HERCULES

Sustainable futures for Europe's HERitage in CULtural landscapES: Tools for understanding, managing, and protecting landscape functions and values

GA no. 603447

D2.2 Spatial Data Infrastructure (SDI) for linking geographical, archaeological, historical, and ecological data and information for the case studies

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Executive summary

The second deliverable of WP2 (D2.2) of the HERCULES project contains the outlines of the Spatial Data Infrastructure (SDI) for retrieving and linking archaeological, historical, and ecological data and geo-information to support the interdisciplinary study of landscape change. It reports on the *current state* of the infrastructural facility, as the content (data) and functionality (query, analysis and visualization functions) will be refined further in the process of the modelling conducted in three regional case studies (task 2.3) and inter-regional comparisons within the HERCULES project. The SDI outline defines an innovative SDI conceptualization and architecture, grounded in international SDI literature and the functionality and data needs of interdisciplinary research of the long-term development and transformation of cultural landscapes. Furthermore, it describes how the architecture has been implemented in order to achieve a user-centric facility that meets the demands of the WP2 researchers and their societal partners and that enables the SDI to be linked to the Knowledge Hub developed in WP7.

The SDI outline subsequently deals with the following topics and issues:

1. A short description of its main *aim* and its relationship to the work being done in other WPs of the HERCULES project (Section 1);
2. A detailed description of an innovative methodology for the development of a user-centric SDI (Section 2)
3. An elaboration on the SDI architecture (technical components) implemented to support the researchers of WP2 (Section 3)
4. An elaboration on the SDI content (data) with specific reference to the modelling conducted in WP2 (Section 4)

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Abbreviations

AD	Anno Domini
BC	Before Christ
BP	Before Present
DEM	Digital Elevation Model
GI-literacy	Geospatial Information literacy
GIS	Geographic Information System
HE	Historical Ecology
LB	Landscape Biographies
LiDar	LIght Detection And Ranging or Laser Imaging Detection And Ranging
LUS	Land Use Scanner
SDI	Spatial Data Infrastructure
WP	Work Package

1 Introduction

This report describes the outlines for a "Spatial Data Infrastructure for interdisciplinary study of landscape change", which is the second deliverable (D2.2) of WP2 of the HERCULES project.

HERCULES strives for the empowerment of public and private actors to protect, manage, and plan for sustainable landscapes of significant cultural, historical, and archaeological value at local, national, and Pan-European scales. By applying and developing innovative technologies and tools for assessing and mapping cultural landscapes, HERCULES will:

- Synthesize existing knowledge on the drivers, patterns, and outcomes of persistence and change in cultural landscapes
- Close knowledge gaps regarding the dynamics and values of cultural landscapes
- Generate tools for landscape observation and modelling in order to understand values of and threats to cultural landscapes in Europe
- Develop a strong vision of pathways towards protecting heritage in cultural landscapes, especially for landscapes of high historical and archaeological value
- Provide policy makers and practitioners with a cutting-edge Knowledge Hub to guide decision-making for the benefit of cultural landscapes with significant archaeological / historical components

In achieving these goals, the HERCULES project responds to the European Landscape Convention's call for trans-disciplinary research and involves important actors with stakes in cultural landscapes across all project stages.

Within the HERCULES project, WP2 focuses on the study of long-term landscape change. The principal aim of WP2 is to enhance methodologies to collect data and to create knowledge about the long-term dimension of cultural landscape change. Its specific objectives are:

- To define an innovative methodological procedure for understanding the long-term development and transformation of cultural landscapes, drawing on recent insights from geography, landscape archaeology, (historical) ecology, anthropology, and information science. The procedure will be informed by the definitions and the conceptual framework developed in WP1
- To develop and test an infrastructural facility for retrieving and linking archaeological, historical and ecological data and geo-information to support the interdisciplinary study of landscape change
- To develop models for analyzing long-term trends in landscape history in the case study sites

This report outlines the progress made towards the second mentioned task in the first 18 months of the project.

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 as a tool to analyze and visualize spatial phenomena (van Manen et al., 2009; Lee et al., 2014).

To follow up on this trend there are several aspects to take into account. First, the availability of data; second, the variety of visualization and analysis tools; third, the different levels of Geospatial Information Literacy (GI Literacy); and, fourth, the methods to share relevant information. This deliverable focuses on these issues by discussing the implementation of a Spatial Data Infrastructure (SDI) to facilitate the activities for WP2.

The SDI aims to facilitate the organization of data derived from a variety of data sources as input for task 2.3 of WP2 (Description of Work) in which long term landscape change is modelled. This has to date been done for two case study areas: the Dutch Delta and the Swedish Uppland; the third study landscape, Kodavere/Vooremaa in eastern Estonia, will be served during the next stage of the project. Although the SDI has been developed and is fully operational offering the necessary functionalities to support the data management for the long term landscape change modelling, it must be noted that at the time of writing the modelling activities are still ongoing. Hence, the modelling results have not yet been fully included into the SDI. Furthermore, the SDI offers the required functionalities to share knowledge with local professionals, but these will only be put to use once the modelling has been completed. Since this data will be available at the end of the project and integrated with the WP7 Knowledge Hub, a more elaborate description and discussion will be provided as part of Deliverable 2.3.

