and requires the development of new methodologies. Contextualization for example, requires multidisciplinary datasets, integrated overviews of diachronic development, and illustration and presentation means.

World heritage is the organisational pinnacle of cultural-heritage conservation. The World Heritage Convention was adopted by UNESCO in 1972 and resulted in the formation of the World Heritage List. Originally this list differentiated between cultural and natural sites only, the former being appraised by ICOMOS (the International Council on Monuments and Sites) and the latter by IUCN (the International Union for Conservation of Nature; [39]). Each world-heritage site is judged to contain either cultural or natural characteristics that are of 'Outstanding Universal Value' (OUV) for humanity. However, already in the 1980s it became clear that in several potential sites differentiating between 'culture' and 'nature' was not evident. Subsequent discussions eventually led to the introduction of cultural landscapes to the list in 1993 (e.g. [59]). Cultural landscapes are defined by UNESCO [[39], art. 47] as *"..cultural properties and represent the "combined works of nature and of man".. They are illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal."*. To simplify matters, cultural landscapes are further divided into: (1) the clearly defined landscape designed and created intentionally by man, (2) the organically evolved landscape (further subdivided into: (a) relict or fossil landscape and (b) continuing landscape), and (3) the associative cultural landscape [39]. It is important to note that cultural landscapes, although containing clear natural heritage factors, differ from 'mixed' sites. The latter reflect both cultural and natural OUVs and are judged by ICOMOS and IUCN collectively. Cultural landscapes however are appraised based on their cultural values only, although ICOMOS can be advised by IUCN for the natural components of the potential site [59]. Currently, the World Heritage List holds 1121 (predominantly cultural) sites (Table 1).

Following the definition of 'cultural landscapes' by UNESCO, these sites are the product of a complex interplay between cultural and natural factors. Renes [31] already advocated that the protection of these landscapes, and heritage sites in general, is only possible by a movement towards 'management of change' (cf. [11]). Since landscapes are dynamic in nature and heritage sites never isolated from their environment a flexible and dynamic approach towards heritage management is essential for sustainable preservation (e.g. [35]). Renes [31] continued by concluding that within UNESCO's framework change is possible but needs to be done with care and caution and in search of quality. Rather than solely focusing on the authenticity of the original situation, development and conservation should be based on ideas of layering and path dependency of the landscape.

Unravelling these layers and path-depended relations is complex and requires new tooling mapping the diachronical development of, not only cultural landscapes, but heritage sites in general. This tooling should support dynamic and integrated heritage management, and facilitate contextualization, accessibility, multidisciplinary data integration, and multi-perspective data analyses (i.e. data analyses that suit specific interests from a wide range of different stakeholders). Mapping methodology proven to have potential in this area can be found in concepts derived from Historical Geographical Information Science (HGIScience) and Geographical Information Science (GIScience). HGIScience is an interdisciplinary field of research which uses methodology from Geographical Information Systems (GIS) in order to design and facilitate tailormade spatial analyses for integrated historical research purposes (e.g. [[9],[18],[26]]). Its theoretical framework is especially well suited for integrated knowledge management and multi-perspective data analyses because it highlights the role of spatial context and interrelationships within historical systems and cultural-landscape development [56]. Systems designed in line with HGIScience are typically well suited for integrating both spatial and non-spatial data pertaining the genesis of landscapes and creating integrated diachronical overviews based on multiple sources. GIScience is the scientific discipline that studies computational techniques and data structures (e.g. data models; standards) in order to process, visualize and analyse spatial information [[7],[15]]. It differs from HGIScience as it focuses much more on the technical aspects of spatial analyses and less on the historical context. Within GIScience, traditional GIS are regarded as mere tooling for visualisation and representation purposes, which by themselves lack the conceptual frameworks for scientific analyses (e.g. [16]).

In this paper we present a Historical Geographical Information System (HGIS) specifically designed to help contextualize, manage, and analyse the world-heritage site of Schokland (NL; Fig. 1). This former island is characterized by a highly dynamic landscape setting and a long-term history of human-landscape interaction resulting in complex historical layering and extensive path-depended relations (Section 3). This complexity neces-

**Table 1**
Global overview of world-heritage sites and specification of sites located in the Netherlands. Overview: October 2021.

| Total WH sites | Cultural | Natural | Mixed |
|---|---|---|---|
| 1154 | 897 | 218 | 39 |
| **World heritage in the Netherlands** | | | |
| Total WH sites | Cultural | Natural | Mixed |
| 12 | 11 | 1 | 0 |
| **Site description** | | | |
| Name of site | Type of site | | |
| Schokland and Surroundings | Cultural site | | |
| Dutch Water Defence Lines | Cultural site | | |
| Historic Area of Willemstad, Inner City and Harbour, (Curaçao) | Cultural site | | |
| Mill Network at Kinderdijk-Elshout | Cultural site | | |
| Ir.D.F. Woudagemaal (D.F. Wouda Steam Pumping Station) | Cultural site | | |
| Droogmakerij de Beemster (Beemster Polder) | Cultural site | | |
| Rietveld Schröderhuis (Rietveld Schröder House) | Cultural site | | |
| Wadden Sea | Natural site | | |
| Seventeenth-Century Canal Ring Area of Amsterdam inside the Singelgracht | Cultural site | | |
| Van Nellefabriek (Van Nelle factory) | Cultural site | | |
| Colonies of Benevolence* | Cultural site | | |
| Frontiers of the Roman Empire – The Lower German Limes* | Cultural site | | |

* Transboundary property.


**Fig. 1.** Left: the location of Schokland within the Netherlands. Right: Seen from the north, the old contours of the former island are still clearly visible in the modern-day landscape (aerial photograph by: Jan Willem Schoonhoven, Wikimedia).

sitates a new dynamic, integrated approach towards managing and studying the historical landscape. By applying concepts derived from HGIScience and GIScience we developed a HGIS facilitating integrated-knowledge and dynamic-heritage management, diachronic reconstructions, and multi-perspective data analyses. The system is specifically designed to integrate cultural and geoscientific data. The main goal of this study is to (1) show the necessity of multi-perspectivity and multidisciplinarity when analysing and managing (world-)heritage sites in dynamic environments, and (2) determine the versatility and the application potential of the HGIS-methodology for dynamic heritage management. This is operationalised by presenting four selected analytical results: (1) high-resolution chronological reconstructions of the integrated cultural and natural development of Schokland, (2) detailed historical site maps on professional occupance and (3) property rights, and (4) high-resolution maps facilitating informative heritage management. Additionally, we explore how the HGIS-methodology increases the (digital) accessibility of the site, helps to analyse the complexity of historical landscapes, and its implementation potential for other (world-)heritage sites, especially those located in culturally or naturally dynamic environments

## 3. The former island of schokland

### 3.1. Palaeogeographical development

The site of Schokland is located near the centre of the Netherlands, in the present-day *Noordoostpolder* (Fig. 1). It is a former island located in the *Zuiderzee* and has been part of the Dutch mainland since the final reclamation of this area in 1942 (e.g. [45]). The formation of Schokland started during the Saalian glaciation (ca. 150.000 years ago) when ice covered the northern parts of the Netherlands and formed a ground moraine along the line

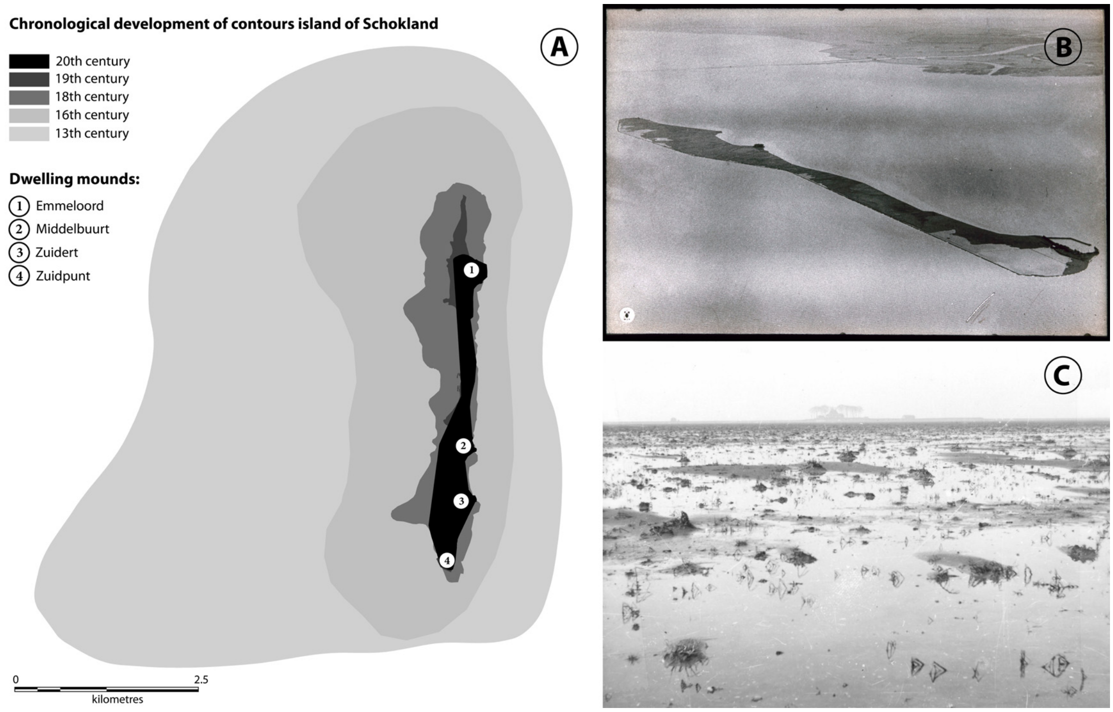


**Fig. 2.** (A): Chronological development of the contours of the island of Schokland, including large dwelling mounds mentioned in the text. Gradual (from grey to black), mainly westward erosion is clearly visible from the middle ages to the 20th century. (B): Aerial photograph of the island of Schokland in 1933 (facing southwest). (C): Recently reclaimed land (bottom of former *Zuiderzee*) surrounding Schokland in 1941, the outlines of the former island are visible on the horizon.

