A landscape biography of the 'Land of Drumlins': Vooremaa, East Estonia

Veldi, M.

Author: Veldi, M.
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5 Methods and sources: A Historic GIS for Vooremaa

5.1 Introduction: GIS in archaeology

Over the past two decades GIS has become a widely applied tool, both in historical (e.g. Gregory 2005; Gregory & Ell 2007; Gregory & Healey 2007; Knowles 2002; Knowles & Hillier 2008), and archaeological landscape research (e.g. Conolly & Lake 2006; van Leusen & Kamermans 2005; Kamermans et al. 2009; Löwenborg 2010; McEwan 2012; Mehrer & Wescott 2006; Verhagen 2007; Verhagen & Whitley 2012).

Geographical Information Systems (GIS) essentially go back to the early 1960s, when the Scottish landscape architect Ian McHarg introduced the method of "overlay" in North American landscape research and design. The method later became the main methodological concept of GIS. McHarg was exploring possibilities to find the most optimal route for a new motorway with least disturbance on existing landscape and housing. He applied layers of translucent tracing paper representing different landscape features and placed them on top of each other on a light table. The overlaying sheets revealed him the most logical route with minimal impact on the surrounding environment (Gregory et al. 2009, 280). In 1969 McHarg published an influential book titled *Design with Nature* (McHarg 1969), which in addition to introducing ideas of ecological planning stated the basics of Overlay Method for Site Analysis, which later developed into Geographical Information System.

Gradually the methodological approach introduced by McHarg gained popularity, and with technological innovations the paper and light table were exchanged for computers and specialised software. Still, it was not until the mid-1990s when GIS saw its wide application across a variety of disciplines (including archaeology), which was notably due to the shift in the usage of software, e.g. the replacement of command-line software with much more convenient graphical user interfaces. At the same time databases became more sophisticated, enabling combinations of quantitative and qualitative media and data (Gregory et al. 2011, 26).

Whereas in the first half of the 1990s GIS was considered as a "processual" tool in archaeology, it started gaining admiration in the second half of the decade among postprocessual phenomenologists exploiting GIS for cost-distance and viewshed. Even theories of agency (Robb & van Hove 2003) and the concept of taskscape (Ingold 1993; Ingold 2000) have been backed up with GIS methodology (Verhagen & Whitley 2012, 61 –

62; with references cited). Employing GIS in phenomenological research practices is still considered an interesting issue for discussion (see e.g. Gillings 2012).

The previous decade has witnessed an extremely fast development of GIS in landscape archaeology, and from being an instrument in the archaeologist's "toolbox" it has become a research field on its own with specialised journals (e.g. *Journal of GIS in Archaeology*) and conferences. GIS has also found its solid place in heritage management strategies and cultural mapping (e.g. UNESCO GIS; GIS applications of various national heritage agencies).

In general, the most common applications of GIS can be summed in two types of studies:

1. *Spatial studies using GIS as a method for analysing and mapping archaeological or historical data*. Usually these studies are not very complex, and mostly apply GIS for different mapping purposes like artefact plotting or settlement and site topography. Also, low-level analyses (e.g. viewshed, least cost, settlement patterns, DEM) are applied. Today, practising landscape archaeology without GIS is unimaginable.
2. *Studies on GIS for predictive modelling of past environments.* The main difference is that in these studies GIS itself is the subject of theory and practise. Verhagen and Whitley (2012, 67) have pointed out that predictive modelling lacks sufficient middle range theory, and therefore needs further elaboration to model actual past environments. Efficient models consist of a myriad of variables with complicated algorithms behind them and are foremost spatial statistical problems. The choice of right variables is a theoretical problem by itself.

The methodological scope for the current thesis can be characterised as historical GIS, fitting into the framework of the first type of studies. Historical GIS combines various historical spatial data (mostly archival maps and location-specified folklore records), which can be efficiently compared against archaeological data and contemporary landscape situation. Some aspects of the use of historical GIS are discussed in more detail in the following paragraphs. First, some basic concepts are defined.

5.2 Basic concepts

Attribute data **–** qualitative (text) or quantitative data (numbers, figures), which is recorded in a database or spreadsheet table and generally applied to characterise spatial features (presented in raster or vector form) on the map.

Cadastral maps **–** small-scale maps of land units, usually defined by ownership.

Geocoding **–** by geocoding location is assigned to information; paper maps are digitized and converted into computer readable form (Gregory et al. 2009, 275); *geocoding*, *georeferencing* and *positioning* can be used as overlapping terms.

Geographic Information System (GIS) **–** unified platform with specialised hardware, software and practises for spatial analyses and mapping. GIS software enables to combine spatial information with attribute data into easily manipulated layers, which can be analysed, integrated, separated, and displayed according to chosen variables.

Georeferencing **–** allocating spatial references (x/y coordinates or longitude-latitude) to a scanned map or image, which in this way are positioned on the surface of the Earth.

Raster data **–** data presented in the form of pixels (images, also scanned maps). Every pixel is provided with a spatial reference, which can be related to their attribute data. For example, raster surfaces are most convenient for presenting elevation data (in this case attribute data is z).

Spatial data – any kind of data, which has spatial reference, and therefore can be mapped. Spatial data can be both, in raster or vector form.