Before elaborating on the SDI architecture (section 3) and content (section 4), the deliverable will present a framework for developing an SDI that takes into account fully the tooling and data required by the WP2 researchers (section 2).

Please refer to the Executive Summary for an outline of the full deliverable structure.

2 Spatial Data Infrastructure[1]

The core function of an SDI is to enable users, beyond the level of a single institute or organization, to share geospatial information. Since the first research and initiatives to develop SDIs in the early 1990s, researchers have identified three generations of SDIs. SDI initiatives have evolved from first-generation product-based centralized spatial information repositories for small groups of GI-experts to second-generation, top-down information assets management by linking metadata, data, and people; and, third-generation, bottom-up user-centric SDIs (Rajabifard et al., 2002; Rajabifard et al., 2006; Masser, 1998; Hennig and Belgui, 2011; Craglia and Annoni, 2007). This evolution has gone parallel with the development of the Internet. The development of faster data transfer technologies and interactive capabilities that the Internet supplies, together with conceptual changes on communication, have influenced the understanding of what an SDI comprises, and how it should be developed.

[1] This section is based on De Kleijn et al., 2014.

The constantly evolving character of SDIs has resulted in a continuous redefinition of what an SDI encompasses. It is therefore not surprising that a variety of SDI definitions exist (e.g., Masser, 1998; Chan et al., 2001; Rajabifard et al., 2002; Craglia and Annoni, 2007). The recent study of Hendriks et al. (2012), which presents a thorough analysis of 28 SDI definitions, makes a distinction between SDI objectives and components. *SDI objectives* are, for instance, the access to, or sharing of, geospatial information, while the *components* are identified as technologies and human resources.

In redefining SDIs, we use the concepts, objectives and components, identified by Hendriks et al. (2012) as a starting point. The users define their objectives which are to be translated into requirements that enable the users to perform the necessary tasks. However, besides the objectives, the requirements for the SDI are also highly dependent on the users' GI-literacy. We therefore propose to split the users from the objectives and components, and approach them as separate concepts. Furthermore, we have separated content, and split the remaining components into technological and governance (Fig. 1). We treat content as a separate entity because it is determined by the users' needs, and the other components are developed or implemented according to what the users intend to do with them. In addition to users, content, technological, and governance components, we have extended the concepts of Hendriks et al. (2013) with GI-literacy. We define GI-literacy as formulated by Hennig as the "knowledge, understanding and expertise to be prepared to use spatial data and associated tools in a competent manner and in an emancipatory way" (Hennig et al., 2013, p.99). Differences in user GI-literacy result in different SDI implementation requirements. Users with high GI-literacy need different components and education than users with a relatively low level of GI-literacy.

The relationship between GI-literacy, objectives and technological components is of vital importance in the light of user-centric third-generation SDIs. The character of the users' objectives influences the users' needs to improve specific GI-skills, thus stimulating the user to increase his or her GI-literacy. However, technological components can be developed that allow users with relatively low GI-literacy to perform tasks that were previously too challenging. Developing a user-centric SDI must therefore focus on the interplay between these concepts. Understanding, and achieving, a balance between the time that users are willing to invest in education and the effort to put in developing technological solutions should be the focus of user-centric SDI development.

To apply this reconceptualised SDI concept, the following subsections provide a framework for GI-literacy and an overview of existing technological and governance components. But first, we present a workflow diagram that integrates these concepts, leading to a methodology for the development of a user-centric SDI.

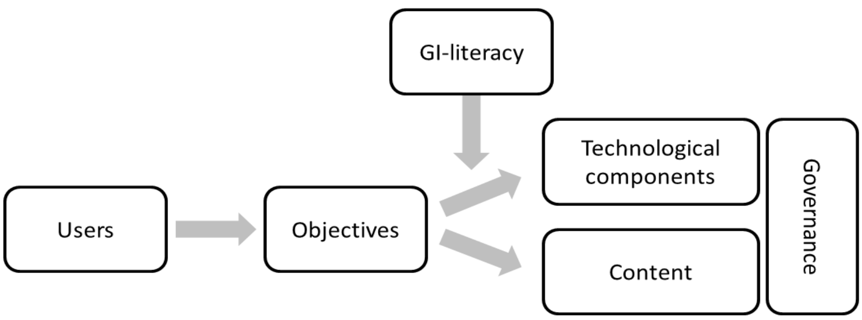


Fig. 1: SDI concepts redefined

2.1 GI-literacy

Although the relationship of GI-literacy to spatial thinking and education has been previously researched (e.g., Goodchild and Janelle, 2010; Van Leeuwen and Scholten, 2009; Lee and Bednarz, 2012), few have explicitly analyzed this topic in relation to SDI development. Hennig et al. (2013) have discussed GI-literacy in the context of spatially enabled societies, clarifying that GI-literacy has to be seen as the interplay between technological skills and spatial thinking skills. They have provided a clear analysis of the users by looking at skill levels, needs and knowledge, and relating those to the challenges of using SDIs for the support of, what they call, "Spatial citizenship". The approach of Hennig et al. is also a valuable starting point for making GI-literacy a workable input for a heterogeneous research community, such as the research community involved in HERCULES WP2. It makes it possible to evaluate researchers in terms of both their ability to approach their discipline from a spatial angle (formulating relevant spatial questions and adopting spatial concepts), and to deploy geospatial technologies in order to solve their research questions. We propose to broaden the GI-literacy concept with different levels, fitting user profiles into a recognizable GI-literacy level. To this end, we propose a model that confronts and combines the study on the conceptions of spatial information and information literacy as developed by Nazzari (2011) with the idea of a GI-skills scale. In essence, Nazzari has developed a contextual model on information literacy for GI in the case of an online distance-learning GIS program. Her model comprises a framework with five stages that students and academics need to go through when facing a spatial challenge:

- Perception, the knowledge of the nature and characteristics of GI and being able to view and understand it
- Preparation, the knowledge of capabilities, applications and limitations of GIS, allowing one to know how to make sense and use of GI and to diagnose knowledge and skill gaps
- Operation, knowing how to use GIS tools and techniques to make the GI meaningful and usable
- Communication, knowing ways of presenting and communicating solutions spatially to others
- Maintaining, having knowledge of GI as a dynamic type of data that involves multiple disciplines and various temporal and spatial dimensions for which skills and knowledge need to be constantly updated

To apply Nazzari’s framework in the developing process of a user-centric SDI, the model is related to the users’ objectives. A certain objective is mapped onto each of the stages defined by Nazzari. For example, if the users’ objective is understanding how the study area looked like at a specific moment in history and having access to spatially prepared information generated by other researchers, this objective can be related to *perception*; if a users’ objective is to model long-term developments of the area by combining various sources necessary to reconstruct past spatial dynamics, the objective is more related to *operation* and *maintaining*.

Nazzari’s model can thus be related to the users’ objectives, which reflects the complexity of the spatial questions and the concepts they deploy in their research and hence their spatial thinking skills. However, in order to relate such research to the technological SDI components that need to be developed, we propose to extend the model with the researchers’ technological

GI-skills. Because of the fast development of IT and technological components, the technical skill level of the users can be compensated by these technological components (Van Manen et al., 2009; Goodchild, 2006; Hennig et al., 2013). Therefore, we call for a distinction between GI-literacy related to spatial thinking skills and objectives, for which we apply Nazzari's framework, and GI-literacy related to technological skills, for which we propose a 4-tiered scale: (1) no GI-knowledge or praxis (e.g., users who understand basic web viewer, but are not familiar with desktop GIS software); (2) basic GIS users (e.g., those familiar with GIS desktop software and basic skills for analysis); (3) advanced GIS users (e.g., those familiar with more complex GIS analysis and understand server technologies); (4) highly advanced GIS users (e.g., those that conduct complex GIS analysis with large data sets who are able to organize their own servers). Technical understanding of how to use the tools is different from understanding how a research discipline can be studied with the help of spatial questions and concepts. The combination of these two aspects is what we refer to as GI-literacy. Approaching GI-literacy from two angles enables us to clearly identify any gaps between spatial thinking skills and technological skills, which can be solved by implementing or developing the technical components (Table 1).

Table 1: Overview on the effort to be put into developing tools for different levels of user GI-literacy

Character of SDI objectives				
Maintaining	very high	very high	high	high
Communicating	very high	very high	high	medium
Operation	very high	high	medium	low
Preparation	high	medium	low	low
Perception	medium	low	low	low
	No knowledge or praxis	Basic	Advanced	Highly-advanced
	Technological GI-skills			

Estimated effort to be put in developing the technological components

Very high	(dark grey)
High	(grey)
Medium	(light grey)
Low	(white)

2.2 SDI components

To apply the GI-literacy framework, the different technological and governance SDI components need to be discussed in detail. Having an overview of the SDI components enables us to apply them to the GI-literacy model discussed above.

Technological SDI components

Through various services, an SDI enables users to share and exchange spatial data and information. The services formulated within the framework of the INSPIRE Directive for a European SDI, as well as by the Open Geospatial Consortium (OGC), offer a clear classification: discovery, view, download, coordinate transformation and processing services (Network Services Drafting Team, 2008; Nebert, 2009; OGC, 2014). In addition to these services, we are adding upload and publishing services.

Discovery services enable users to find and discover information. In order to do so, the data set needs to be enriched with systematically formulated metadata about subject, keywords, data quality, category, the geographical extent, the projected coordinate system, date, etc. (e.g., ISO 19115; ISO, 2014). Through linking online catalogues, users are able to find the spatial information they require.

Viewing services enable users to view the geographic information. Protocols for two-dimensional viewing services have been formulated and developed (e.g., Nebert, 2009; OGC, 2006), enabling users to access digital spatial information available through a server on a variety of clients.

Download services enable users to download the information so they can edit or use it for spatial modelling on local machines. Downloading content is useful to deal with issues relating to the performance of viewing services and avoid dependency on a stable Internet, which can for example be problematic during fieldwork.

Coordinate transformation services make it possible to combine data sets that are defined in different coordinate systems. Most desktop clients have coordinate transformation tools available. However, coordinate transformation services that enable different projected data to be interchangeable as viewing services will, especially for users with hardly any GI-skills, be very useful.