Urk-Vollenhoven, creating the oldest deposits on the island [61]. In the course of the following glacial period, the Weichselian (ca. 120.000–8.000 BCE) the colder climate promoted aeolian transportation and cover sands were deposited, resulting in several river dunes further enhancing the elevation of the area [17]. During the Holocene (starting ca. 8.000 BCE) higher temperatures led to rising sea- and groundwater levels and the formation of peat in the area [[17],[57]]. These processes eventually led to the closing of sea ingressions and the formation of the so-called Flevo lakes around 1500 BCE [57]. The long-term formation of peat in the lower areas, and the erosion of the elevated Pleistocene soils generally decreased height differences in the region. During the first century AD the Flevo lakes slowly turned into a lagoonal system (the Almere) and salinization took place [[51],[52]]. Around AD 800, a new tidal inlet opened in the north-western part of the Dutch coastline, resulting in renewed drainage of, and increase marine influence on, the study area [43]. In the following centuries, this increased drainage combined with subsequent soil subsidence and increased marine influences such as storm events led to increased erosion of the clay and peat soils [14]. These reoccurring storm events eventually led to the deterioration of the peat barrier separating the Almere and the North Sea, resulting in the gradual formation of the *Zuiderzee* during the 12th and 13th century [4]. A storm surge around 1446 eventually eroded the last peat area connecting Schokland to the mainland, resulting in the definitive formation of the island of Schokland [41]. During the following centuries gradual erosion continued, steadily reducing the size of the island ([53, 57]; Fig. 2). This process was only halted in the 20th century by the construction of the *Afsluitdijk* ("Enclosure Dam"; 1933), which transformed the salient *Zuiderzee* to the freshwater lake *IJsselmeer* (e.g. [57]). The geomorphological transformation of Schokland reached its current state in 1942, when the former island was converted to a (fully) man-made landscape by its incorporation into large-scale and systematic reclamation of the *Noordoostpolder* ([45]; Figs. 1 and 2).

### *3.2. Cultural development*

Archaeological data demonstrate that the island has a long-term cultural history with the first humans inhabiting the area around 12.000 years ago (e.g. [[6],[36–38], [40],[52],[55]]). The earliest archaeological remains are remnants of a late-Palaeolithic flint-working site (ca. 10.000 BCE) found on the relatively higher Saalien ground moraine in the north-eastern part of the study area [[42],[44]]. With the increasingly wetter conditions during the early- and middle-Holocene (8000–1000 BCE), archaeological finds are confined to the higher Pleistocene deposits. As is the well-preserved Neolithic and Bronze Age site "*Kavel P14*" (Lot P14), which is internationally renowned especially for the Neolithic burial site that was excavated there. The site gave essential insights in the gradual adoption of small-scale agriculture, animal domestication, and the prehistoric habitation of low-lying wetlands [36]. However, around 1900 BCE the area appears to have been completely abandoned again (Geurts, 2005; [45]). With the exception of some isolated and sparse Roman finds (i.e. pottery and tiles) of indecisive context, Schokland remained uninhabited until the 9th century AD [[44],[45]]. This repopulation synchronously occurred with increased natural drainage through the development of a new tidal inlet (Section 'Landscape setting'). From this period onwards the human impact on the landscape of Schokland increased drastically. Ongoing exploitation and reclamation in the following centuries increasingly led to soil subsidence (through the oxidation of peat), marine influences, and related erosion of the peninsula [42]. To cope with these wet conditions numerous artificial dwelling mounds (*terpen*) were constructed from the 9th century onwards [53]. The ongoing subsidence, storm surges, and erosion increasingly hardened habitation conditions and subsequent construction of embankments started in the 11th to 12th century. Archaeological finds suggest that habitation during the Middle Ages (AD 1050–1500) increasingly moved to the peripheral areas of the peninsula, most probably using the higher central parts for agricultural activities and animal husbandry [33]. At the end of the 14th century four larger dwelling mounds were created, designed to house multiple families: Emmeloord, Middelbuurt, Zuidert, and Zuidpunt (Fig. 2). The construction of these mounds suggests that storm surges had an increasing effect on Schokland (i.e. most notably the storm of 1375; Geurts, 2005). These mounds were located on the east side of the study area, sheltering them from most storm and flooding events and facilitating fishing activities which increasingly became important after the formation of the island [53]. Continuous erosion, combined with general poverty and unsafe living conditions eventually led to the evacuation of Schokland by royal decree in 1859 [45]. During the following decades the former island functioned as a breakwater and navigational beacon. After the construction of the *Afsluitdijk* in 1933 and the following reclamation of the *Noordoostpolder* the island of Schokland (again) became part of the Dutch mainland.

### 3.3. World-heritage protection

The newly reclaimed land was intended to facilitate large-scale food production. Consequently, during the first years awareness of the cultural-historical importance of Schokland was generally low. However, this quickly changed with the planting of trees on the local ground moraine (which was less suited for agricultural use) as a first sign of landscape planning. As a result, these trees fixated the contours of the former island in the landscape [13]. From the 1940s onwards archaeological interest in Schokland intensified and especially its prehistoric significance became increasingly clear (e.g. [[30],[36],[45]]). This raised awareness accumulated in Schokland receiving the world-heritage status in 1995, as the first heritage site in the Netherlands [50]. According to UNESCO the site symbolizes the heroic, age-old struggle of the people of the Netherlands with water [24]. OUVs are mainly based on two criteria: (1) Schokland representing the last surviving evidence of a prehistoric and early historic society continuously adapting in wetland environments and (2) Schokland as an integral part of a newly reclaimed agricultural landscape. Since receiving its world-heritage status, the former island has been intensively managed by varying parties in order to preserve its natural and cultural values [49]. This results in complex tensions between amongst other agricultural activities, historical landscape elements, ecological values and the preservation of archaeological remains (e.g. [22]). The world-heritage status therefore reflects a new chapter in the development of Schokland, one where natural and human-induced events have to coexist in preserving the long-term historical dimension of this cultural landscape.

## 4. Materials and methods: a HGIS of schokland

Preserving historical elements is precarious and starts with available information, especially in culturally and naturally dynamic sites such as Schokland. Our HGIS is designed to integrate multiple data sources, qualitative as well as quantitative, historical and modern. In line with a methodology presented by Van Lanen & Kosian [48], we developed a HGIS specifically designed to combine cultural and geoscientific data pertaining Schokland. The system is however not limited to these scientific domains (cf. Section 6). Below each of the datasets imported into the system are presented, differentiating between cultural, present-day topographical, and geoscientific data (Fig. 3; Sections 4.1-4.2). Monitoring data are not included in the system since these are often frequently updated and would require active knowledge management which was beyond the scope of the current study. This section is concluded with a short overview of the technological background and design of the HGIS (Section 4.3).

### 4.1. Cultural data

Several cultural datasets were incorporated in the HGIS ranging from archaeological to genealogical data, including recently-developed overview studies (Fig. 3).

#### 4.1.1. Archaeological data

Data on archaeological finds and monuments were extracted from the Archaeological Information System of the Netherlands (ARCHIS; [[34],[60]]). ARCHIS is maintained by the Cultural Heritage Agency of the Netherlands and contains an overview of archaeological sites and finds in the Netherlands registered from 1992 onwards. In order to improve data quality the extracted archaeological data were compared with and enhanced by data published in recent overview studies (Van Popta, 2015; [52]).

#### 4.1.2. Cultural-historical elements

Cultural-historical elements on Schokland such as dwelling mounds, dikes, ditches, canals, roads etc. were extracted from CultGIS (Cultural-historical GIS). This online dataset contains a national overview of historical-geographical phenomena in the Netherlands (e.g. [1]). Combined with regional descriptions published in individual reports (e.g. [[19],[20]]) the dataset describes 82 historically-geographically characteristic areas in the Netherlands. For the study area, these data were enhanced and expanded by including recently-published reconstructed elements on Schokland (e.g. mounds, dikes) and its surroundings ([[28],[42]]; Van Popta 2015; [52]).

#### 4.1.3. Intangible heritage

The legacy of Schokland includes both tangible and intangible cultural heritage. Mainly due to its navigation and fishing importance many stories and anecdotes, especially from the 19th century, have survived. The HGIS facilitates combining for example transcriptions with spatial information (through e.g. cadastral maps). We added examples of these anecdotes, oral history, and portraits to the system through online (mainly genealogical) sources provided by the *Schokkervereniging* (i.e. local association founded in 1985 aimed to improve the preserve and present the history of Schokland).

### 4.2. Spatial data

The HGIS is designed to combine spatial datasets, ranging from historical maps, to modern topographical and geoscientific data (Fig. 3).

#### 4.2.1. Historical maps

Several historical maps were used to enhance existing reconstructions or datasets (Table 2). Rather than georeferencing these maps, we applied a similar regression-mapping method as developed by Van Lanen & Kosian [48]. Regression mapping originates from GIScience and is a technique designed to link specific present-day landscape elements with their counterparts depicted on historical maps in order to gradually work back from present to past. This approach allowed us to fixate historical information on existing landscape elements and reconstruct the location of vanished cultural and natural features in the past without the need of georeferencing each individual map. As a result we were able to improve existing reconstructions and increase the number of chronological reconstructions (cf. Section 5).