Vector data **–** data presented in the form of lines, polygons or points, which have spatial reference. Raster images can be vectorised into different layers of features, which combined with attribute data can be analysed separately. Linking vectorised features with attribute data converts rigid scanned historical maps into flexible databases, which can be easily altered and complemented.

5.3 What is a Historical GIS?

The underlying aim of historical GIS is to combine the disciplines of history and geography. In 1994 Michael Goerke edited a set of conference papers published under a title *Coordinates for Historical Maps* (Goerke 1994), which is considered the first milestone in the field. Another early advocate of historical GIS, Anne Kelly Knowles, has pointed out: *Geography is the study of spatial differentiation, history the study of temporal differentiation. Historical GIS provides the tools to combine them to study patterns of change over space and time* (Knowles 2002, xii). Another important aspect of geography is that it is not about space on its own, but about interrelations between people – and between people and places – in space and time (“time geography”), which creates spatiotemporal trajectories in the landscape (Kemp 2009, 16). Thus, historical GIS enables to study these human patterns in the context of place and time. This notion also correlates with the concept of landscape biography discussed earlier.

Historical GIS, which has its roots in history and historical geography, has developed significantly since the end of the 1990s, and has by now become a popular tool in both history and geography (Gregory & Healey 2007, 638). Over the years also special issues of journals dedicated to historical GIS have been published, such as *Social Science History* (vol. 35, 2011, edited by D.A. DeBats & I. N. Gregory), *Historical Geography* (vol. 33, 2005, edited by A. K. Knowles) and *History and Computing* (vol. 13, 2001, edited by P.S. Ell & I.N. Gregory). One of the most recent publications in the field is the collection of research articles *History and GIS: Epistemologies, Considerations and Reflections* (2013) edited by Alexander von Lünen and Charles Travis (Lünen et al. 2013).

Even though GIS is often treated merely as a mapping application, its true potential lies in being an effective spatial database. The data stored in a GIS database uniquely combines geographical location with a variety of forms like points, lines, polygons (areas or zones) or raster pixels, which can be presented in any chosen combination of variables (DeBats et al. 2011, 455).

GIS also enables to analyse data based on its geographical location, providing a unified platform for linking together various pieces of information from different sources. Geographical location is the connecting factor associating otherwise seemingly accidental incidents. Historical GIS is able to layer these features, and highlight the relationships within spatial categories (Gordon 2011, 4). Karen Kemp has addressed historical GIS as *means of using the canvas of the landscape to graphically illustrate relationships and changing patterns and places* (Kemp 2009, 16).

In their study on structure and abilities of historical GIS, Gregory and Healy identify three principal topics that are concerned with research applying historical GIS (Gregory & Healey 2007):

1. *Creation and dissemination of databases*. Creating a database is the most costly and time-consuming phase in building a historical GIS. In order to use archival data electronically, it needs to be digitised and georeferenced, which is time-consuming.

Another aspect is the dissemination of the database, which requires an internet-based application or another electronic medium.

2. *Performing quantitative and qualitative analyses*. Depending on the database structure, historical GIS enables to ask very different location-specific questions, both on a macro and micro scale. It also enables to incorporate and combine different layers of databases creating a synthesis and providing researchers with results, which would be difficult to reach with other methods. While the dimensions of time and space are applied simultaneously, historical GIS is a good method for detecting changes through time in a specific place.
3. *Conceptual issues of historical GIS.* Very much like predictive modelling, historical GIS largely lacks sufficient theoretical discussion, and it still needs to prove its position as an empirical enquiry, rather than a mere mapping tool.

There has also been some constructive criticism on the subject, for example Onno Boonstra has stated (Boonstra 2009, 6):

Without georeferenced historical maps and without location-stamped data, historical GIS will remain an exercise which takes too much time and too much effort to compete with 'traditional' historical research. Only when a relevant number of maps have been digitised, vectorised and georeferenced, and only when location-stamped data have become abundantly available, historical GIS has a chance of taking off.

Besides obvious advantages a number of setbacks related to historical GIS have also been pointed out (DeBats et al. 2011, 456). In addition to the time of building a database mentioned earlier, technical skills to use GIS software demand extra effort and more time. Still, the main fundamental problem is to find a good link between available data and the research questions.

5.4 Why use Historical GIS for archaeological research?

Landscape archaeology and heritage management both deal with sites and issues in specific geographical locations that develop through time. The spatial data of these disciplines is based on real-world coordinate systems, such as Estonian National Grid (1997, Lambert Conformal Conic) for current research. Any georeferenced dataset can be integrated with any other projected dataset. This means that, for example, data on historic land-use derived from historical maps can be integrated with archaeological data. Of course, the existence of historical spatial data is the main prerequisite for building up a historical GIS. Fortunately, Estonia has highly detailed cartographic sources, starting from the second half of the 17th century.

Thus, for Estonia it is possible to track down historic land-use retrospectively and until the mid-17th century. This provides us with a coherent and detailed sequence of about 350 years of land-use, pointing out which parts of the land were used for agriculture, pastures and meadows, and which were covered by forests, swamps and bogs. Much of the wetland in Estonia was not drained until the beginning of the 20th century, so historical maps are a good source for detecting suitable arable land cultivated before the mechanisation of agriculture. When integrating archaeological sites with different layers of land-use from different centuries, we can make inferences about the position of the site in the historic landscape, and also look for continuities and discontinuities in settlement patterns. In search for local power centres (prehistoric hillforts, medieval stone castles), the study of old maps can give clues of the size of the agricultural area or territory supporting the centre. It also enables to position the sites on centre/periphery axes. This in turns helps to understand why some of the sites became important places of local identity, evoking local narratives, whith others left unknown. Historical land-use data combined with contemporary soil maps and adequate digital elevation models also provides a good platform for elementary predictive modelling, which could be effectively used in preventive heritage management.