Processing services make it possible for the users to query data sets and execute spatial analysis, such as overlay and proximity, on a server, and generate dynamic outputs (Lucchi and Millot, 2009). Processing services "defines how a client can request the execution of a process, and how the output from the process is handled" (OGC, 2007). It allows users to develop dynamic spatial models based on data sets stored on different servers.

Upload and publish services allow users to upload and publish newly produced or edited information. As addressed by Diaz and Schade (2011), SDI initiatives lack mechanisms to assist users to publish content. They propose a service publication profile. Legal issues and complex methods to upload and publish form a bottleneck in most SDI initiatives. Developing easy-to-use, generic publish and upload services will increase the user interaction and better serve the users' needs.

Having discussed the different services as technological components for an SDI, it must be emphasized that these are closely related to standards. Standards in metadata facilitate discovery services; standards in data format are needed for viewing services; standards in projected coordinated systems facilitate data exchange between different projected coordinate systems; standards for the services make SDI initiatives interoperable, thus enable to relate the SDI services from WP2 with the Knowledge Hub developed in WP7.

Governance

For whom, and what, spatial information in an SDI is available, and which services are allowed to be used, are also dependent on legal issues, and requires SDI governance. Although the tendency is to put data in the public domain (Kulk and Van Loenen 2012; PDOK, 2014), data with restricted access will continue to be generated and require protection. Agreements on data usage are therefore a vital part of SDIs (Box and Rajabifard, 2010). Data sets on privacy-sensitive information, or costly data that are made available only for research purposes are undesirable in the open domain. From a technological perspective, this means that, to a certain extent, user access has to be controlled through registered accounts.

Another aspect of SDI governance is which party has the responsibility to keep the services updated. Who takes care of server updates and who pays for the services to maintain availability requires ownership and strong leadership (Craglia and Annoni, 2007). For HERCULES, the long term viability of the infrastructure is ensured by the Knowledge Hub developed in WP7.

2.3 Components and GI-literacy User-centric SDI

In order to correlate GI-literacy to the different SDI components, and generate input for the development of a user-centric SDI for HERCULES WP2, we elaborate Table 1 presented in subsection 2.1 with the different technical SDI components discussed in section 2.2. The result is visualized in Table 2.

Table 2: Character of the SDI objective in relation to the technical components

Character of SDI objectives	No knowledge or praxis	Basic	Advanced	Highly-advanced
Maintaining	Processing Upload Download	Processing Upload Download	Processing Upload Download	Processing Upload Download
	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing
Communicating	Upload Download	Upload Download	Upload Download	Upload Download
	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing
Operation	Download	Download	Download	Download
	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing
Preparation	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing
Perception	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing	Discovery Transformation Viewing

Technological GI-skills

Estimated effort to be put in developing the technological components

Very high

High

Medium

Low

As stated above, we propose to divide GI-literacy into users' technical skills to perform specific tasks and the understanding of which tools are needed for pecific objectives. As shown in Table 1, the objectives have been related to the stages formulated by Nazzari, and combined with the technical skill levels of the users, resulting in an overview of the effort necessary to put into the development of GI-tools. By integrating services in Table 1, we obtain the overview in Table 2. The services discussed in subsection 2.2 have been related to the character of the objective. We assume that for all stages of the objectives, discovery, viewing, and coordinate transformation services are needed; o*peration* also needs download; *communication* requires upload and publish in addition; and *maintaining* adds processing.

For users with a low level of GI-skills, more attention needs to be paid in the developing process to the user-friendliness and usability compared with users with a high level of technical skills. Therefore, the more complex the objectives for low-GI-skilled users are, the higher the effort required to develop technological components. If the objective for the user is, for example, the *communication* of spatial information to others, but he/she has a low GI-skill level, the effort to develop the necessary download, upload and publish services for these *communication* objectives are higher than when the GI-skill level of the user is already high.

SDI governance is of vital importance and needs great attention and effort when developing SDIs. However, since these components are conceptually easily implemented – by developing login systems, work with proxy servers, and agreeing who is responsible for the maintenance – these have not been incorporated in the model presented in Table 2.

3 SDI architecture for the study of long-term landscape change

As stated in D2.1, 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.

1. An SDI can offer functionalities to integrate digital spatial data (also from different repositories e.g. different universities, governmental institutes etc.).
2. An SDI can offer functionalities to communicate historical and heritage spatial data to various stakeholders ranging from history and heritage experts to the people of the place for purposes of validation. The GI literacy of these stakeholders varies a lot.
3. An SDI can offer functionalities to process and/or download data into specialist software with which complex long term landscape change models can be developed and executed.(e.g. ArcMap, Quantum GIS, GeoDMS, MapINFO, etc.).
4. An SDI can offer functionalities to share the models and the outcomes of long term landscape change models dynamically, allowing changes to the data to automatically update the model.
5. An SDI can offer functionalities to disseminate the research results as services which, in this case, will be done as part of the Knowledge Hub developed in HERCULES WP7 and possibly also linked with existing local heritage management data infrastructures.