#### 4.2.2. Topographical data

Besides historical spatial data, the HGIS also contains several topographical datasets (Table 2). These datasets provide information on past and present-day elevation, modern topography, existing buildings and addresses, and the world-heritage contour. For

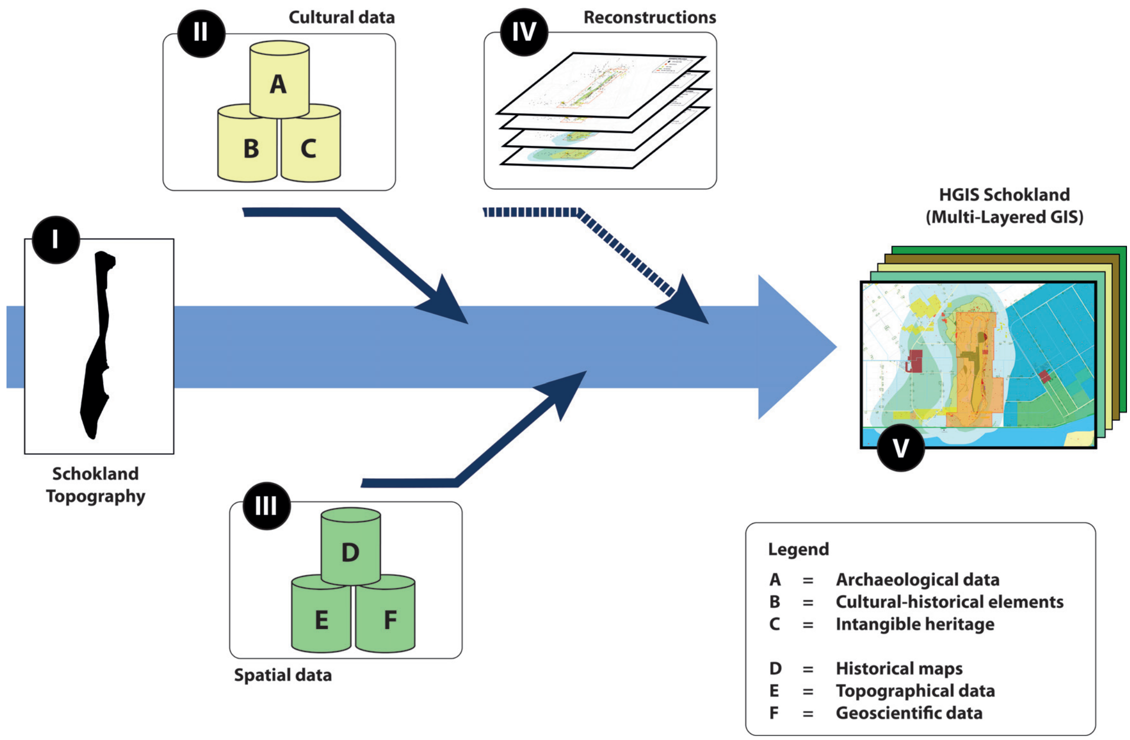


**Fig. 3.** Methodological overview of the development of the Schokland HGIS. Based on present-day topographical data the outline of the study area was selected (step: I). Cultural and spatial data pertaining our research focus or reflecting stakeholder interests were then included based on spatial correspondence (steps: II and III). As a next step, these datasets were used to improve the data quality of individual datasets where possible and to create improved chronological reconstructions (step: IV). These reconstructions were subsequently incorporated into the system (dashed line) as new data layers to further aid our research goals. As a final step all data layers were thematically grouped and tailormade queries developed resulting in the Schokland HGIS (step: V).
(For more detailed information on individual datasets see: Sections 4.1 and 4.2).

**Table 2**
Overview of the historical maps and modern topographical and geoscientific data used in the HGIS. For more detailed referencing compare the Reference list.

| | | |
|---|---|---|
| | Historical maps | |
| Van Deventer map | 1558 | Jacob van Deventer, *Hollandt*. |
| sGroten map | 1588 | *Tabula XII Continens Phrisios qui* versus *Meridiem in Palustribus sedent iuxta Sicambros et Batavos.* |
| Schokland map 1600 | ca. 1600 | Map of the island of Schokland. Anonymous, no title. |
| Visscher map 1670 | 1670 | *Comitatus Hollandiae tabula pluribus locis recens emendata a Nicolao Visscher.* |
| Schokland map 1762 | ca. 1762 | Map of the island of Schokland. Anonymous, no title. |
| Kadaster: *Minuutplans* | 1832 | Minute plans of the Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster). |
| Kadaster: *Verzamelplan* | 1832 | Collected plans of the Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster). |
| Topographical Military Maps | 1850 | Topographical Military Maps (TMK) of the kingdom of the Netherlands (1:50,000). |
| Bonnebladen | 1933 | Chromo-topographical map of the kingdom of the Netherlands (1:25,000). Successor of the TMK. |
| | Topographical data | |
| BAG | 2014 | Basic registration (polygons) for addresses and buildings in the Netherlands. |
| TOP10NL | 1995 | Basic registration topography in the Netherlands. |
| AHN 1 | 2004 | National LIDAR survey data of the Netherlands, version 1 (grid-cell resolution 5 × 5 m; measuring date Schokland 1997–1998). |
| AHN 2 | 2012 | National LIDAR survey data of the Netherlands, version 2 (grid-cell resolution 0.5 × 0.5 m; measuring date Schokland 2009). |
| AHN 3 | 2019 | National LIDAR survey data of the Netherlands, version 3 (grid-cell resolution 0.5 × 0.5 m; measuring date Schokland 2019). |
| TOPhoogteMD | 1992 | Historical elevation model of the Netherlands (prequel to the AHN). |
| Water-system management information of the Dutch waterboards | 2020 | Portal for sharing and combining water-system management information of the Dutch waterboards. Consisting out of administrative areas polygons, information on watersupply and discharge areas, and polder datum areas. |
| World heritage contour | 1995 | Contour of world-heritage protected site of Schokland [24]. |
| | Geoscientific data | |
| Geomorphology | 2017 | Geomorphological map of the Netherlands (1:50,000) |
| Palaeogeography | 2018 | Palaeogeographical reconstructions of the Netherlands during the Holocene [58]. |
| Soil | 2018 | Soil map of the Netherlands (to a depth of 1.2 metres; scale 1:50,000). |
| Top Pleistocene | 2018 | Top soil during the Pleistocene, extracted from the palaeogeographical reconstructions of Vos et al. [58]. |

each of the datasets the geographical outlines were clipped to the study area. Topical information on amongst other parcelling and buildings were derived from the BAG and TOP10NL datasets. Past-elevation data were included in the HGIS based on TOPhoogteMD-data. This national overview is maintained by the Ministry of Infrastructure and Water Management and provides data on historical elevation mainly to be used for soil-subsidence monitoring (which is increasingly becoming a problem also in the region of Schokland). Present-day elevation data were derived from AHN 1–3, reflecting a higher resolution with each update. Current data on water-system management were added through the centralized portal of Dutch waterboards. The exact contours of the world-heritage site were extracted from UNESCO [24].

*4.2.3. Geoscientific data*

The HGIS incorporates a number of geoscientific datasets (Table 2). Geomorphological data were added to the system through the Geomorphological Map of the Netherlands. This map, maintained by Wageningen University and Research (WUR), provides data on relief, genesis, and age of landscape elements. Although it presents the present-day Netherlands the data contain invaluable information on historical-landscape elements. Soil data were derived from the Soil Map of the Netherlands (also maintained by WUR) and provide an overview of all current soil types. Especially in dynamic wetlands such as Schokland geomorphological and soil conditions are susceptible to change. Therefore the HGIS also includes palaeogeographical data and TOP Pleistocene data. The first provide information on the palaeogeographical development of the Netherlands during the Holocene (< 8000 BCE). The latter offers a detailed overview of the top soil during the end of the Pleistocene era (> 8.000 BCE).

*4.3. The HGIS*

Our HGIS combines these cultural and spatial data into one integrated system (Fig. 3). The system is best described as a multi-layer GIS consisting of multiple folders and tables. Each of these folders reflects a specific thematic group (e.g. scientific domain) storing a variety of datasets (e.g. attribute tables or polygons; Table 3). Such a design purely based on spatial correspondence has three main advantages: (1) it makes the system flexible allowing for an easy integration of new datasets within existing domains or groups, (2) the system is not limited to a predefined set of data sources, and (3) full data integration in for example the area of normalization, standardization, and (inter)relationships is not needed.

*4.3.1. The HGIS data structure*

The HGIS consists of 15 thematically divided groups which are further subdivided between one of more base tables. Each of these tables in turn reflects one dataset (Table 3). In the system, cultural data are stored in groups 1 and 2, modern topographical data (e.g. present-day parcelling and buildings) in group 3, 19th-century cadastral information in group 5, newly developed reconstructions in groups 4, and 6–9, and geoscientific data (e.g. hydraulics, soil, geomorphology, elevation etc.) in groups 10–15.

By applying this multi-layered approach we were able to create overviews based on multiple datasets covering a multitude of chronological periods. The approach allowed us to improve general data quality in the system and design pinpointed analyses. Data quality of individual datasets was enhanced by combining datasets or thematic groups. Integrated spatial analyses were designed and implemented for each of the four selected results based on unique combinations of datasets ranging from cultural, topographical, and geoscientific (Section 5).

## 5. Results

The first results of our ‘Schokland-HGIS’ are promising and underline the versatility of the system. The datasets currently included in the system already reflect a large part of the dynamic cultural and natural history of the site. To underline the application potential and versatility of the system for management- and analytical purposes we present four selected results below: (1) new high-resolution chronological reconstructions of the island, (2) detailed maps of the 19th-century town of Emmeloord depicting amongst other professional occupance and (3) property rights which can be used for explorative genealogical analyses, and (4) high-resolution maps facilitating informative heritage management (cf. Introduction section).

*5.1. Chronological reconstructions*

By combining cultural and geoscientific data stored in the HGIS we were able to manufacture five high-resolution reconstructions of the island of Schokland (Figs. 4 and 5). We have limited our reconstructions to depicting the islandic phase of the site because: (1) data availability is higher during these later periods, and (2) information on especially these later phases are of crucial importance for site preservation and future development. All reconstructions were based on palaeogeographic and archaeological data provided by Vos [58] and Van Popta (2015; [52]) and further enhanced using other datasets (e.g. historical maps) stored in the HGIS (Table 2). This allowed for more detailed reconstructions and time slices for the period between the 13th-20th centuries.

Our first reconstruction shows Schokland during the 13th century (Fig. 4). Since detailed historical sources for this early period are lacking our model is solely based on archaeological and palaeogeographical data. Using these integrated data we were able to reconstruct the extent of the island including artificial dwelling mounds used by contemporary inhabitants. The model clearly shows that during this time the area was characterized by strong marine influences (i.e. numerous mounds, and extensive salt marshes and mudflats).

Towards the 16th century many changes occurred on Schokland (Fig. 4), most of which can be extracted from historical maps dating to this period ([[63],[65],[67]]; Table 2). Our reconstruction clearly shows that ongoing erosion and subsidence strongly reduced the surface area of the island and habitation was no longer scattered but concentrated on four large dwelling mounds. The large-scale construction of dikes underlines the considerable impact of water incursions from the 13th century onwards.