Finally, it needs to be stressed that historical GIS as a research method is very much data and location driven. It can be applied only in cases with enough relevant historical sources and spatial data. Similar to other historical sources maps need to be critically assessed, and it should always be kept in mind that their initial purpose was loaded with political, economic and military ambitions and considerations.

5.5 Swedish cadastral maps as a source of historic land use

In the 17th century Swedish kingdom was at the peak of its power. The period is also known in historiography as *stormakstiden* – the age of greatness (1611 – 1718). At that time the territory of today's Estonia was incorporated in the Swedish empire (Küng et al. 2013).

The northern part of Estonia was subjected to Swedish power already during the Livonian War (1558 – 1583)[13], while the southern part of the country was ruled by the Polish-Lithuanian *Rzeczpospolita* till 1629. The Swedish rule in mainland Estonia lasted till 1710/1721, when it was overpowered by the Russians (Kala et al. 2012; Küng et al. 2013).

In 1628 the Swedish king Gustav II Adolf gave an order to the state's general mathematician Anders Bure (Andreas Bureus) to establish an organisation for surveying and mapping the entire Swedish kingdom. One of the aims of this undertaking was to provide the king with a complete overview of the empire's potential for economic development (Baigent 1990, 62). In the instruction document presented to Bure the king reasoned: *whereby His Majesty will then all the better be able to survey and consider by What Means and Where there is needed for repairs and improvements* (the preamble to the Instruction of the 4th of April, 1628 to Andreas Bureus: Rystedt 2006, 156).

Various geometric surveys of cropland for taxation purposes and defining property boundaries already had been carried out before the 1628 Instruction, but no maps were made. The surveyors known as *revkarlar* just measured the land with simple ropes and rods, writing down descriptions of land use in special forms (Kain et al. 1992, 50).

Bure was also proposed the task of training the surveyors, who besides technical cartographic skills needed to have a proper knowledge of agricultural land management. After surveying and describing the lands and land use of each village, they were expected to suggest how the land could be improved and exploited more efficiently. They were also to estimate the timber value of forests and point out suitable areas for deforestation and further cultivation into arable land (Baigent 1990, 63). Special landscape features, such as rivers, lakes, streams, bogs and marshes with their toponyms had to be recorded as well. The maps present valuable information on the location and nature of roads (summer/winter), bridges and bog-land causeways (Mead 2007, 1803). In addition, it was instructed to point out which lands, forests and fishing-grounds belonged to which villages, marking down clear boundaries between manors, villages, and farms.

[13] Livonian war is a general term applied by historians referring to several different conflicts between Livonian/Estonian based military orders and bishoprics of German origin, Russia, Sweden, Poland and Denmark. As a result, power relations changed so profoundly, that this period of wars marks transition from the Middle Ages to the Early Modern Era.

Based on the data gathered during the survey works two kinds of maps were compiled: 1) small-scale topographical maps, which were known as *geographical maps* (Figure 12), and 2) large-scale cadastral maps of villages and farms, also known as *geometrical maps* (Baigent 1990, 62). In essence, the large-scale cadastral maps, normally in the scale of ca. 1: 10 400

Figure 12. Geographical map of Kudina manor with descriptions of land use on the right, 1684. EAA 308.2.80.

formed the basis for the topographical maps at a scale of ca. 1: 48 000 (Figure 13).

The uniformity of the maps was astonishing for its time. The colour scheme applied was the first of its kind in Northern Europe and was required to be precisely the same for all the maps. Finished maps had to be in the same size and format (Mead 2007, 1802).

The survey works in Estonia were mainly carried out in 1680 – 1690 under supervision of the survey inspector Arnold Emmerling, though the mapping continued sporadically till 1710 (Must 2000; Koppel 2005, 14).

Figure 13. Topographical map of northern Tartu County, southern part of Vooremaa, 1684. EAA 308.2.69.

Kalev Koppel in his MA thesis on historic land use of the Kasaritsa manor in South Estonia (Koppel 2005) has pointed out that the representation of the landscape on these historic maps can never be taken for granted without critical assessment. The world around us is in constant change, and in the similar way the conceptual models created for describing and interpreting the world change along with it. In this sense, we can never fully comprehend past landscapes, but only search for different methods to support our hypotheses (Koppel 2005, 13).

It must be kept in mind that the map itself is first and foremost an interpretation of part of the Earth's surface and not a fact on its own. However, for studying landscapes of the past on larger scale they can nonetheless provide us with information with a spatial resolution that is incomparable to other historical sources. It has been claimed that no other country in the world possesses such a collection of highly detailed large-scale maps from the 17th – 18th century (Kain et al. 1992, 49).

There has been some debate over the reasons why the cadastral mapping campaign was initiated. In general there are three main explanations: 1) to estimate the value of land for taxation 2) to map the economic capacity of the state, and 3) for military purposes (Baigent 1990, 64).