3.1 Scenarios using the SDI in WP2

Relating the SDI to the activities in WP2 three scenarios of usage can be distinguished.

First, the SDI will be used by the spatial modellers to integrate and share their spatial information. These users will work with the SDI to systematically store their information and share their modelling outcomes within the partners of the WP. The users can be classified as "Advanced" to "Highly advanced" skilled GI-users. All spatial modellers involved in

HERCULES WP2 have years of experience using dedicated GIS software and lecture in spatial modelling and the use of GIS software at B. Sc. and M. Sc. levels. For these users, the SDI mainly functions as a repository to integrate different data sources and process these as viewing, upload and download services. Their objective for this scenario is considered to be *Operation.*

The need to integrate processing services that allow for cloud based Grid computing has been explored, but appears to be unnecessary in the context of HERCULES WP2. Although we believe that in the future complex modelling will need such functionality, the current state of technology development and the nature of the modelling conducted, mean that developing such processing services lies outside the scope of the project.

The second scenario in which the SDI plays an important role for HERCULES WP2 is when interacting with local professionals. As stated in the Protocol for understanding long-term landscape dynamics (Deliverable 2.1 by WP2), combining the landscape biography and historical ecology research strategies promotes a focus on long term landscape change. Approaching the landscape diachronically and focusing on human-environmental interactions are leading for the modelling task 2.3 of WP2. The SDI can be used as a communication tool by providing viewing services to facilitate exchange of insights from these models with local professionals. The outcomes of the models generated as part of task 2.3 provide a heritage management instrument that will support local professionals in understanding past spatial dynamics, thus allowing them to make better heritage informed decisions. In order to do so, the SDI in WP2 requires the spatial modellers to generate custom views that can then be shared with, and used by, local professionals. By not only offering static model outcomes but also allowing the local professionals to go through the model input and bandwidths of outcomes, the professionals can provide feedback based on their own knowledge – through interactive workshops, which are scheduled to be part of WP8 – and at the same time increase their knowledge on past diachronic spatial dynamics.

The GI literacy of the local stakeholders varies from "No knowledge or praxis" to "Basic". These local professional will foremost be needing services in which custom views can be accessed. For them, the objective would be more on the level of *perception*, whereas for the modellers, in this scenario, it would be *communication*.

The third scenario is more towards knowledge dissemination of the modelling activities. These activities will take place in close collaboration with the Knowledge Hub developed in WP7. The modelling results will be presented and sustainably preserved by WP7. This scenario should also take into account the capabilities to offer the services developed in HERCULES to be implemented in provincial or municipal map viewers / data infrastructures.

3.2 SDI Architecture

A preliminary version of the schematic architecture for the WP2 SDI has already been presented as part of D2.1. It shows how the data servers are related to the clients and how the SDI aids long term landscape change modelling (Fig. 2). Furthermore, it shows how the SDI components are related and how the SDI interacts and will be integrated with the HERCULES Knowledge Hub developed in WP7.

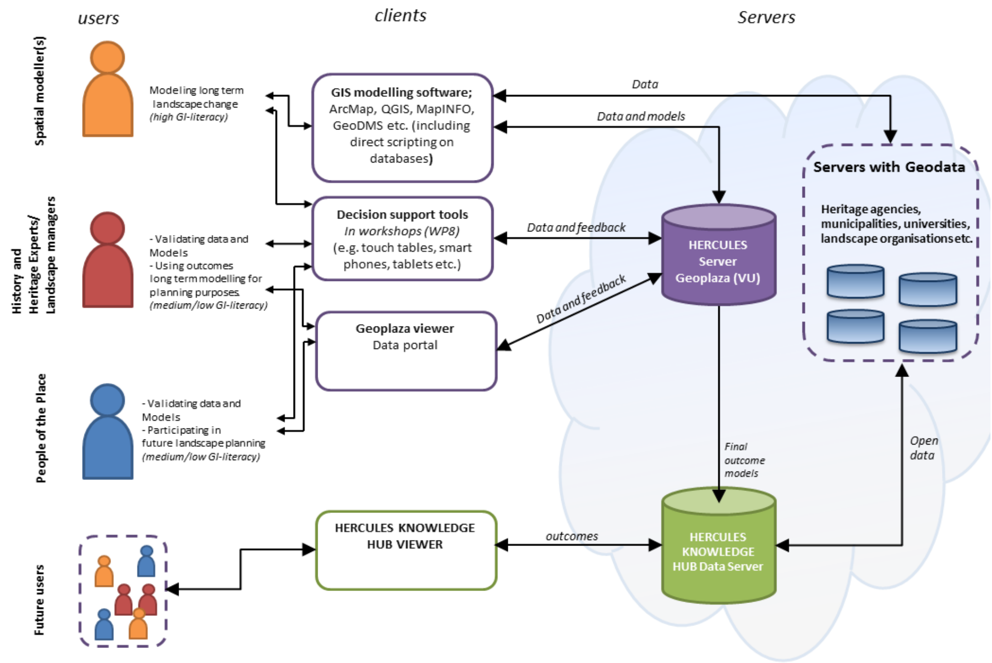


Fig. 2: Schematic overview Spatial Data Infrastructure (as pictured in D2.1)

Projecting this architecture to the scenarios sketched is presented in Fig. 3.