During the 18th century the size of the island was further reduced (Fig. 5). Contemporaneous dike systems, inhabited areas, and organizational structures were modelled based on palaeogeographic, archaeological, and historical data (cf. Table 2; Visscher, 1670; [64]). The reconstruction shows even more clustering of inhabited areas (most notably the abandonment of the southernmost dwelling mound *Zuidpunt*) and an evolution in the types of dikes (i.e. pole dikes). Perhaps most noticeable during this period is the subdivision of the island in a northern Catholic part: Emmeloord (governed by the province of Holland and owned by the town of Amsterdam), and a southern Protestant part: Ens (governed by the province of Overijssel). The impact of this organizational subdivision is well known in historical sources but also clearly visible in the distribution of dikes during this phase. Whereas the northern part of the island was completely diked, the south still had an open connection to the sea.

In the following 19th century storm surges, soil subsidence, and ongoing erosion further reduced the extent of the island and conditions became increasingly wetter (Fig. 5). By additionally extracting data from cadastral and topographical maps we were able to

**Table 3**
Overview of thematic groups and corresponding datasets in the Schokland-HGIS. For more information on abbreviations see Table 2 and the Reference list.

| # | Thematic group | Dataset (base table) | Description |
|---|---|---|---|
| 1 | Archaeology | ARCHIS data | Data extracted from ARCHIS |
| | | Coring data RAAP | Coring data into old dikes RAAP |
| | | Archaeological monuments | Contours of archaeological monuments |
| 2 | Cultural-historical Elements | World-heritage contour | Contour of world-heritage site |
| | | Dwelling mounds | Dwelling mounds in the study area |
| | | Dikes | (Historical) Dikes in the study area |
| | | River dunes | River dunes in the study area |
| | | CultGIS data | Data extracted from CultGIS |
| 3 | Topography modern | BAG | Data extracted from the BAG dataset |
| | | TOP10NL | Data extracted from TOP10NL dataset |
| 4 | Schokland 20th century | Schokland_topo_1933 | Reconstruction Schokland AD 1933 |
| 5 | Cadastral data 1832 | Schokland_1832 | Thematic outline of habitation information based on the cadastral information included in the Schokland 1832 dataset. |
| 6 | Schokland 19th century | Schokland_1832 | Reconstruction Schokland AD 1832 |
| 7 | Schokland 18th century | Schokland_1700 | Reconstruction Schokland AD 1700 |
| 8 | Schokland 16th century | Schokland_1550 | Reconstruction Schokland AD 1550 |
| 9 | Schokland 13th century | Schokland_1250 | Reconstruction Schokland AD 1250 |
| 10 | Water-system management information of the Dutch waterboards | Aanafvoergebied | Information on watersupply and discharge areas |
| | | Peilgebied (level area) | Information on polder datum areas |
| 11 | Soil data | Soil-map data | Data extracted from the soil map |
| 12 | Geomorphological data | Geomorphology-map data | Data extracted from the geomorphological map |
| 13 | Top Pleistocene data | Plmgeul (top layer Pleistocene) | Data on the top layer during the Pleistocene |
| 14 | Palaeogeography | AD 2000 | Palaeogeographical reconstruction AD 2000 |
| | | AD 1850 | Palaeogeographical reconstruction AD 1850 |
| | | AD 1500 | Palaeogeographical reconstruction AD 1500 |
| | | AD 1250 | Palaeogeographical reconstruction AD 1250 |
| | | AD 800 | Palaeogeographical reconstruction AD 800 |
| | | AD 100 | Palaeogeographical reconstruction AD 100 |
| | | 250 BCE | Palaeogeographical reconstruction 250 BCE |
| | | 500 BCE | Palaeogeographical reconstruction 500 BCE |
| | | 1500 BCE | Palaeogeographical reconstruction 1500 BCE |
| | | 2750 BCE | Palaeogeographical reconstruction 2750 BCE |
| | | 3850 BCE | Palaeogeographical reconstruction 3850 BCE |
| | | 9000 BCE | Palaeogeographical reconstruction 9000 BCE |
| 15 | Elevation models | AHN 3 | Current altitude data, version 3 |
| | | AHN 2 | Current altitude data, version 2 |
| | | AHN 1 | Current altitude data, version 1 |
| | | TOPhoogteMD | Historical elevation model |

not only reconstruct the contour of each dwelling mound, but also to reconstruct towns on an individual-household level (Cadastral map, 1832; [66]; cf. Table 2). During this time the organizational subdivision of the island was dissolved and the dike system improved to shield the whole of the island. A new type of dam was also introduced within the system, the cofferdam.

In 1859 Schokland was abandoned, but the island itself persisted until the reclamation of the area in 1942 (cf. Section 3). This final phase of the island could be reconstructed using high-resolution data from the Bonnebladen [62] and palaeogeography. According to our reconstruction erosion of the island has come a standstill during the mid-19th-20th century and dike systems only slightly changed (Fig. 5). Houses were deconstructed on a large scale and only a handful of buildings remained. The increased wetter conditions on the island are also clearly visible with marshes substituting grasslands.

### *5.2. Professions in nineteenth-century emmeloord*

Next to chronological reconstructions, the HGIS also facilitates high-resolution small-scale spatial analyses. These analyses require the availability of detailed information, which for Schokland are available from the 19th century onwards mainly through the cadastral map (1832). Using these data we made a high-resolution reconstruction of 19th-century Emmeloord (Fig. 6). The modelled outcome demonstrates the potential of the HGIS for spatial analyses on multiple scales. Using cadastral data we were able to reconstruct individual houses and parcels, and to combine these with professional occupance at the time. Our analysis shows that the vast majority of the inhabitants of Emmeloord were involved with fishing, which is not surprising since this period reflects the islandic phase of the study area. Besides fishermen the town population consisted of various government officials, two ferrymen, several day laborers, a shopkeeper, a baker, and a carpenter. These kinds of analyses greatly aid the reconstruction of everyday life on Schokland during the 19th century.

### *5.3. Property data and the potential of the HGIS for genealogical analyses*

Cadastral data provide a wide variety of information, for example on property rights. Through the HGIS we were able to connect house-owners' names to reconstructed properties in 19th-century Emmeloord. It was beyond the scope of the study to present a complete genealogical overview of the town. Therefore, we have limited the presented results to two inhabitants: Jacob Alberts Goosen (1776–1840) and Dubbel Alberts Goosen (1781–1847; Fig. 7). Our analysis shows that these men were brothers,

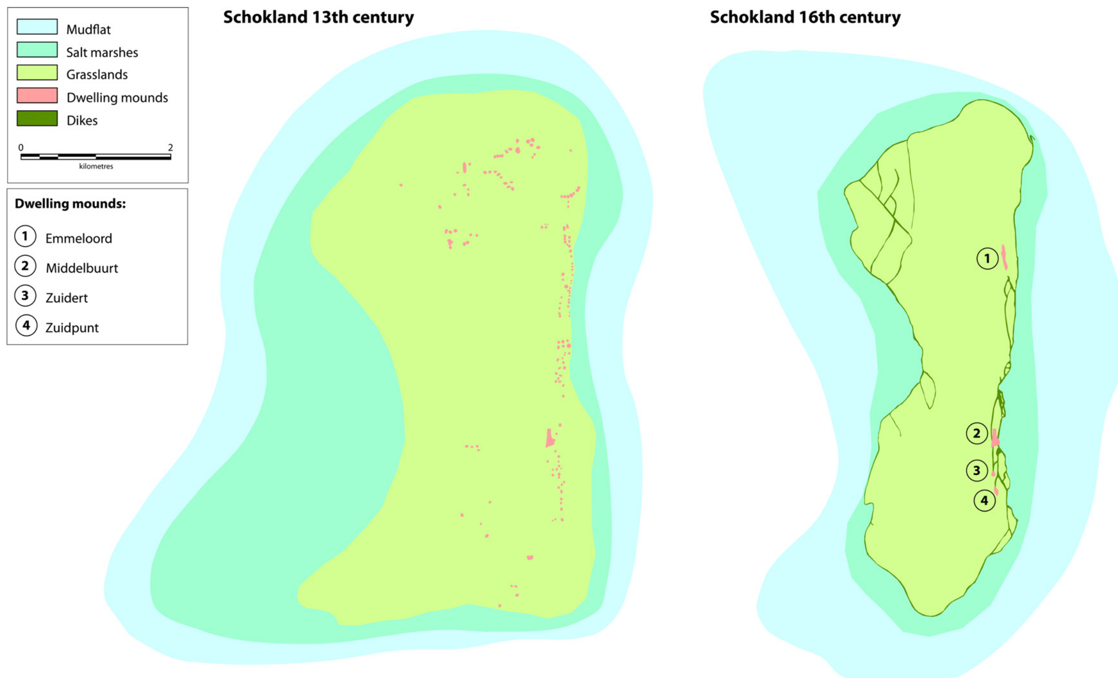


**Fig. 4.** Chronological reconstructions of the island of Schokland for the 13th (left) and 16th century (right). Ongoing erosion and water incursions are clearly visible through the reducing size of the island and implementation of dike systems.


**Fig. 5.** Chronological reconstructions of the island of Schokland for the 18th (left), 19th (middle), and 20th century (right). Further reduction of the island's surface area and increasingly wetter conditions are clearly visible towards the most recent reconstruction.

both lived in the northern part of Emmeloord, and were fishermen (Fig. 6). As an exploration we combined these data with genealogical information available online (see: Reference list). This allowed us to add information on birth- and death dates to the system, and to determine ancestors and descendants. These data can easily be expanded with links to oral history, anecdotes, other genealogical connections, of family-history information on 'Schokland-families'. An example of this can be found via the '*Schokkervereniging*' where a portrait of Dubbel Alberts Goosen's son was found (see Reference list: Genealogical data).