In the wider European context cadastral mapping was not anything new or innovative, but what makes the Swedish cartographic enterprise a unique achievement is its quantity and comprehensiveness, but also the early stage of systematic cartographic surveying (Baigent

1990, 68). Not only the core areas of the kingdom were mapped, but also the most distant and remotest parts, including Estonia, which at that time belonged tot the periphery of the periphery.

The campaign for cadastral mapping in Sweden was initiated by the king, and besides the economic assessment of the land, most definitely conveyed political and military intentions. This proved to be especially important for the empire's border countries like Estonia with Russia or Western Pomerania with Germany. In case of warfare these maps would provide the army with detailed knowledge of the local landscape and its settlement pattern.

5.6 Cartographic sources

In order to study the historic land use of Vooremaa, I have analysed maps from four different periods:

1. Early Modern regional maps compiled in 1680s by the Swedish land surveyors, in a of ca. 1: 48 000 scale. In principle, these maps reflect the land use pattern in the middle of the 17th century. From these maps we can learn that at that time, most of the land suitable for crop cultivation was in effective use. At the same time no large-scale drainage projects had been carried out yet, thus the landscape itself had not gone through extensive transformations. This makes the 17th century maps a good starting point for studying long-term landscape change. The maps provide us with an excellent reference for detecting later changes. The 17th century maps are most valuable for making reconstructions of and inferences about the studying the peasant landscape (and its manors) that originated during the second half of the 13th century.

   The 17th century regional maps applied included:

   - The district map of Northern Tartu County (EAA.308.2.69 1684)
   - The district map of Southern Tartu County (EAA.308.2.68 1684)

2. The Livonian *Special map* completed in 1839 by C. G. Rücker is the first map of Estonia that is based on triangulation (EAA.1393.1.81). The map's scale is 1: 185 000 and therefore it is not in such detail as the 17th century topographical maps. Still, the detail is sufficient enough to identify land use in a larger area. The map was created on the basis of land use maps of manor estates, which were compiled to inforce the 1804

peasant laws (Varep 1957, 6). Interestingly, the Livonian *Special map* by Rücker contains a large number of toponyms, which are valuable for micro-regional studies.

3. The topographic map (1935 – 1939) of the Estonian Republic 1: 50 000, is the map that most reliably represents the land use conditions between the two world wars. The map conveys the effects of the land reform initiated in 1919 and gives a good overview of how the Early Modern manor/peasant landscape was turned into a landscape of private farms (Estonian Land Board Public WMS).
4. The Estonian Basic map 1: 10 000 (digital version; 2010-2018) is currently the most accurate map the informs about contemporary land use (Eesti põhikaardi vektorkaart). Comparison with the topographic map of 1935 – 1939 enables us to detect and map the large-scale changes that took place during the Soviet collective farming.

In addition to the above-mentioned historical maps, also soil maps (Eesti mullakaart) and LIDAR elevation data provided by the Estonian Land Board were incorporated in the analyses. Both, vectorised soil maps (polygons) and elevation data (points), were converted into raster layers to obtain cell values for specific archaeological sites.

5.7 Digital mapping

The digital analysis of historical maps with GIS software (e.g. MapInfo, ArcGIS) requires that the physical maps stored in the archives be scanned or photographed into raster images, georeferenced with the Earth's coordinates (e.g. with Estonian map in scale 1: 20 000) and supplied with relevant vector data. Thanks to innovations during the last 10 years, the Historical Archives of Estonia has scanned, and also photographed a large number of

historical documents including hand drawn maps, which enabled researchers to access them over the Internet (http://www.ra.ee/kaardid/).

The georeferencing (Figure 14) of hand drawn historical maps poses several obstacles, which have been addressed by many authors (e.g. Boonstra 2009; Koppel 2005; Koppa 2006; Schuppert & Dix 2009; Veldi 2009). Schuppert & Dix (2009, 423 – 424) stress that only maps which were made with modern surveying methods can be georeferenced, and that maps from before the late 18th-early 19th centuries are simply too inaccurate for geocoding. Of course, older maps are less accurate, but the efficiency of georeferencing very much depends on the scale and detail of the map.

Because the historical maps of Estonia and Livonia are not based on triangulation before 1839, e. g. the special map of Livonia by Rücker (for more detail see Varep 1957), the georeferencing of hand drawn maps demands digital manipulation of the maps to some extent: in some cases the maps need to be shrunk, in other cases stretched. This means that large-scale maps must be georeferenced and analysed in smaller fragments and later "stitched" together. While the georeferencing of modern physical maps can be based on latitude and longitude lines or specific pre-given coordinates (Koppa 2006, 17 – 18), then the