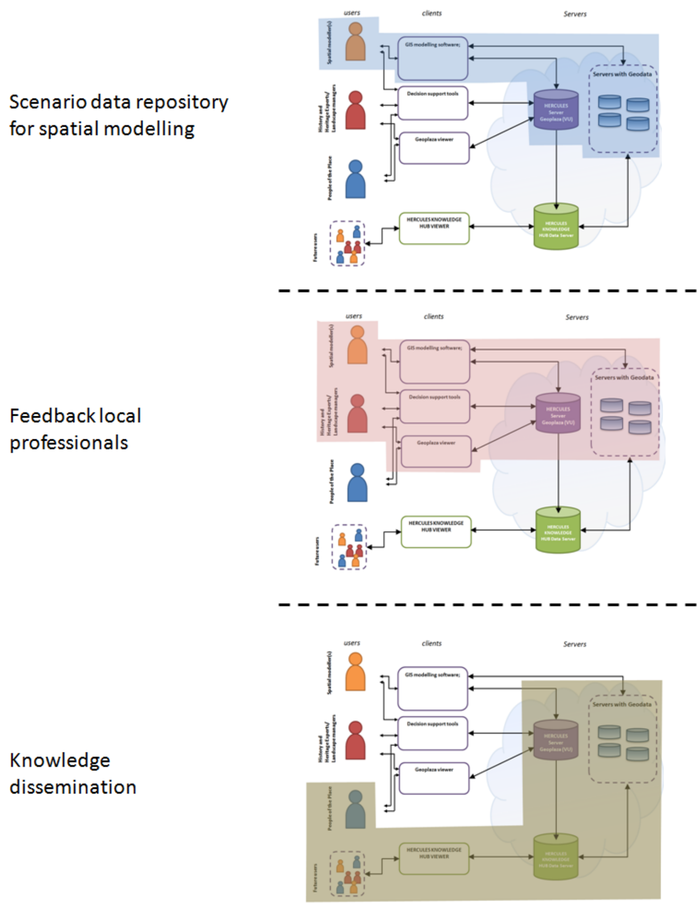


Fig. 3: Scenarios projected on SDI architecture

3.3 Technological components implemented for SDI

The SDI that has been developed exists of several components supporting different functions.

Mapping services

The infrastructure developed offers a variety of servers through which the data can be processed into map viewing, processing and download services. The servers that are available for the WP2 SDI are:

- Mapserver with the data stored in the open source PostgreSQL database with the PostGIS extension (http://mapserver.org/ , http://www.postgresql.org/ , http://postgis.net/). http://mapsrv.ubvu.vu.nl/cgi-bin/mapserv? ;
- ArcGIS Server 10.3 installed on an Amazon Cloud instance. http://54.228.203.57:6080/arcgis/rest/services ;

The Mapserver is mainly for mapping services that are meant to endure on the longer term and can be used for other purposes as well. The ArcGIS Server is put in place because of its strong integration with the commonly used GIS software ArcMap. Having the ArcGIS server in place allows the modellers to easily upload their model results through ArcMap to the server, thus easily producing mapping services (Web Mapping services, Web feature services, Web Coverage Services) (A manual on how to use the ArcGIS server be found here: http://geoplaza.vu.nl/cms/images/stories/manuals/Tutorial_upload_map_to_server.pdf).

The mapping services produced on these servers are all according to the mapping protocols formulated by the Open Geospatial Consortium (http://www.opengeospatial.org/), allowing the services to be interoperable with various clients (i.e. desktop and mobile dedicated GIS software and/or web mapping instances).

Content Management

To allow users to search through the metadata – as required for scenarios 2 and 3 – and create custom interfaces with additional information on what is shown (scenario 2 and 3), the open source Content Management System (CMS) *Joomla!* (http://www.joomla.org/) has been implemented. From there, the services can be found and then be integrated into various desktop client (e.g. QGIS, ArcMap, MapInfo, etc.) or visualized through a web viewer. For the visualization of the mapping services through a web map the open source java script library Openlayers has been implemented (http://www.openlayers.org/).

To create custom web maps we have developed an online tool in which functionalities of Joomla and Openlayers are integrated. This provides functionality that allows the modellers to share the modelling results with local professionals. A manual on how to do so can be found here: http://geoplaza.vu.nl/cms/100-support/211-create-and-publish-map-view-article#publish

4 SDI Content

4.1 Data categories for long term landscape studies

As presented in D2.1 (Kolen and Crumley et al. 2014), the data required for the study of long-term history of landscapes and ecosystems will have to come from various sources. Optimally, these will include a combination of the following data.

- Data and information that (can) inform landscape researchers and stakeholders (spatial planners, landowners, heritage managers, local interest groups, etc.) about the natural characteristics and physical properties of the landscape, both past and present, like geological and soil data, soil maps, digital elevation maps, palaeo-geographical maps, botanical data, data on climate and climate change, etc. Especially when it comes to reconstructions (or more precisely: simulations) of past landscapes, uncertainty on how the landscape must have functioned appears to be challenging and requires input from physical geography experts.
- Data and information that (can) inform landscape researchers and stakeholders about social economic land use and land use systems, both past and present, like archival sources, cartographical databases, archaeological databases (e.g. large-scale vectorised excavation plans and survey databases), specific soil data and botanical data, databases for historical landscape features, monuments and historical urban structures, etc.
- 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.