### *5.4. Informative heritage management through the HGIS*

Besides scientific analyses, the HGIS is also designed to facilitate heritage-management applications. To illustrate this we created two integrated overviews showing: (1) the distribution of ar-

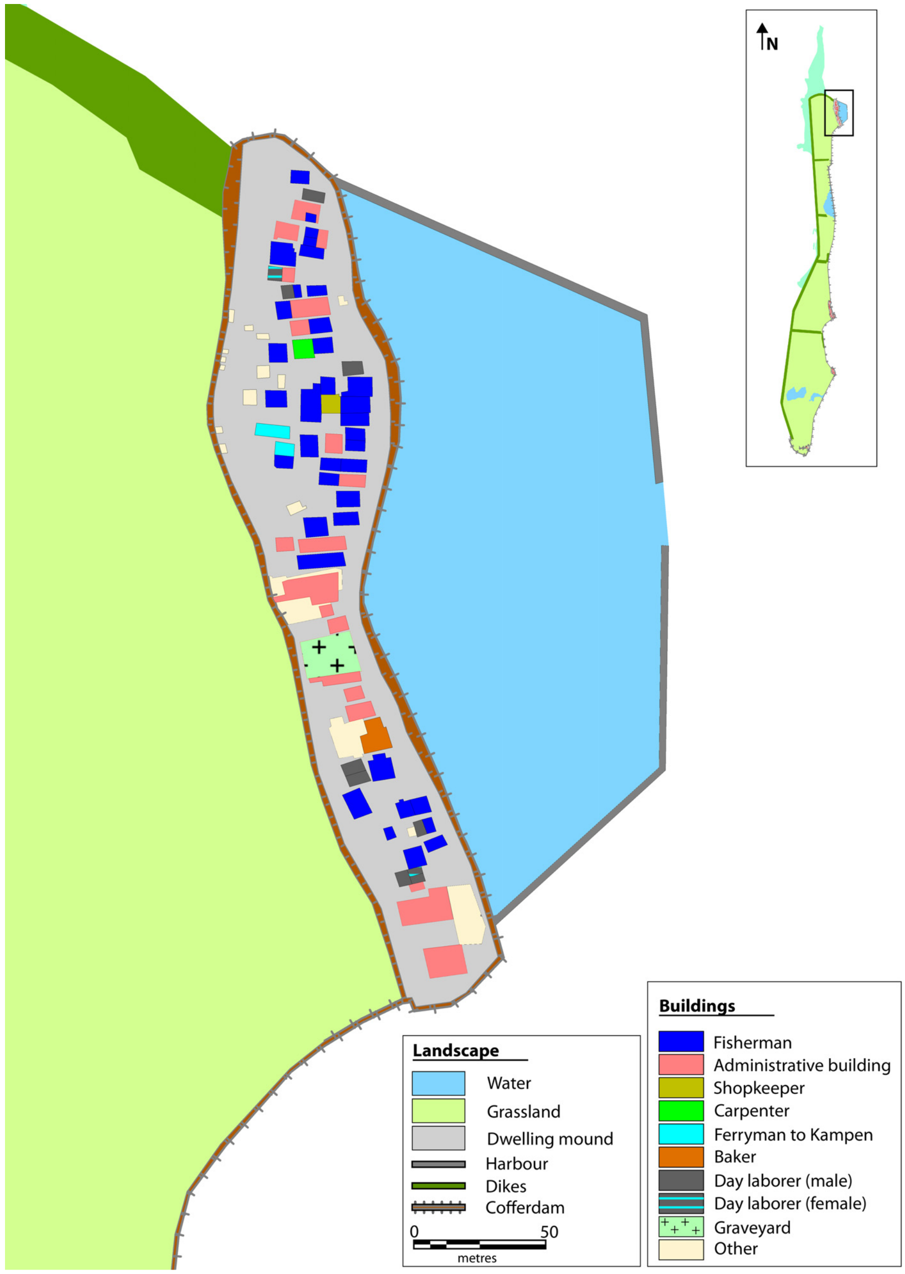


**Fig. 6.** Detailed reconstruction of 19th-century Emmeloord located on the northside of Schokland. Based on cadastral data dominant professions for each individual household were determined and depicted. The majority of the towns' occupance was fishery.

chaeological finds per reconstructed period, and (2) a present-day survey of cultural-historical elements located in the study area. Archaeological data were plotted on the four reconstructions reflecting the inhabited phases of the island: 13th-19th centuries (Fig. 8; A-D). For each of these overviews we only selected archaeological finds relevant for the reconstructed period (Table 4). These surveys give insight in the dispersal of archaeological remains in the study areas and can be used amongst other for predictive-modelling purposes or to create new heritage-management maps.

The HGIS also facilitates other heritage-management applications, such as integrated overviews of cultural-historical elements located in the present-day landscape (Fig. 9). Because the system supports selecting or alternating between cultural and topographical data, it is possible to create dynamic overviews. Consequently, we combined present-day data on spatial planning and heritage for integrated spatial analyses. These combined overviews prove essential for multi-perspective data analyses and integrated-knowledge management. This is underlined by our overview which shows areas of archaeological importance that have been assigned

**Table 4**
Overview of archaeological finds and their corresponding Schokland-reconstruction phase. Archaeological finds were linked to reconstructions based on period classifications derived from the Archaeological Basic Register (see Reference list).

| Schokland phase | Historical period ABR |
|---|---|
| 13th century | Middle Ages |
| 16th century | Early modern history |
| 18th century | Modern history |
| 19th century | Modern history |


**Fig. 7.** Property listing of two brothers (J.A. Alberts Goosen and D.A Goosen) living in the northern part of 19th-century Emmeloord.

values ranging from extremely high to medium, and the exact location of world-heritage protection. Our map clearly points out that not all archaeologically valued areas are part of the world-heritage site. The same applies for part of the historical dike systems, archaeological finds, and dwelling mounds which sometimes are not legally protected at all. In facing future redevelopment issues, awareness of these data is essential for making durable and informed choices. This underlines the application potential of the HGIS for heritage management.

## 6. Discussion and outlook

### *6.1. Schokland results*

Our Schokland-HGIS shows great potential for creating chronological reconstructions of cultural landscapes. However, the reconstructive potential of the system greatly depends on the availability of accurate cultural and geoscientific data. Despite containing data covering the whole of the Holocene, the reconstructive capacity of the HGIS greatly improves in more recent phases thanks to the increased availability of high-resolution data. This became evident in the two earliest reconstructions (13th and 16th century) where resolution was limited to individual dwelling mounds, island contours, and first dike systems (Fig. 4). In spite of the island increasingly becoming smaller, later reconstructions (18th-20th centuries) show a greater amount of detail (Fig. 5). This is especially true for the 19th and 20th century where we were able to locate and analyse individual households and professions (Section 5; Figs. 6 and 7). Including more datasets (e.g. through future fieldwork) will help to enhance the reconstructive potential of the HGIS further, especially for earlier periods.

The results of the current study underline the versatility and broad application potential of the HGIS methodology for managing and analysing historical landscapes. This was further underlined by our professional-occupance and property-rights analyses of 19th-century Emmeloord. These results demonstrate the potential of the HGIS for multi-perspective and multidisciplinary data analyses on multiple scales. Moreover, the HGIS facilitates integrating quantitative and qualitative data and is well suited for conducting amongst other genealogical analyses and incorporating intangible heritage. Within the system new data are easily added and in turn linked to spatial locations (Figs. 6 and 7). By linking genealogical data, images, or anecdotes with family names and parcels (e.g. houses) it is possible to include eyewitness reports or other intangible heritage (e.g. stories, images, or videos). It would be worthwhile for future research to explore the incorporation of intangible heritage in a HGIS further. Linking spatial data with intangible heritage would greatly benefit amongst other participation and public outreach purposes and the formation of shared identities.

The heritage-management potential of the HGIS was underlined by the creation of several heritage-management maps (Figs. 8 and 9). Results show that the HGIS facilitates the creation of flexible or integrated overviews. In this study we have focused on archaeological and cultural-historical data, but the HGIS is not limited to these scientific fields. By alternating between datasets, queries, and surveys the system provides flexible overviews which are essential for modern-day heritage management. This is especially important in dynamic environments, where data are essential for making informed choices regarding the presentation, conservation, or (re)development of cultural heritage remains (cf. Introduction). This became particularly apparent during our spatial analysis of cultural-historical elements (Fig. 9). Here, results showed that some of the elements belonging to older phases of the island (e.g. dwelling mounds and historical dike systems) are located outside the world-heritage protection. Awareness of these elements is essential for the future conservation Schokland's history.

### *6.2. Application potential HGIS*

The HGIS presented in this study was designed in line with a modelling technique developed by Van Lanen & Kosian [48]. Our results show that the HGIS-methodology is not limited to their subject or region alone, and can be transferred to other areas, (smaller) scale levels, and periods. Our analyses of Schokland underline that the HGIS-approach is highly useful to diachronologically analyse cultural landscapes by supporting multidisciplinarity, tailormade solutions, and research flexibility. Contrary to the study by Van Lanen & Kosian [48] who mainly focused on re-