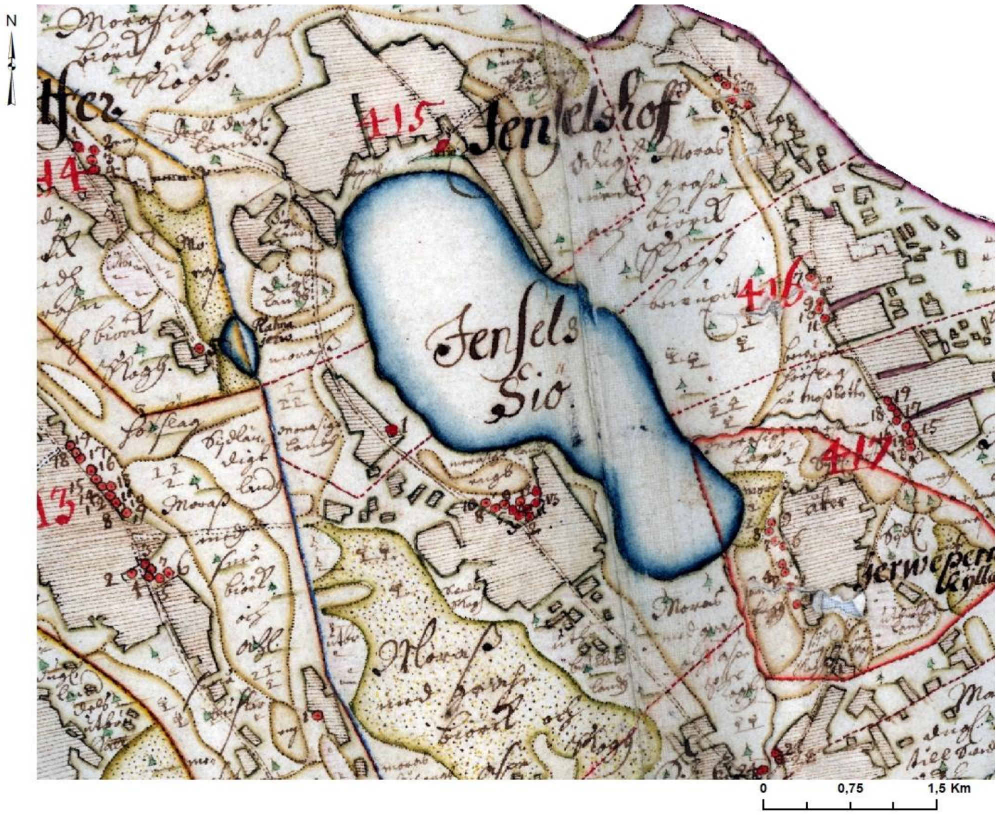

Figure 14. Fragment of the georeferenced topographical map, surroundings of Lake Kuremaa. EAA 308.2.69.

georeferencing of historical maps can only be based on characteristic landscape features, like river valleys, lakes or hills, that have not changed significantly over time. However, it is almost impossible to georeference the older maps with 100% accuracy, for very often the objects and distances on historical maps are out of proportion. Still, the Swedish Era (1558 – 1710) regional maps at a scale of ca. 1: 48 000 (Must 2000, 255) are surprisingly accurate and the differences in location of landscape features are minimal.

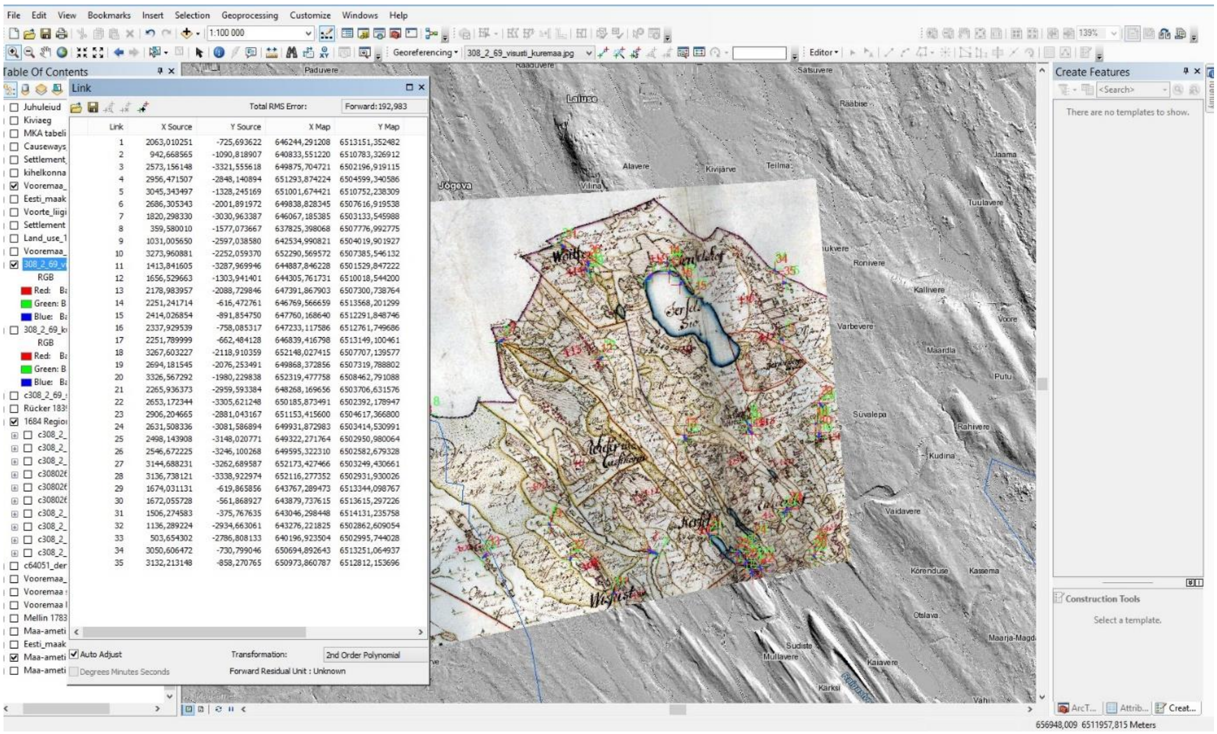

Figure 15. Georeferencing historical maps in GIS software. EAA 308.2.69.