4.2 Data and spatiotemporal scale

It should be noted that the feasibility of integrating all four data types depends on the scale at which the modelling is conducted. The smaller the area and temporal scale, the more sophisticated the model can be. To date, most research conducted at regional level on long-term dynamics have focused primarily on physical aspects of the landscape. Through innovative methods, techniques, and technologies the WP2 team is attempting to avoid this preoccupation with the physical landscape and present new directions of research that genuinely provide opportunities to incorporate socio-economic, political, religious, and ideological parameters in the model. The SDI plays a primary role in these attempts. The following section therefore discusses the status of the two main case study landscapes for WP2. Although the progress of the modelling activities varies between the two, it is important to describe for both the data sources used and how we foresee to use the modelling output in discussions with local professionals. A full report on the dynamic modelling will be provided as part of Deliverable 2.3 which also marks the end for WP2 in HERCULES.

4.3 Case study 1: The Dutch Delta, the area around Nijmegen

4.3.1 Description of case study landscape[2]

Parts of the Dutch river landscape were occupied already during the Mesolithic and Neolithic. Initially, land use will have been limited to the stream ridges of the rivers and the adjacent parts of back swamps, as well as on Pleistocene river dunes and their surroundings. In the Middle and Late Bronze Age, significant sections of the stream ridges were transformed into true rural landscapes, with scattered (and roaming) farmyards with associated burial mounds, gardens, field systems, and roads. This rural landscape was part of a mosaic environment with forests, wetlands, and more open cultivated areas. In the Roman Period, the study region formed the Northwestern 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. 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. 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 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 was sometimes dammed 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. 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.

Within our study landscape we (i.e. the VUA team) have zoomed in to a smaller case study area. This has allowed us to directly involve local stakeholders and build on knowledge generated in previous studies. The area of interest exists of eight municipalities around the city of Nijmegen (i.e. Beuningen, Druten, Groesbeek, Heumen, Millingen aan de Rijn, Nijmegen, Overbetuwe, Ubbergen and Wijchen; Fig. 4).

[2] Based on the description provided in Deliverable 2.1.

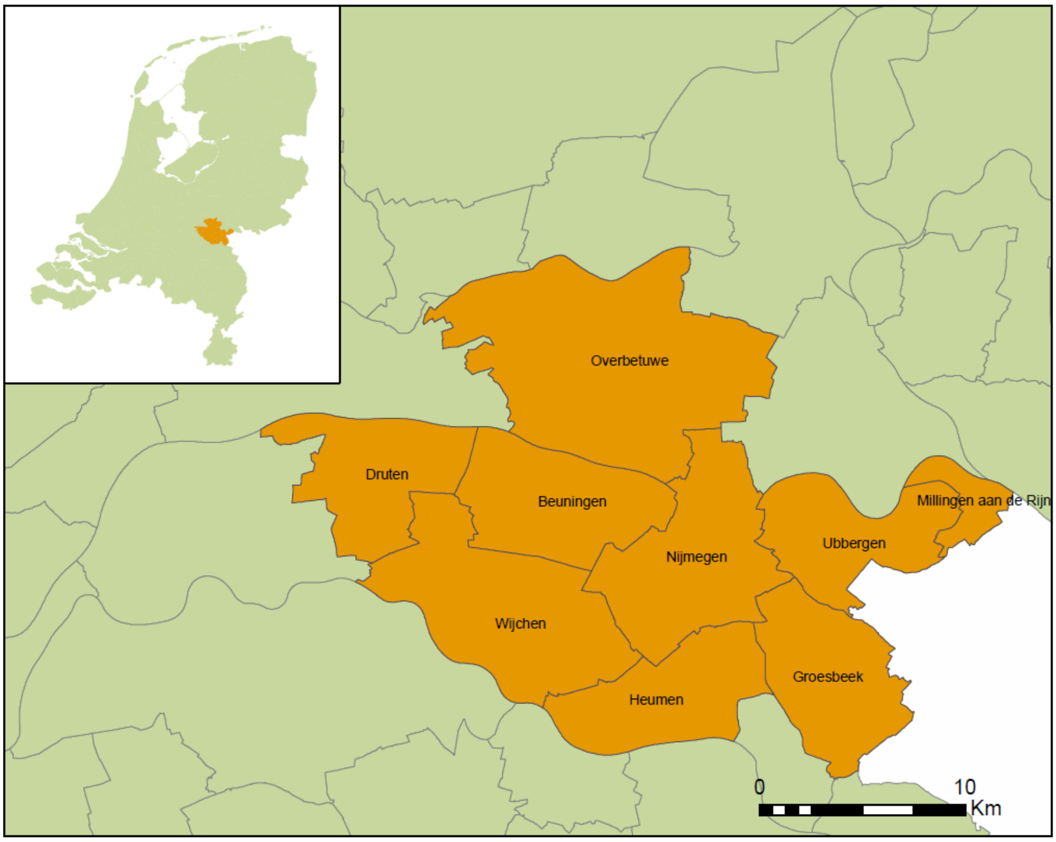


Fig. 4: Selection from case study landscape

4.3.2 Evaluation of existing models for assessing long term landscape change for heritage purposes in case study area

Previous initiatives for modelling long term landscape change for the study area could not be found. The closest works we could identify are the Archaeological Indicative Values Maps (Indicatieve Kaart Archeologische Waarden, IKAW, Deeben et al., 2008; Deeben et al., 1997; Deeben & Wiemer, 1999) and the archaeological predictive models, which form the basis for municipal archaeological policy maps. The insights and data derived from these projects are considered to be valuable input for the modelling activities in WP2.