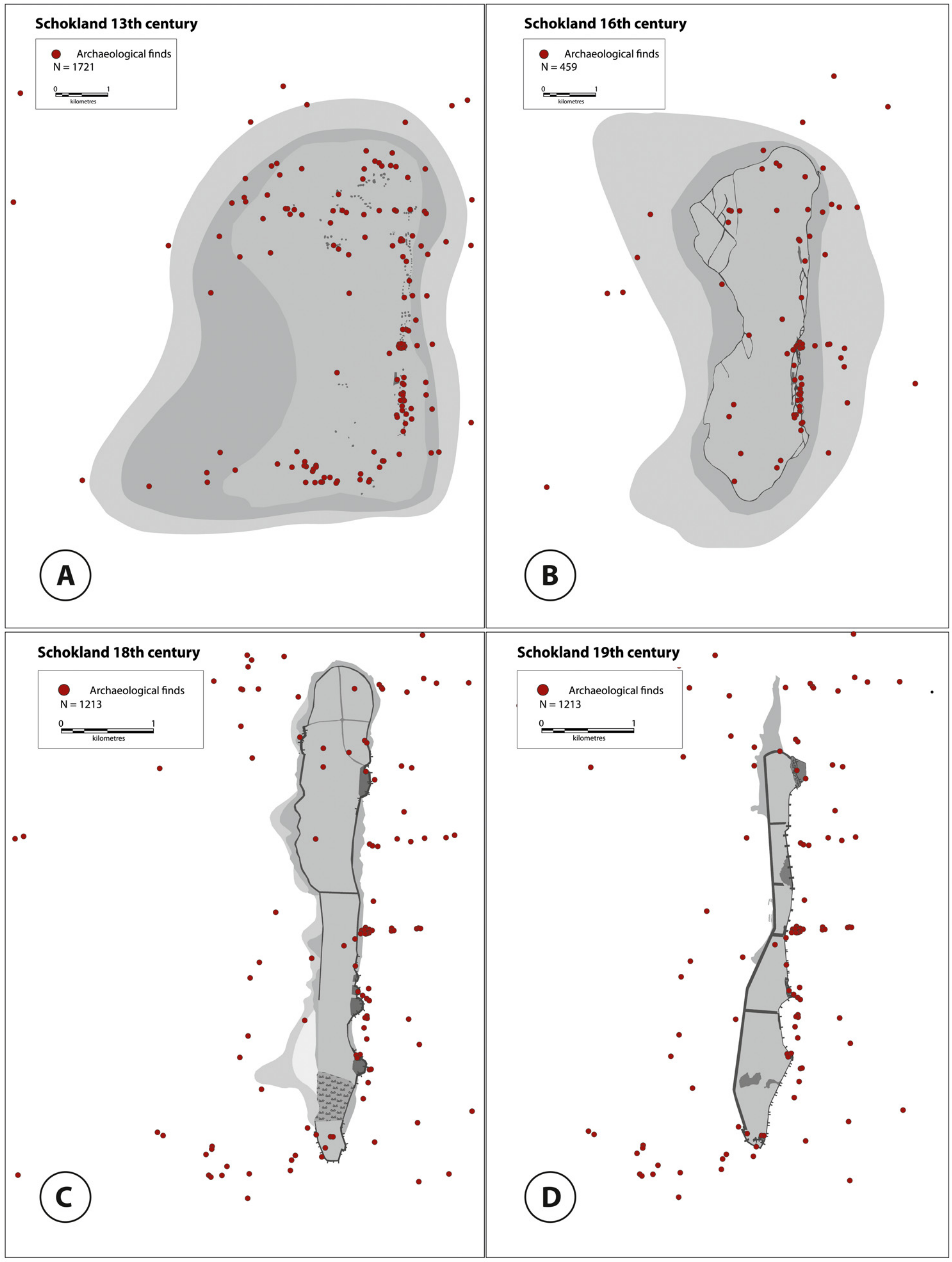


**Fig. 8.** Distribution of archaeological finds per reconstructed period of Schokland (*A* = 13th century, *B* = 16th century, C = 18th century, and *D* = 19th century). Reconstructions were limited to inhabited phases of the island. Archaeological dispersal clearly shows the influence of reclamation activities on find collection.

gression mapping, our analyses fixated on stacking multiple data sources embodying the layeredness of the cultural landscape in order to create high-resolution reconstructive overviews. The differences between both studies underline the versatility and flexibility of the HGIS-methodology which is essential for unravelling the diachronic complexity of cultural landscapes.

A method that has increasingly gained interest for unravelling the diachronic complexity of landscapes is deep mapping (e.g. [8]). The concept of deep mapping involves the accumulation and layering of different kinds of geo-locatable data within GIS. 'Deep maps' provide fundamentally explorative environments consisting out of a near limitless range of sources [[3],[32]]. Recently, the approach has been described as the next essential stap for humanity studies. However, the approach in itself does not present accessible tooling. In line with deep mapping, the HGIS-methodology provides data flexibility, near limitless expansion of datasets, layering, easy querying, and the possibility to create multiple integrated overviews. We argue that the HGIS-approach therefore is well suited to also function as tool for deep-mapping analyses.

Such tooling is highly desirable in the context of rapingly changing environments and increasing computational possibilities and the growing number of available data in Digital Humanities (e.g. [[27],[46],[47]]). These developments require new theories and methodologies in order to adapt to these changing circumstances. The HGIS-methodology represents a way to meet these challenges by: (1) allowing the continuous addition of new data or datasets, (2) thematically grouping of data, (3) spatial querying, and (4) generating tailormade integrated overviews. It is important to note that although we have limited ourselves in current study to only include existing cultural and geoscientific datasets, the system

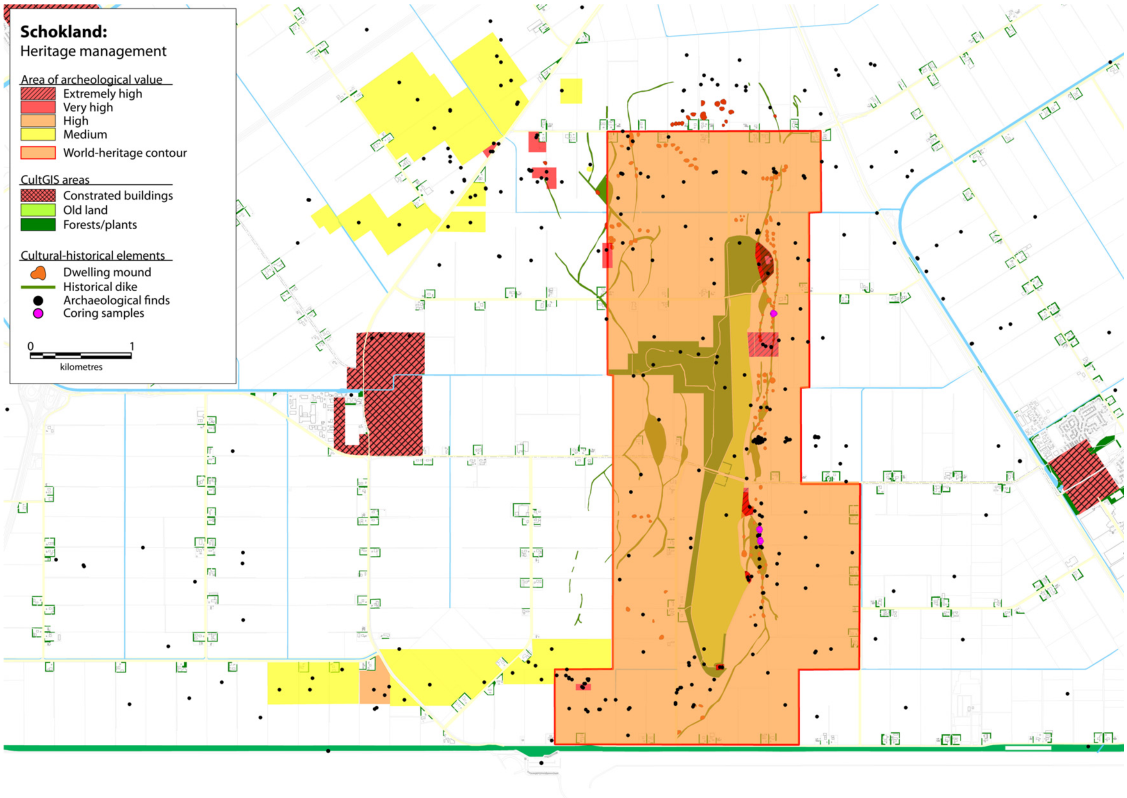


**Fig. 9.** Heritage-management map for het world-heritage site of Schokland. The map depicts areas of archaeological value (ranging from extremely high to medium), world-heritage protected area, CultGIS areas, and cultural-historical elements such as dwelling mounds, dikes, archaeological finds, and coring samples.

could easily be expanded to include other datasets (e.g. monitoring data) or scientific domains (e.g. social sciences).

Flexibility is one of the major advantages of the HGIS-methodology. The multi-layered approach allows creating overviews based on multiple datasets. Through querying it is possible to analyse data covering different time periods and depicting these within one integrated overview. Furthermore, the easy addition of datasets or thematic groups facilitates data management even in highly dynamic environments. The HGIS achieves this by only linking data together based on spatial characteristics. Consequently, there is no need for datasets to be directly linked (through e.g. database relations), integrated, or standardized. These processes often prove to be extremely costly. And although data analyses benefit greatly from such processes, our presented approach provides means to choose between both the timing and selection of these processes. Additionally, data included in the HGIS functions as an overview of available datasets (i.e. integrated knowledge hub) which helps to better design and substantiate (conservation) strategies and scientific analyses. Based on these decisions, efforts then can be directed to link, integrate, or standardize selected datasets. This way the HGIS does not differentiate between stakeholders and analyses from all interested parties (representing multiple perspectives) are facilitated. This makes the HGIS a low-cost, low-energy management tool facilitating tailormade analyses, substantiating strategies, and developing informed choices which can be executed by specific stakeholders interested in targeted analyses.

### 6.3. (World-)Heritage management

World heritage, or heritage in general requires sustainable conservation and accessibility. Since heritage sites are never isolated from their surrounding (dynamic) landscape, heritage management requires the development of tailormade conservation strategies supporting the movement towards 'management of change' ([11, 31]; cf. Introduction Section). Our study of world-heritage Schokland underlines the need for such an integrated and flexible approach. In line with the definition of a typical cultural landscape, the site is the result of a long-term complex interplay between natural and cultural factors (Sections 3 and 5). Despite being classified as a 'cultural' world-heritage site, the history of Schokland can only be understood by preserving both cultural and natural values. One could argue that classifying Schokland as merely 'cultural' insufficiently reflects the complex interplay between cultural and natural processes that originally created the site. And such a focus is too unilateral for sustainable conservation strategies. Heritage conservation requires a different view. We argue that world-heritage sites set in dynamic environments do not benefit from strongly differentiating between cultural and natural settings. Such sites require flexible and integrated management approaches facilitating the development of tailormade conservation strategies incorporating the layering and path dependency of historical landscapes. For built heritage such a framework has increasingly been recognized and implemented through Building Information Modelling (BIM; e.g. [29]). However, such a framework is not yet available for cultural landscapes or heritage sites in dynamic environments. And although recently Schepers et al. [35] presented an interesting conceptual model for the Wadden-Sea region based on a triangular perspective on landscape development, their efforts mainly focus on visualisation and actual quantitative tooling for such an integrated management approach is still lacking. Based on our results we argue that the HGIS-methodology could prove highly useful in this respect.

### 6.4. Outlook

The HGIS presented in this paper was specifically designed for Schokland as a first step towards tooling facilitating dynamic, integrated heritage management and scientific analyses. However, as previously stated the approach is not limited to this merely this site. Through supporting integrated knowledge management based on multiple datasets, the approach can prove useful for other (world-)heritage sites as well. This especially applies to those sites located in dynamic environments or having a strong natural context. With the concept of heritage increasingly moving away from mere conservation towards contextualization and digitization, integrated approaches (such as the HGIS) are becoming progressively important.