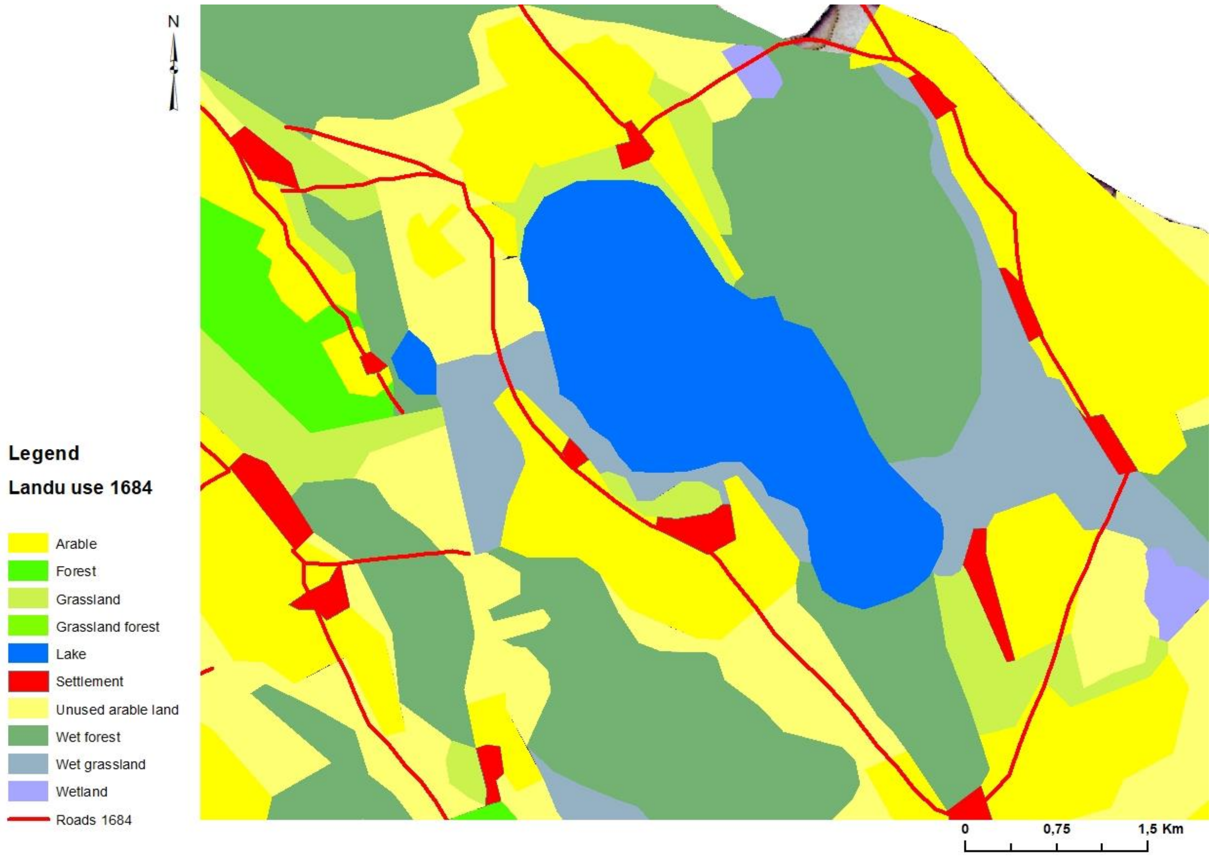

Figure 16. Fragment of the georeferenced and vectorised map, surroundings of Lake Kuremaa.

After digitising and georeferencing (Figure 15), separate layers of vectorised features based on the historical maps were created (Figure 16). In order to have a detailed overview of the land use patterns of Vooremaa, different units of land were vectorised into polygons : 1) settlements 2) arable land 3) unused arable land 4) grassland 5) forest 6) wetland 7) water bodies 8) roads. Simultaneously with creating vectorised layers, a database with relevant attribute data (information about land use) was inserted. The layers based on historical maps could then be integrated with known archaeological sites (Figure 17), resulting in a detailed map (re)presenting the pre-industrial landscape roughly from the mid-17th century.

Because of the large amount of manual work, only the 17th century maps were digitised into separate vector layers. The Livonian Special map of 1839 and the topographic map of 1930s were applied for comparison as raster maps.

