HERCULES: Studying long-term changes in Europe's landscapes

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HERCULES: Studying long-term changes in Europe's landscapes


This paper presents the outlines of a new EU-funded research program for the long-term history, present-day management and further development of the European landscapes, including their natural and cultural heritage: HERCULES. One of the subprojects of this program (Work Package 2) links archaeological, historical and historical ecological data to the analysis of geo-information in order to develop models of long-term landscape change in three carefully chosen study regions in the Netherlands, Sweden and Estonia. This is framed theoretically by integrating insights from landscape biography, historical ecology and complex systems theory. The linking and analysis of data will be done using a Spatial Data Infrastructure and by means of dynamic modelling.

1 INTRODUCTION

In December 2013 a new large-scale program was launched for the research, protection and management of the European cultural landscapes within EU Seventh Framework Programme: HERCULES (Sustainable Futures for Europe’s Heritage in Cultural Landscapes). The major aim of HERCULES is “to empower public and private actors to protect and sustainably manage cultural landscapes that possess significant cultural, socio-economic, historical, natural and archaeological value, at a local, national and Pan-European level” (www.hercules-landscapes.eu). This will be achieved through academic and applied research by a network of 13 partners from 11 countries, including European universities and research institutes, small and medium-sized enterprises and non-governmental organisations. Together they will develop an integrative approach that incorporates diverse stakeholder perspectives to appropriately address landscapes changes. The University of Copenhagen and the Humboldt-Universität zu Berlin act as the coordinators of the program.

HERCULES includes no less than 10 work packages e.g. for case studies of short-term developments in the European landscapes, landscape typologies, broad and fine-scale modelling (scenarios) of future landscapes, the re-coupling of social and ecological landscape components, building a Knowledge Hub for landscape research and best practices in management, etc. The research will focus on a selection of nine case study landscapes in the UK, Sweden, Finland, Estonia, The Netherlands, France, Switzerland, Spain and Greece.

In this paper we present an overview of Work Package 2, as it brings together archaeological, historical and ecological data and insights in order to reconstruct the changes that have taken place in the European landscapes from earlier prehistory (the Neolithic) up to the present. In many ways, these changes are still operating as landscape forming processes in the European landscapes we live and work in today. This is the case, for example, where water management and land use had long-term or delayed effects, such as in the extensive water management systems in the Netherlands, in Mediterranean landscapes that suffer from erosion, ‘desertification’ and loss of biodiversity, in urban areas with long histories of ‘path-dependent’ trajectories of urbanization, etc. The research in Work Package 2 is coordinated and conducted by an interdisciplinary team of archaeologists, geographers, experts in geo-information science and land use managers from the Netherlands (Spatial Information Laboratory, VU University; Faculty of Archaeology, Leiden University), Sweden (Dept. of Archaeology and Ancient History, University of Uppsala), Estonia (Estonian Institute of Humanities, Tallinn University) and the UK (Forest Communication Network Ltd.).

2 STUDYING LONG-TERM CHANGES IN EUROPE’S CULTURAL LANDSCAPES

Within HERCULES, Work Package 2 (from now on ‘WP2’) specifically addresses the long-term changes in the European landscapes. Its objectives are:

1. To define an innovative theoretical framework for understanding the long-term development and transformation of landscapes, drawing on recent insights from geography, landscape archaeology, (historical) ecology, anthropology and information science.

2. To develop and test an infrastructural facility for retrieving and linking archaeological, historical and ecological data and geo-information (SDI) to support the interdisciplinary study of landscape change.

3. To develop dynamic and interpretive models for analysing long-term trends in landscape history in three
In 1996, The Danish-American geographer Kenneth Olwig tried to synthesize ecological/environmentalist and cultural/social science approaches in landscape research, based on a thorough investigation of the origins of the landscape concept, by re-introducing what he calls the ‘substantive’ nature of landscape (Olwig 2002; 1996). Although such a synthesis of paradigms, if possible at all (as many researchers oppose the idea of paradigms itself), is not an explicit goal of the integrated long-term approach to be developed in HERCULES, there is certainly a link between WP2 and Olwig’s endeavour. WP2 too aims at developing an integrated approach to the study of landscapes, combining the long-term perspective of archaeology and history with recent insights from cultural ecology, anthropology and geography. To achieve this goal, elements of recent ‘landscape biography’ and ‘historical ecology’ will be used as theoretical building blocks. Landscape biography and historical ecology are among the prominent emerging approaches to the study of long-term landscape history, and are now being combined and integrated with a complex systems approach to human-land and human-nature interactions.