Accessibility of heritage is one of the key concepts of world heritage and in redefining the concept of heritage (cf. Introduction Section; [39]). In this context, accessibility is defined in the broadest scene, including digital accessibility. Increased access to the internet, combined with new technological developments and improving computational possibilities, can improve the global accessibility of heritage. We advocate that our HGIS-approach can greatly contribute to raise (digital) accessibility of (world-)heritage sites. For example, our analyses of 19th-century Emmeloord (Figs. 6 and 7) showed that the system was able to reconstruct local history on a household level. These high-resolution data easily could serve app-development providing pinpointed, localised information using techniques such as augmented or virtual reality. Such techniques would allow visitors to experience history at first hand or hear anecdotes while visiting the actual locations in the landscape or sitting at home. Increasing the accessibility of the site for visitors and non-visitors alike.

## 7. Conclusion

In this study we developed a HGIS for the world-heritage site of Schokland. This approach proves versatile and extremely helpful in analysing the diachronic development of heritage sites. The system lets researchers stack multiple datasets and integrate these in well-defined thematic groups. As such the HGIS embodies the layeredness of the landscape and helps to unravel the complex interrelationships responsible for the development of the cultural landscape. By combining cultural and geoscientific data we were able to model five high-resolution chronological reconstructions of Schokland from between the 13th-20th centuries. The system also facilitates detailed small-scale spatial analyses on an individual household level and the creation of various heritage-management maps.

Versatility of the HGIS-methodology is underlined by its application potential for informative-heritage management, public outreach, and digital accessibility. Through multi-disciplinary data integration the system provides an overview of datasets pertaining world-heritage Schokland reflecting a variety of application possibilities. Because data in the HGIS is linked based on spatial characteristics only, a wide variety of data sources can be included without the need for full integration. The makes the HGIS a low-cost management system perfect for creating integrated overviews of datasets pertaining a specific heritage site or cultural landscape. The HGIS is flexible and open-ended, which is essential in dynamic environments. It allows frequent data updates, expansions, and queries and can contain a near limitless number of datasets. Consequently, the system supports multi-perspective data analyses representing the full scope of stakeholders connected to a site.

World-heritage classifications are limited to cultural, natural or mixed sites. Our analyses of Schokland show that such a rigid differentiation between culture and nature in dynamic environments is at least impractical and hampers the development of sustainable conservation strategies. The complex interplay between cultural and natural factors has been essential for the development of world-heritage Schokland. Since these factors remain to continuously influence one and other, insight in to their interactions is crucial for understanding the development of the site and conserving it for the future. Our HGIS shows great potential in unravelling these complex, path-depended interactions and facilitating integrated, dynamic heritage management. We would argue that such management is not only needed for Schokland but for all (world-)heritage sites located in dynamic environments. Sustainable conservation and presentation of these sites requires dynamic, flexible, and integrated approaches (like the HGIS) within heritage management, allowing for multi-disciplinary data integration and multi-perspective data analyses. We need to change our view on (world-)heritage, moving away from rigid classifications and find methods to help embrace the layering and path dependency of the landscape.

## Acknowledgements

The authors declare that there has been no conflict of interests. The presented research was conducted as part of the JPI-CH (Call: Heritage in Changing Environments) funded project 'WETFUTURES' (Wetland Futures in Contested Environments: an inter- and transdisciplinary approach to wetland heritage in the Netherlands, United Kingdom and Ireland) project (www.wetfutures.eu). The authors thank Marcella Marinelli (Site manager Schokland) and Vera Smit (Wageningen University and Research) for their input during various stages of the research and HGIS development. Finally, the authors would like to thank the two anonymous reviewers for their very helpful comments on the manuscript.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.culher.2021.11.011.

## References

[1] Baas, H.G., (2001). Ontgonnen verleden. Inzoomen op De Historisch-Geografische Ontwikkeling Van Het Nederlandse landschap. Landview, Hoorn.
[2] T.J.H.F. Bloemers, H. Kars, A. Van der Valk, M. Wijnen, The Cultural Landscape & Heritage Paradox. Protection and Development of the Dutch Archaeological-Historical Landscape and Its European Dimension. Landscape and Heritage Studies, Amsterdam University Press, Amsterdam, 2010.
[3] D.J. Bodenhamer, J. Corrigan, T.M. Harris, Deep Maps and Spatial Narratives, Indiana University Press, Bloomington, 2015.
[4] J. Buisman, Duizend Jaar weer, Wind En Water in De Lage Landen. Deel 1: Tot 1300, Van Wijnen (Franeker), 1995.
[5] CoEExplanatory Report to the Council of Europe Framework Convention on the Value of Cultural Heritage For Society, Council of Europe Treaty Series No. 199, 2005 URL https://rm.coe.int/16800d3814 .
[6] G. De Boer, Zuidelijk rivierduincomplex Schokland, gemeente Noordoostpolder; een geoarcheologisch booronderzoek in het kader van de bescherming van archeologische waarden in het werelderfgoed Schokland, Rapportage RAAP Archeologisch Adviesbureau (2014).
[7] M. Duckham, M.F. Goodchild, M. Worboys, Foundations of Geographic Information Science, CRC Press, 2004.
[8] T. Earley-Spandoni, Spatial History, deep mapping and digital storytelling: archaeology's future imagined through an engagement with the Digital Humanities, J. Archaeol. Sci. 84 (2017) 95–102, doi:10.1016/j.jas.2017.05.003.
[9] P.S. Ell, I.N. Gregory, Adding a New Dimension to Historical Research with GIS, Hist. Comput. 13 (1) (2001) 1–6.
[10] G. Fairclough, New heritage, an introductory essay – people, landscape and change, in: The Heritage Reader, Routledge, Abingdon, 2008, pp. 297–312.
[11] G. Fairclough, S. Rippon, Europe's landscape: Archeologists and the Management of Change. EAC, Occasional Paper 2, EAC, Brussels, 2002.
[12] G. Fairclough, H. Van Londen, Changing landscapes of archaeology and heritage, in: (2010) The Cultural Landscape & Heritage Paradox, Protection and Development of the Dutch Archaeological-Historical Landscape and its European Dimension, 2010, pp. 653–669.
[13] A.J. Geurts, De 'groene' IJsselmeerpolders. Inrichting van Het Landschap in Wieringermeer, Noordoost-polder, Oostelijk en Zuidelijk Flevoland, Lelystad, 1997.