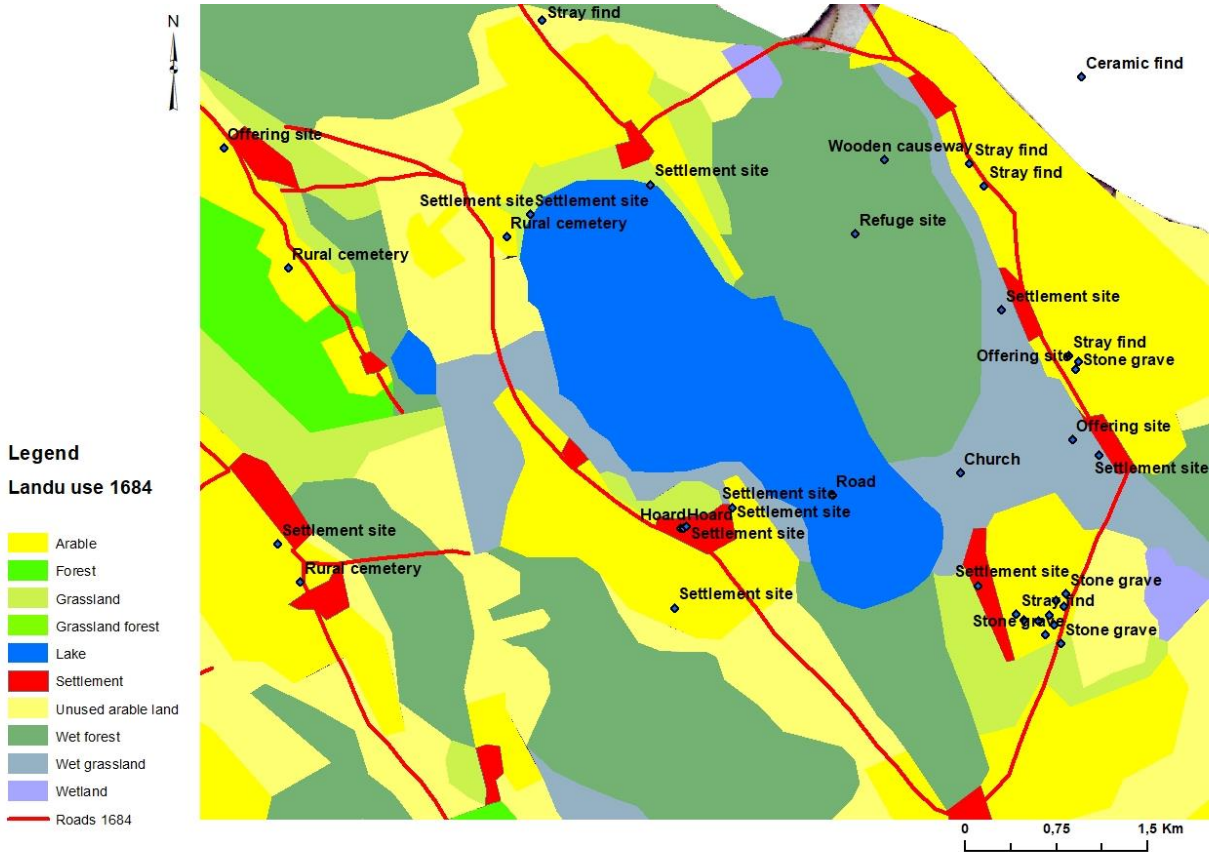

Figure 17. Fragment of the georeferenced and vectorised map with archaeological sites, surroundings of Lake Kuremaa.

5.8 Historic land use analysis for evaluating landscape change

On the bases of long-term landscape change, a value system for assessing archaeological distribution patterns was created. In the detailed study of land use, the position of every archaeological site was analysed, and assigned with specific numbers characterising the surrounding landscape and its features. The immediate surrounding was defined as extending150 m around the site, which constitutes a buffer zone 300 m in diameter. From a methodological point of view, the size of the buffer may alter the results quite considerably. The buffer zone of 150 m was chosen for the following reasons:

1. 150 m is large enough to characterize the surrounding landscape
2. small enough to convey the most essential features; larger buffer would incorporate more characteristics and lose its focus and purpose.
3. overlay with neighbouring sites can be kept to a minimum

Because there are no large-scale archaeological settlement sites in the Vooremaa region, the geometrical centre of the site was applied (Figure 18). For this purpose, special buffer layers