Landscape biography studies the long-term transformations in landscapes, preferably from prehistory to the present, viewing landscape at each point in time as a complex interplay between social and economic developments, culturally specific perceptions of the environment, the history of institutions and political formations, and ecological dynamics (Kolen 2005; Roymans et al. 2009; Kolen et al. 2015). As a historical research strategy, it expresses a strong sense of the multi-layered nature of landscapes. It acknowledges the non-linear and path-dependent character of landscapes and the active role they play in the life histories and social memory of people (cf. Ingold 2000). This means that landscapes are not only seen as the (interim) outcomes of drivers, but in themselves are considered drivers for social, economic and climate change as well.

Historical ecology, which emerged in the US within the Boasian paradigm, developed a practical framework of concepts and methods for studying the past and future of the relationship between people and their environment (Balée 1998; Balée and Erickson 2006; Crumley 1994; 2012; Hornborg and Crumley 2007; Meyer and Crumley 2011). While historical ecology may be applied to spatial and temporal frames at any resolution, it finds particularly rich sources of data at the ‘landscape’ scale, where human activity and cognition interact with biophysical systems, and where archaeological, historical, ethnographic, environmental, and other records are plentiful. The term historical ecology draws attention to a definition of ecology that...
includes humans as a component of all ecosystems and to a definition of history that goes beyond the written record to encompass both the history of the Earth system and the social and physical past of our species. It provides tools to construct an evidence-validated, open-ended narrative of the evolution and transformation of specific landscapes, based on records of human activity and changing environments at many scales. Historical ecology offers insights, models, and ideas for a sustainable future of contemporary landscapes based upon this comprehensive understanding of their past.

Being complex systems, landscapes are self-organizing and exhibit what are known as ‘emergent properties’, which cannot be deduced from the individual natural or cultural components of the system. Agent-based perspectives on complex systems (cf. Van der Leeuw and McGlade 2013; Bentley and Maschner 2003) combine the principles of complex systems theory with the concept of interacting agents. Dynamic modelling allows to study whether developments inevitably lead in a certain direction (path dependence), and whether different scenarios will produce similar outcomes (equifinality). By this, it is very suitable for exploring long-term developments in cultural landscapes, allowing to test different hypotheses of the development of the cultural heritage embedded in these landscapes. As dynamic modelling may also be explored to create insights on how micro-scale processes give rise to macro-scale phenomena, it is of great interest to landscape archaeology, where we can usually only observe the macro-scale results of micro-scale actions in the past. Several archaeological studies have used dynamic modelling for this purpose (Kohler et al. 2007; Wilkinson et al. 2007).

Together, these frameworks encompass the range of variation that is currently found in international landscape studies. While the frameworks largely overlap, landscape biographic approaches focus on the regional scale of analysis and are more explicitly phenomenological and aimed at heritage studies, while historical ecological approaches are multi-scalar and are more comprehensive and explicitly empirical. Both frameworks embrace the stakeholders, planners, and managers of landscapes. For the first time, the HERCULES program aims at integrating the so far separate concepts of landscape biographies and historical ecology with a complex systems-based perspective on cultural landscapes. With spatial dynamic models specifically designed for the needs of interdisciplinary study of landscape change, HERCULES intends to provide landscape researchers with new tools to understand long-term developments in European landscapes by more effectively linking archaeological, historical, ecological and social data.

By integrating landscape biography, historical ecology and complex systems theory, WP2 wishes to realize a trans-temporal approach to landscape, treating epochs, periods, and other temporal divisions as ripe for research and not firewalls that protect temporal specialties. Such a trans-temporal approach has several advantages. Particularly important for planning and heritage, the coupled human/environment system can be analysed with regard to effective management strategies under specific (local, regional) social and environmental conditions and the results used to formulate future scenarios.