[14] A.J. Geurts, Schokland: De historie Van Een Weerbarstig Eiland, Stichting Uitgeverij De Twaalfde Provincie, Lelystad, 2002.
[15] M.F. Goodchild, Geographic information systems and science: today and tomorrow, Ann. GIS 15 (1) (2009) 3–9, doi:10.1080/19475680903250715.
[16] M.F. Goodchild, Twenty years of progress: gIScience in 2010, J. Spat. Inform. Sci. (1) (2010) 3–20, doi:10.5311/JOSIS.2010.1.32.
[17] W. Gotjé, Catalogus Van Geologische Kaarten Van De Noordoostpolder, Gotje Environmental Consultancy, 2014.
[18] I.N. Gregory, R.G. Healey, Historical GIS: structuring, Mapping and Analysing Geographies of the Past, Prog. Hum. Geogr. 31 (5) (2007) 638–653.
[19] A. Haartsen, Ontgonnen verleden. Regiobeschrijvingen provincie Flevoland. Directie Kennis, Ministerie van Landbouw, Natuur en Voedselkwaliteit, Rapport DK nr. 2009/dk116-E, 2009.
[20] A. Haartsen, Ontgonnen verleden. Landschappen en deellandschappen. Directie Kennis, Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2010 Rapport DK nr. 2010/dk131.
[21] C. Holtorf, Can you hear me at the back? Archaeology, communication and society, Eur. J. Archaeol. 10 (2–3) (2007) 149–165, doi:10.1177/1461957108095982.
[22] D. Huisman, G. Mauro, Archaeological Heritage Management Reports 2019: Schokland UNESCO World Heritage site: 3rd Monitoring Round, Cultural Heritage Agency of the Netherlands, Amersfoort, 2013.
[23] Ickerodt, U., (2010). My Story – your Story: three levels for reflecting and debating the relationship between contemporary archaeological heritage management and the public. A comment from Germany. In: Bloemers, T.J.H.F., Kars, H., Van der Valk, A., Wijnen, M., (2010) The Cultural Landscape & Heritage Paradox. Protection and Development of the Dutch Archaeological-Historical Landscape and its European Dimension, pp. 351–362.
[24] ICOMOS, Schokland and Surroundings. Advisory Body Evaluation (ICOMOS)World heritage list, No. 739, 1995 URL https://whc.unesco.org/en/list/739/documents/ .
[25] J. Janssen, E. Luiten, J. Renes, E. Stegmeijer, Heritage as sector, factor and vector: conceptualizing the shifting relationship between heritage management and spatial planning, Europ. Plan. Stud. 25 (9) (2017) 1654–1672, doi:10.1080/09654313.2017.1329410.
[26] Knowles, A.K., (2005). Emerging Trends in Historical GIS, In Special Issue: Emerging Trends in Historical GIS. Historical Geography 33, pp. 7–13.
[27] K. Kristiansen, Towards a new Paradigm? The Third Science Revolution and its Possible Consequences in Archaeology, Curr. Swed. Archaeol. 22 (2014) 11–34.
[28] Molenaar, S., (2000). Hydrologische Bufferzone Schokland, gemeente Noordoostpolder; archeologisch onderzoek modulen A en D. RAAP-Rapport 625, Amsterdam.
[29] D.P. Pocobelli, J. Boehm, P. Bryan, J. Still, J. Grau-Bové, BIM for heritage science: a review, Herit. Sci. 6 (2018) article no. 30, doi:10.1186/s40494-018-0191-4.
[30] Reinders, H.R., (1980). Het archeologisch onderzoek. In: Van Duin, R.H.A. (ed.). 50 Jaar Onderzoek Door De Rijksdienst Voor De IJsselmeerpolders, Flevobericht 163, Lelystad.
[31] J. Renes, Levende cultuurlandschappen als werelderfgoed, Tijdschrift voor Historische Geografie 4 (3) (2019) 168–184.
[32] M. Ridge, D. Lafreniere, S. Nesbit, Creating Deep Maps and Spatial Narratives through Design, Interna. J. Humanit. Arts Comput. 7 (1–2) (2013) 176–189.
[33] Rijksinstituut voor NatuurbeheerNatuur En Landschap Van Schokland; Bouwstenen Voor Een Geïntegreerde Beheersvisie, Rijksinstituut voor Natuurbeheer, Leersum, 1989.
[34] I.M. Roorda, R. Wiemer, The ARCHIS Project: towards a New National Archaeological Record in the Netherlands, in: C. Larsen (Ed.), Sites and Monuments: National Archaeological Records, The National Museum of Denmark, Copenhagen, 1992, pp. 117–122.
[35] Schepers, M., Meijles, E.W., Bakker, J.P., Spek, T., (2021). A Diachronic Triangular Perspective on Landscapes: a Conceptual Tool for Research and Management Applied to Wadden Sea Salt Marshes. Maritime Studies (2021). https://doi.org/10.1007/s40152-021-00215-4
[36] T.J. Ten Anscher, Leven Met De Vecht: Schokland-P14 En De Noordoostpolder in Het Neolithicum En De Bronstijd, University of Amsterdam, Amsterdam, 2012 PhD thesis.
[37] T.J. Ten Anscher, Bureaustudie ten behoeve van de instandhouding van de archeologische waarden in het werelderfgoedgebied Schokland, kavels E170/E171, gemeente Noordoostpolder, Rapport. RAAP Archeolog. Adviesb. (2013).
[38] T. Ten Anscher, G. De Boer, Y. Van Popta, S. Van der Veen, Erfgoed in de polder! Actualisatie van de archeologische waarden- en verwachtingskaart van de gemeente Noordoostpolder, Rapport. RAAP Archeolog. Adviesb. (2018).
[39] UNESCO, (2019). Operational Guidelines for the Implementation of the World Heritage Convention. Paris. URL: http://whc.unesco.org/en/guidelines/
[40] D.F.A.M. Van den Biggelaar, New land, Old history: Past Landscapes and Hominin Activity Covering the Last 220,000 Years in Flevoland, The Netherlands, 17, Vrije Universiteit Amsterdam, Geoarchaeological and Bioarchaeological Studies, Amsterdam, 2017 PhD thesis.
[41] D.F.A.M. Van den Biggelaar, S. Kluiving, R. Van Balen, C. Kasse, S. Troelstra, M. Prins, Storms in a lagoon: flooding history during the last 1200 years derived from geological and historical archives of Schokland (Noordoostpolder, the Netherlands), Netherlands Journal of Geosciences (93) (2014) 175–196.
[42] D.F.A.M. Van den Biggelaar, S. Kluiving, A niche construction approach on the central Netherlands covering the last 220,000 years, Water Hist. 7 (4) (2015) 533–555.
[43] D.F.A.M. Van den Biggelaar, J. Wallinga, R. Van Balen, C. Kasse, S. Troelstra, S. Kluiving, High-resolution optical dating of Late Holocene storm surge deposits – a showcase from Schokland (Noordoostpolder, the Netherlands), Earth Surface Proces. Landfor. (44) (2019) 886–899.
[44] R.M. Van Heeringen, G.V. Mauro, A. Smit, A Pilot Study On the Monitoring of the Physical Quality of Three Archaeological Sites at the UNESCO World Heritage Site at Schokland, Province of Flevoland, Amersfoort, The Netherlands, 2004.
[45] G. Van Hezel, A. Pol, Schokland En omgeving. Leven met Water, Utrecht, Matrijs, 2008.
[46] R.J. Van Lanen, Changing ways: Patterns of connectivity, Habitation and Persistence in Northwest European Lowlands During the First Millennium AD, Utrecht Studies in Earth Sciences (USES), 137, Utrecht University, 2017.
[47] R.J. Van Lanen, Revealing the past through modelling? Reflections on connectivity, habitation and persistence in the Dutch Delta during the 1st millennium AD, Netherlands J. Geosci. 99 (2020) e14, doi:10.1017/njg.2020.12.
[48] R.J. Van Lanen, M.C. Kosian, What wetlands can teach us: reconstructing historical water-management systems and their present-day importance through GIScience, Water Hist. 12 (2020) 151–177, doi:10.1007/s12685-020-00251-7.
[49] Van Lier, L. (2015). Schokland beheerplan 2015-2020. Lelystad: het Flevolandschap.
[50] Van Oorsouw, M.F., (1998). Schokland En omgeving. UNESCO Werelderfgoedlijst. Jaarverslag van De Rijksdienst voor Het Oudheidkundig Bodemonderzoek 1995/1996, Amersfoort.
[51] Y. Van Popta, Flevoland ondersteboven: een interdisciplinair onderzoek naar de bodemprofielen van scheepswrakken in de provincie Flevoland, Paleo-aktueel 24 (2013) 91–97.
[52] Y. Van Popta, When the Shore becomes the Sea: New maritime Archaeological Insights On the Dynamic Development of the Northeastern Zuyder Zee Region (AD 1100 –1400), the Netherlands, University of Groningen, Groningen, 2020 PhD thesis, doi:10.33612/diss.135931299.
[53] Van Popta, Y., Aalbersberg, G., (2016). Onbekend, maar niet onbemind: terpen en terponderzoek in de Noordoostpolder. In: Nieuwhof, A., (ed.) Van Wierhuizen tot Achlum. Honderd Jaar Archeologisch Onderzoek in Terpen En wierden. Vereniging voor Terponderzoek, Groningen, pp. 129–140.
[54] M. Vecco, A definition of cultural heritage: from the tangible to the intangible, J. Cult. Herit. 11 (3) (2010) 321–324, doi:10.1016/j.culher.2010.01.006.
[55] Velthuizen, D., Heise-Roovers, H., (2014). Bodemkundig onderzoek op kavel J112. Gemeente Noordoostpolder.
[56] A. Von Lünen, C. Travis, History and GIS. Epistemologies, Considerations and Reflections, Springer, 2012.
[57] P.C. Vos, Origin of the Dutch coastal landscape. Long-term landscape Evolution of the Netherlands during the Holocene, Described and Visualized in national, Regional and Local Palaeogeographical Map Series, Utrecht University, Barkhuis, Utrecht, 2015 PhD thesis.
[58] Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T., Bazelmans, J., (2018). Atlas van Nederland in het Holoceen. Landschap En Bewoning Vanaf De Laatste Ijstijd Tot nu, Amsterdam.
[59] C. Westrik, UNESCO culturele landschappen en management uitdagingen, Tijdschrift voor Historische Geog. 4 (3) (2019) 139–148.
[60] R. Wiemer, Standardisation: the key to archaeological data quality, in: Mapping the Future of the Past, Managing the Spatial Dimension of the European Archaeological resource, Sevilla, 2002, pp. 103–108.
[61] Wiggers, A., (1955). De wording van het Noordoostpoldergebied: een onderzoek naar de physisch-geografische ontwikkeling van een sedimentair gebied. Zwolle, Ministerie van Verkeer en waterstaat, Directie van de Wieringermeer (Noordoostpolderwerken).
[62] Bonnebladen, (1933): Chromo-topographical map for the kingdom of the Netherlands, Blad 269, scale 1:25.000. Topografische inrichting. 1933.
[63] Schokland, (1600): Kaart van Schokland. Anonymous, no title, Stadsarchief en Athenaeumbibliotheek (SAB) Deventer, ca. 1600.
[64] Schokland, in: Kaart Van Het Eiland Schokland. Anonymous, No Title, University of Amsterdam, ca, 1762, p. 1762.
[65] sGroten, C., (1588): Christiaan sGroten. *Tabula XII Continens Phrisios qui* versus *Meridiem in Palustribus sedent iuxta Sicambros et Batavos.* In: orbis Terrestris Tam Geographica Quam Chorographica Descriptio. 1588.
[66] TMK, in: Topographische En Militaire Kaart Van Het Koningrijk der Nederlanden op Een Schaal Van 1:50.000, Dienst Militaire Verkenningen, 1850, p. 1850.
[67] Van Deventer, J., (1558): Jacob van Deventer, *Hollandt*, 1558.

## Referenced maps:

Basic registration for addresses and buildings: Basisregistratie Adressen en Gebouwen (BAG). Kaartlaag Pand. Kadaster, 2014.
Basic registration topography, (1995): TOP10NL. Basisregistratie Topografie (BRT). Kaartlaag Terrein_vlak. Kadaster, 2010.
Collection plans of the Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster), (1832): Kaart van de Gemeente van Schokland gelegen inde Provincie Overijssel volgens de perceelsgewijze Plans voor het Kadaster van die Gemeente. Opgemaakt in den Jare 1822.
Geomorphological map of the Netherlands, (2017): Geomorfologische kaart van Nederland, scale: 1:50.000. Wageningen University and Research. 2017.
Historical elevation model (TOPhoogteMD), (1992): Digitaal hoogtebestand aan de hand van de Nauwkeurigheidswaterpassingen (NWP) uit de periode 1942-1983. Rijkswaterstaat, 1992.

Minute plans of the Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster), (1832): Cadastre map 1811-1832: minuutplan Schokland, Overijssel, section A, sheet 01, section B, sheet 01, and section C, sheet 01. 1822.
National LIDAR survey data of the Netherlands (Actueel Hoogtebestand Nederland; AHN), version 1, 2004.
National LIDAR survey data of the Netherlands (Actueel Hoogtebestand Nederland; AHN), version 2, 2012.
National LIDAR survey data of the Netherlands (Actueel Hoogtebestand Nederland; AHN), version 3, 2019.
Palaeogeographic reconstructions, (2018): extracted from: vos, P.C., (2018). Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T., Bazelmans, J., (red.), Atlas van Nederland in het Holoceen. Landschap en bewoning vanaf de laatste ijstijd tot nu. Amsterdam.
Soil map of the Netherlands, (2018): Bodemkaart van Nederland. Bodemkaart (SGM), beschrijving van de bodem van Nederland tot een diepte van 1,20 m, scale: 1:50.000. Ministerie van LNV /Wageningen Environmental Research. 2018.
Top Pleistocene soil, (2018): extracted from: vos, P.C., (2018). Vos, P.C., Van der Meulen, M.J., Weerts, H.J.T., Bazelmans, J., (red.), Atlas van Nederland in het Holoceen. Landschap en bewoning vanaf de laatste ijstijd tot nu. Amsterdam.
Water-system management information of the Dutch waterboards, 2021 URL: https://www.hetwaterschapshuis.nl/, Service: http://maps.waterschapservices.nl/wsh/wms?.
World-heritage contour UNESCO site Schokland, (1995): ref: schokland and Surroundings. Advisory Body Evaluation (ICOMOS), World heritage list, No. 739.