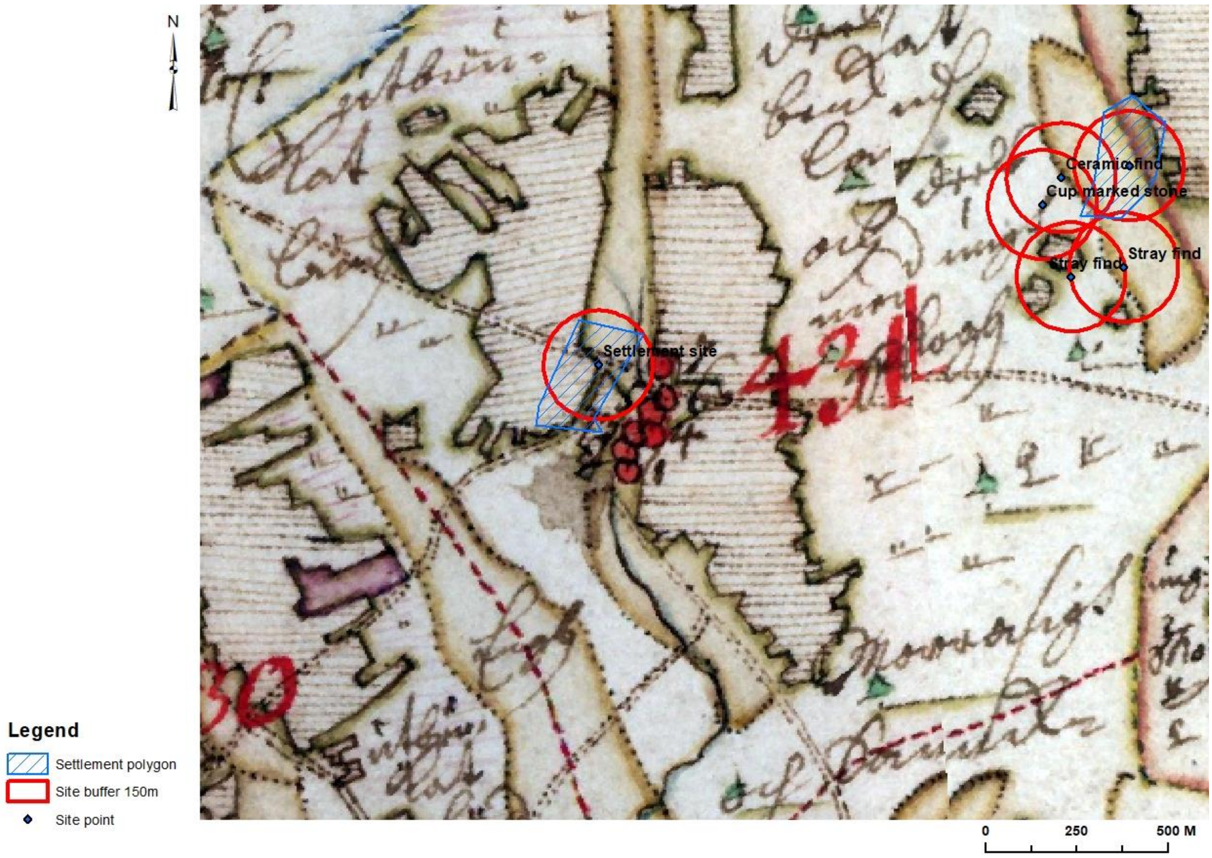

Figure 18. Archaeological settlement sites are often situated in or near 17th century villages. Topographical map of Tartu County 1684. EAA 308.2.69.

in GIS software were created. Still, everything had to be checked manually site by site, and several minor corrections had to be done to compensate for the inaccuracy of the historical maps.

Numbers were assigned according to principle of growing (except for water, roads, and gravel pits) when moving further away from the settled areas. The numbers in the GIS database represent following landscape features:

1. **Settlement** – refers to the position in relation to the historic (17th-century) settlement pattern, including settlement types such as village, manor, farm, mill, tavern, and church. For example, archaeological settlement sites are often discovered near the historically documented (17th century) villages and other settlement features, such as mills and taverns. These are areas with high archaeological potential.
2. **Arable land** – the site is situated in arable land. At least from the beginning of the Iron Age, crop cultivation was the most important means of subsistence. Thus, historic villages and older settlements are often directly connected to specific soil types that indicate a high fertility of land. New Iron Age dwelling sites are expected to be discovered in the areas suitable for agriculture.
3. **Unused arable land** – the site is situated in former arable land, which has been exhausted and left to recuperate or has overgrown with bush (including recently harvested forest).
4. **Grass** – meadows, pastures, paddocks, also meadows in river valleys and inter-drumlin depressions. Suitable grasslands are as important to the local agricultural economy as arable land.
5. **Forest** – all types of forest: coniferous, broad leaf and mixed, often combined with swamps. Forests provided both building material and fuel for heating. Without wood supply in sufficient volumes and of sufficient quality, a settlement unit could not function properly. At the same time, large forests were already at the outskirts of settled areas in the 17th century and remained relatively distant from the villages since then.
6. **Wetland –** all types of swamps, bogs, and wetlands. Generally, settled areas were situated at some distance from swamps and wetlands. However, in some cases small swamp islands have been cultivated or used as meadows. Wet and low river valleys, lakesides and depressions between drumlins were also used as meadows.
7. **Water** – lakes, rivers, creeks. Water is of course essential for settlement life, whereas the lakes and rivers of Vooremaa were also important means for traveling, both in summer and wintertime (transport over frozen lakes).
8. **Road** – distance to roads. The 17th century road network is a good indicator for discerning between settlements that predominantly relied on land routes, and those that primarily depended on transportation over water and ice. The 17th century roads

were still unpaved, and generally run along higher mineral-rich grounds. In places, over swampy areas, wooden trackways were built in order to connect mainroads that followed the drumlins.

9. **Gravel or sand quarry** – the site is/was in a former quarry. Archaeological burial places, especially medieval rural cemeteries have often been discovered during gravel/sand extraction.

Generally, each site received several numbers. For example, in the village of Kobratu, the archaeological settlement site is located next to a village in cultivated fields with the river, road, and gravel quarry in close vicinity (Figure 19). The landscape characteristics for the different time periods were therefore described as follows:

Time	**Features in change**
1684	1/2/7/8
1839	1/2/7
1930s	1/2/7/8
2000s	1/2/7/8/9

Table 2. Landscape characteristics for archaeological settlement site in Kobratu village

The most profound change in the case of Kobratu is, that in 2010s the hill next to the site has been excavated for gravel extraction. In this analysis, the number assigned to the site indicate environmental variation in terms of different features.

By characterising certain features of the landscape over longer periods it is possible to detect broader landscape changes vis-à-vis the pattern of archaeological sites. In this way, we are able to detect which landscape features are more site-specific, and which combinations of features occur more frequently in relation to the settlement pattern, both in space and over time. In the same way, we are also able also infer the economic activities that have been going around the sites, and why certain sites may have been destroyed or, conversely, remained intact. In the GIS database it is then possible to analyse deatailed historic land use over a total period 330 years and detect overall landscape changes around archaeological sites.

Figure 19. Landscape change in the village of Kobratu in 1684, 1839, 1930s and 2010s.