In order to tackle these challenges, the protocol for understanding long-term landscape dynamics produced by the WP2 team (Crumley 2014) starts from 15 premises. Here we present only a selection thereof:

- **Much of what we know about landscape changes in the past cannot be based on extrapolation from present conditions.** Yet initial conditions of landscape systems are a strong predictor of later states. Past decisions shape and constrain subsequent ones and small differences are disproportionately the cause of later circumstances. This is called path dependence. Thus physical infrastructure, social practices, and other conditions can impede necessary system-wide change.

- **Knowing a landscape’s history can be seen as using completed experiments undertaken in the laboratory of the past.** Most (pre-)historic forms of land use have proven not to be sustainable, but it is true that their persistence is, at least in part, witness to their utility.

- **Landscapes have their own temporalities and rhythms,** in relation to but distinctive from individual and community life cycles. The past is also always present in the landscape of ‘today’. All landscapes incorporate “the powerful fact that life must be lived amidst that which was made before” (Meining 1979, 44). Thus landscape biography and historical ecology view landscapes as palimpsests that are transforming continuously, both through conscious interaction by people with the material past in the environment and through less conscious forms of agency. This again illustrates that landscapes cannot simply be seen as the outcomes of drivers, but that landscapes themselves are also drivers of social, political and economic change.

- **Historical ecology and landscape biography both study long-term transformations in landscapes from prehistory to the present** (Crumley 1994, 2015; Kolen et al. (eds.) 2015; Meyer and Crumley 2011; Roymans et al. 2009). It is important to realize that the disciplines contributing to this exercise, like landscape archaeology, historical geography, historical anthropology and palaeo-ecology, explore quite different datasets covering different time-intervals and aspects of landscape change. These datasets and the methods used to analyse and interpret them must be related and integrated in systematic ways in order to synthesize long-term changes.
Together, historical ecology and landscape biography can link social memories to the long term, connecting the micro-histories of places to broad-scale developments, and integrating experience and process. One of the routes to this end is by the study of how, in different mnemonic, religious and social systems, memories, values and ideas concretely interact with the material world of which landscapes are an integral part (e.g. Küchler 2002).

Taking the above set of premises as its methodological starting point, HERCULES will not produce a single paradigm but rather offers a toolbox of concepts and competencies (cf. De Kleijn et al., 2014; Kolen et al. 2015; Meyer and Crumley 2011; Crumley 2015). At the same time, the premises can be chosen as explicit theoretical guidelines for research projects that tackle long-term changes in cultural landscapes.

4 A Spatial Data Infrastructure (SDI) for Landscape Research

The availability of digital tools and data to study long term changes in the landscape has, over the last decade, grown tremendously. Landscape scholars and landscape practitioners are more and more digitally skilled and the use of Geospatial technologies has grown significantly. Landscape research is nowadays unthinkable without the use of Geographic Information Systems (GIS) software to analyse, and Spatial Data Infrastructures to systematically store and share digital spatial information. The theoretical framework proposed in WP2 promotes the integration of data and perspectives produced by academics and Land Management practitioners.

Given their explicit multidisciplinary aim, studies of the long-term history of landscapes and ecosystems make use of datasets from various sources. Optimally, these will include a combination of the following data:

- Data and information that (can) inform landscape researchers and stakeholders about the political (territorial) and religious aspects of past landscapes, like archaeological databases (burial sites, ritual depositions), archival sources (monasteries, parishes, manorial estates, etc.), cartographical databases (historical maps), databases for specific monuments and religious architecture (like churches), etc.;
- Data and information that (can) inform landscape researchers and stakeholders about past experiences and meanings of landscape, like databases for field and place names, oral history databases, cartographical databases (historical maps), visual databases for landscape painting and historical photography, etc.

It has been acknowledged recently that in order to explore and combine multidisciplinary datasets optimally these kinds of data could best be organized by means of a so-called Spatial Data Infrastructure or SDI (De Kleijn et al. 2014). The core function of an SDI is to enable users to share geospatial information beyond the level of a single institute or organization. This need is generally found in landscape research. In understanding what an SDI encompasses we make a distinction between the user objectives, technological components, Geospatial Information (GI)-literacy, content and governance (De Kleijn et al. 2014). The combination of the GI-literacy and the objectives determine the extent to which the technological components need to be developed and the content to which access is needed.

At the core of an SDI lies the technical infrastructure of services, varying from data viewing services to download and more complex processing services. On top of these services applications can be built with which users, with different objectives and GI-literacy levels, can perform their tasks. The applications through which the services can be accessed vary from web viewers for users to view and validate data, to dedicated GIS software with which modelling experts can perform complex analyses (e.g. ArcMap, Quantum GIS, GeoDMS, MapINFO, etc.).

For governance of an SDI three aspects can be distinguished. First, a party coordinative institute has to take the on leadership and ensure long-term viability and educate where necessary users how to use the tools. Second, the users’ requirements for functionality and content have to be closely looked at in order to ensure that their needs are translated to (technical) requirements for the SDI and the applications that are implemented on top of it. Third, considering the content, the management of who can use what information for which purposes is also a fundamental part of SDI governance. Although the current trend is to publish data in the public domain as open data, to which the HERCULES project also strives to, some data cannot be put in the public domain due to privacy issues and restrictions of the data providers.
The study of long-term landscape change would benefit considerably from improved availability of data about the history and heritage of the landscape and functionalities with which the data can be processed and shared through an SDI. In the process of studying long-term landscape change, five areas in which an SDI has the potency to play an important role can be distinguished.

First, an SDI offers functionalities to integrate digital spatial data (also from different repositories e.g. different universities, governmental institutes etc.) in structured way enabling users to work systematically.

Second, an SDI offers functionalities to communicate historical and heritage spatial data to various stakeholders ranging from landscape historians and heritage experts to the people of the place for purposes of validation.

Third, an SDI offers functionalities to process and/or download data into specialist software with which complex long-term landscape change models can be developed and executed.

Fourth, an SDI offers functionalities to share the models and the outcomes of landscape research dynamically, allowing changes to the data to automatically update the model.

Fifth, an SDI offers functionalities to disseminate the research results as services that can be part of the Knowledge Hub developed in HERCULES or existing local heritage management data infrastructures.

The areas/themes identified above, except for the fifth, are not to be seen as separate phases, which follow up on each other, but are to be approached as stages through which long term landscape modelling goes through in several iterations.

A schematic overview of the SDI is shown in figure 1. It shows how the data servers are related to the clients and shows how the SDI aids landscape change modelling. It also shows how the SDI components are related and how the SDI interacts and can be integrated with HERCULES’ Knowledge Hub developed in WP 7. The spatial modellers work foremost with professional GIS software, whereas the past-oriented and future-oriented landscape professionals and local stakeholders provide feedback through workshops using decision support tools. These last-mentioned groups are also providing feedback, making use of custom-made data viewers. Finally the project outcomes and results will be transferred to the HERCULES knowledge hub, providing insights in best practices for future landscape research.

5 Modelling landscape change

As stated above, the SDI is essential for giving stakeholders access to relevant spatial information and validate outcomes of spatial models about the past and current landscape. However, in itself, it will provide nothing more than a framework to accommodate the management and visualization and exchange of spatial data sets. Current approaches to mapping and visualizing landscapes of the past can be described as predominantly static. Typically, they only offer snapshots of archaeological or historical periods, showing the places where people settled and used the landscape, as well as the environmental setting itself (notably in the form of palaeo-geographical, or better said palaeo-geomorphological reconstructions). Predictive models (which are essentially statistical extrapolations) are then applied to predict the possible distribution of archaeological remains (see e.g. Kamermans et al. 2009; Verhagen and Whitley 2012). In this approach, time periods are lumped, and the dynamics of landscape transformation are obscured, tacitly assuming that in each period people were experiencing the landscape as a kind of tabula rasa.

Approaches to overcome this static approach are now emerging in geographical and archaeological landscape research. Notably, techniques like Agent-Based Modelling (e.g. Kohler et al. 2007; Wilkinson et al. 2007) and Dynamical Systems Modelling have great potential for better understanding the observed patterns of settlement and land use, and the processes that led to these patterns (cf. Bentley and Maschner 2003; McGlade and van der Leeuw 2013).

Such models are designed as heuristic tools, for example to build scenarios of population development or to develop more sophisticated theories of human (spatial) behaviour and practices, but the outcomes should not primarily be seen and used as accurate predictions of for example past land use. It can therefore be doubted whether these models, in their current state of application, would be of much use to heritage professionals. From their point of view, information needs to be accurate and usable, rather than multi-interpretable explorative.

For these reasons, WP2 will not adopt ABM as a core modelling technique, despite its high potential for academic analysis. The outcomes would not, at this stage, be able to inform heritage policy, and hence not serve the overall aims of HERCULES. WP2 will therefore adopt and further enhance models that are able to close the gap between static mapping aimed at heritage professionals and dynamical modelling designed for academic research. This will be done by developing models that link path dependencies in (pre) historic land use to predictions and mappings that will make sense in a heritage context.

Within WP2 the concrete possibilities of dynamic modelling will be explored by adopting a case study approach. This will be done for three different case study landscapes, each being representative for more widespread environmental and climatic conditions within Europe: Atlantic (the river landscape of the Central Netherlands), Boreal (the Uppland area, Sweden) and continental European conditions (Kodavere/Vooremaa, Estonia). A Mediterranean
wetlands and more open cultivated areas. In the Roman Period, the study region formed the north-western part of the Roman frontier on the continent. By then, land use had been intensified considerably, creating a more open landscape with an increased human impact on the water system.

In about 1000 AD, the inhabitants of the river villages in the study region began building embankments along major rivers like the Rhine and Meuse (Van de Ven (ed.), 1993; Harten 2000). Along with the villages themselves, fields and gardens occupied the highest parts of the banks, while the slopes down to the flood basins behind the banks were used as communal meadows and pastureland. In the period from 800 to 1250 AD, towns in the Dutch river area expanded significantly and there was growing demand for agricultural products. To satisfy this demand, the agricultural land area had to be extended to the low-lying peat areas and river basins (Harten 2000; Renes 2005). But before these areas could be drained and reclaimed, embankments had to be built along the river courses and any obstructing ones had to be dammed. Several centuries later, the still remaining open

Figure 1 Schematic overview of a Spatial Data Infrastructure (SDI)
spaces between the village embankments were closed off and long, uninterrupted dikes were built. This process was completed in most parts of the Dutch delta by about 1300 AD. Inside the dikes, where in winter especially the river water could dam up to a significant extent, river forelands were created.

Thus over the course of five centuries, from 1000 to 1500 AD, the Dutch delta changed dramatically (Van de Ven 1993; Renes 2005). It was transformed from an open delta where the rivers had free reign and where large areas were taken up by fens and marshes to a tightly ordered agricultural territory under human control. With their far-reaching interventions such as dike building, the inhabitants of the Dutch river landscapes unconsciously reset the environmental agenda for themselves. In the long run, their reshaping of wetlands and stream valleys had unexpected repercussions, like dike breaches and large-scale floods.

In the Dutch river delta, the so-called Land Use Scanner (LUS) will be deployed to model land use changes (Hilferink and Rietveld 1998; Koomen et al. 2011). This modelling framework was originally designed for predicting land use development in the near future, based on information about the current situation and the hypothesized development of future land use demand. The allocation methods applied in LUS are the logit-based model to determine probabilities and a discrete allocation method to generate an allocation that is optimal given the suitability of different plots within the region. A major advantage of this approach is that it shifts the pervading focus in archaeology from local settlement sites to various landscape scales as the object of interest. It also looks at the landscape from the angle of its use, rather than from the dominant, geomorphologically based point of view aiming at predicting the landscape’s suitability for settlement – which is of course only one aspect of what people did in the past. The LUS is particularly suitable for the Dutch river delta, given the very extensive data available on settlement distribution and palaeo-geographic reconstructions for the area over long periods of time.

6.2. Uppland, Sweden (figure 2)

Since the regressive shoreline displacement in Uppland, like elsewhere in Sweden, changed the landscape considerably over millennia and offered new land for occupation, it is necessary to examine how the changing topography influenced the choice of locations for settlement and land use.

A strategy to reconstruct this aspect of regional landscape change is to take the physical characteristics of the landscape into account, such as the presence of fresh water. Proximity to fresh water is important in the choice of settlement locations. Streams, lakes and rivers not only provide food and water but are also means of communication. Rivers can connect communities into smaller regional groups, so-called river-based communities (Jordan 2003). Another such natural connective element is a water catchment area. A water catchment area constitutes the area from which all run-off water comes together in a point or in a stream. A watershed is the boundary between two such areas. Typically, a watershed is a height where the rain falls on two different sides forming two different water catchment areas. This method has been used frequently in studies concerning physical geography and to some extent in the study of prehistoric regions where it has been argued that water catchments have influenced the development of territories and administrative regions (Löwenborg 2007; Von Hackwitz 2012; Wijkander 1983).

For these reasons, the Uppland case focuses on the modelling of shoreline dynamics in relation to isostatic land rise. The model used here is based on a shoreline method focused on archaeological sites combined with an isolation method built on analyses to determine when lakes were isolated from the sea. A regression equation is used for making a shoreline reconstruction in order to consider both the isostatic uplift and the eustatic variations. This means that the reconstructions will be more accurately calculated, especially for larger areas, as the uplift is uneven between different land areas. Further, the shoreline can be modelled from any given BP value which means that a site can be put in its specific time context in terms of shoreline displacement as long as there is a valid BP value (Sund 2010). The regression equation used here was originally developed by Risberg et al. (2007) and further developed by Sund for the area of Eastern Central Sweden (Sund 2010). The accuracy of Sund’s model is comparable with that of Risberg (Risberg et al. 2007), but with the advantage of generating a contemporary shoreline over a larger area (Sund 2010, 27).

The applied model is generic and well suited to create a model for the Uppland region as a whole. Local deviations might occur as topographic thresholds could later have been eroded, making it difficult to accurately model the shoreline in detail at every point, but overall the model would be fairly accurate and relevant for the analyses proposed here.

Additionally, water catchments can be calculated from a digital elevation model (DEM) using a set of hydrological functions in a GIS (Geographical Information System). Pour points, the points on the service at which water flows out of an area, are determined. Relevant pour points are selected, considering the modelled shoreline, and from the pour points drainage basins can be calculated to identify the upland area that is hydrologically joint at the pour point. The pour point would also act as an important social node in the landscape, connecting everyone using the upstream watercourses, and thus forming a ‘natural’ region that would be easily recognized. If there is a pronounced isostatic land rise in the
part of this case study relies on principles that are similar to the Uppland case study. Water bodies in this area form an extensive communication network, which was and still is being used for food procurement, transport, and trade. Occupation and land use focused on the western shore of Lake Peipsi, which is on the one hand a lake, but on the other hand has many similarities with a sea (i.e. the Baltic Sea) (Karro 2012). Moreover, the lake is part of a larger lake system including Peipsi and Pskov that has been documented as part of a trade route system that covered an enormous area stretching from Scandinavia to Byzantine (Mägi in press).

The method deployed for analysing landscape changes throughout the Iron Age (500 BC – 1200 AD) correlates geological information about the lakeshore with archaeological data, historical maps and cultural historical information (like historical narratives about particular places). The dynamics of shorelines is reflected in geographical shifts of human settlement as well. Water levels in the lakes went up gradually, but the land still rises faster in the southern part of the study area. This implies that the present-day situation in this will affect both shorelines, thus making different pour points relevant at different periods. In areas with level terrain this might also cause the inland boundaries of the watersheds to shift as the land surface is tilting. It is therefore necessary to use a DEM that has been modified to the relevant time period using a method like the one described above. In the Uppland study area, a high resolution DEM has been produced by the Swedish Cadastral Agency (Lanmäteriet) using LiDAR technology.

Using the shoreline and watershed modelling together with the digital database from the National Heritage Board (Fornsök) the aim is to model the development of social relations through regions and regionalism in the area, in order to better understand the long term land use of the area starting with the early Neolithic (ca 4000 BC) and ending with the Viking Age (c. 1050 AD).

6.3. Kodavere and Vooremaa, Estonia (figure 3)

Kodavere and Vooremaa are neighbouring regions in the south-eastern Estonian lakeside landscape. The theoretical part of this case study relies on principles that are similar to the Uppland case study. Water bodies in this area form an extensive communication network, which was and still is being used for food procurement, transport, and trade. Occupation and land use focused on the western shore of Lake Peipsi, which is on the one hand a lake, but on the other hand has many similarities with a sea (i.e. the Baltic Sea) (Karro 2012). Moreover, the lake is part of a larger lake system including Peipsi and Pskov that has been documented as part of a trade route system that covered an enormous area stretching from Scandinavia to Byzantine (Mägi in press).

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Figure 2 Landscape with royal burial mounds on a natural ridge along the lake, at the Medieval political, religious and economic centre of Old Uppsala (Gamla Uppsala; photo Kim von Hackwitz)
the northern part may roughly be indicative of the situation in the past in the southern part. Lake Peipsi has seven visible shoreline terraces dating from different periods since its formation after the last Ice Age, of which the 38 m. shoreline most strongly correlates with historical and present-day settlement patterns. Folklore and historical photographs give some hints about the traditional land cover (19th and the beginning of the 20th century) that was drastically changed during the Soviet period.

For the Vooremaa region a historical GIS is applied. Detailed historical maps are geo-referenced and vectorized into layers based on land use information (e.g. arable, pasture, meadow, forest, swamp, fallow) and settlement features (e.g. farms, manors, mills, taverns, churches, roads, administrative boundaries). Additionally, a database with relevant attribute data (information about land use) is used. The layers based on historical maps can then be integrated with known archaeological sites, which will result in a series of detailed maps representing pre-industrial landscape changes.

This provides us with a coherent sequence of about 350 years of land-use, indicating land use functions in terms of arable land, pastures and meadows, forests, swamps and bogs. Much of the wetland in Estonia was not drained until the beginning of the 20th century, which is why historical maps and archaeological information are a good source for detecting suitable arable land cultivated before the mechanization of agriculture. The model may also help to understand why some sites developed into centres of power and –subsequently- into important places of local identity ‘surrounded’ by local narratives and beliefs. Historical land-use data combined with contemporary soil maps and adequate digital elevation models in the historical GIS also provides a good platform for elementary predictive modelling, which could be effectively used in preventive heritage management.

**7 Epilogue**

In the next two years (2015-2016) the HERCULES WP2 team will study landscape changes in the three regions from a comparative perspective, exploring the conceptual framework and the techniques for linking and analysing archaeological, historical and environmental data outlined above. This exercise will focus on the question to what extent landscape changes either converge or diverge, given different or similar social and environmental conditions. It is important, furthermore, to learn from the effects of ‘experiments’ that people have conducted in and with landscapes in the past. More often than not these experimental interventions caused unexpected and delayed
effects for later generations, who had to ‘invent’ land use systems anew in order to cope with these consequences. An understanding of such iterative landscape histories can be of value for stakeholders, landowners and planners who face the challenge of environmental decision making today.

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Prof. dr. J.C.A. Kolen, Faculty of Archaeology, World Heritage, Universiteit Leiden, Van Steenis gebouw, Einsteinweg 2, 2333 CC Leiden, the Netherlands, j.c.a.kolen@arch.leidenuniv.nl.

Prof. dr. C.L. Crumley, Department of Archaeology and Ancient History, Uppsala University, Engelska Parken, Thunbergsvägen 3H, Uppsala, Sweden, crumley@live.unc.edu.