Furthermore, connections have been made with two relevant on-going research projects, which also develop spatial dynamic models in the study area. These are the "Finding the Limits of the Limes" project (https://www.limeslimits.wordpress.com/; Verhagenet al., 2015) and the project "Dark Age of the Lowlands project in an interdisciplinary light - People, landscape and climate in The Netherlands between AD 300 and 1000" (Jansma et al., 2014). Although these projects have a more limited timeframe than HERCULES WP2 is, the insights derived from these projects can still be valuable.

Combined, the IKAW, the municipal archaeological predictive models and the findings from the Limits of the Limes project and the Dark Ages of the Lowlands projects are the starting point for the long term transformation modelling activities in the Dutch case study landscape conducted by HERCULES WP2.

IKAW

Based on archaeological predictive models, the IKAW produces a map that indicates the chances of finding an archaeological site. This map therefore functions as an archaeological heritage instrument to deal with uncertainty in the policymaking for unknown archaeological sites. The first generation of IKAW maps, produced in the early 1990s, had apparent limitations and were therefore not put to use as functional heritage instruments. Around 2000, the much improved second generation of IKAW maps was published, covering all of the Netherlands and considered sufficient for informing heritage policy. In 2007, the third generation was produced, incorporating more knowledge and including additional major improvements (Deeben et al., 2007).

The IKAW exists of a combination of inductive and deductive models. For the inductive modelling, the known archaeological sites per period are confronted with the physical aspects of the landscape (i.e. soil, geomorphology, and paleogeographic reconstructions). The known archaeological sites are not representative of past human activity because the knowledge we have about the archaeological subsurface archive is biased by the interventions made (some areas have been studied more intensively than others), the visibility of the archaeological remains varies and the available data is highly heterogeneous. The input data is therefore considered as an unbalanced sample, making inductive modelling strategies not always feasible. The IKAW therefore often combines the inductive with deductive models, which are based on expert judgements on past spatial dynamics. The extent to which inductive and deductive modelling techniques are applied varies per period and region.

A vivid debate exists on the predictive modelling techniques applied for the development of the IKAW and the added value of the IKAW as heritage instrument. The main critique for the IKAW is that the knowledge used as input is too limited:

- The research of past landscape reconstructions is limited. The knowledge on Paleogeographical reconstructions and knowledge on past vegetation is too limited, thus influencing the model (Kamermans et al., 2010).
- The deductive models are focused on physical aspects of the landscape and hardly consider social economic and political features or landscape perception and experience. The models are therefore considered as being too ecological deterministic.
- The resolution of the IKAW (500x500 meters) is considered too coarse, thus providing limited insights for heterogeneous landscapes.

Considering these criticisms, it has been debated what the status of the IKAW should be and how (far) it can be used as a heritage instrument (Kamermans et al., 2010). Academic experts in Europe and North America have contested the use of models like IKAW for archaeological heritage management because of its theoretical and methodological shortcomings (Kamermans et al., 2010).

The documentation provided with the IKAW, advises how it can be used at a national level for producing transregional policy. At the regional level, the IKAW can inform policy for regional policy and project management. At the local level, the IKAW should only be used as an indicator for the type of research that should be conducted - often supported by desktop research - in order to produce more detailed local heritage management maps (Deeben, 2007).

Archaeological policy maps at the municipal level

In the Netherlands, every municipality is obliged to have an inventory made of the archaeological heritage as input for local archaeological heritage policy and management. In order to fulfil this task, almost every municipality has produced archaeological policy maps containing an inventory of the known archaeological sites and landscapes combined with a risk management map indicating the chances of finding archaeological sites within the municipality boundaries. The predictive models used as input for the municipal archaeological policy maps build upon knowledge from the IKAW. In most municipalities, a combination of inductive and deductive predictive modelling techniques is applied in order to better understand and act on the municipalities' archaeological sub surface archive. The municipal archaeological heritage maps are subject to similar criticism as the IKAW.

Despite the methodological and theoretical shortcomings of the archaeological policy maps (Kamermans et al., 2009), the insights from the archaeological predictive models are considered valuable for the long term landscape change modelling. We have therefore collected the data used as input for these municipal models and attempted to reproduce the models used for the municipalities in the case study area around Nijmegen (i.e. Beuningen, Druten, Groesbeek, Heumen, Millingen aan de Rijn, Nijmegen, Overbetuwe, Ubbergen and Wijchen).

In analyzing the existing archaeological predictive models for the municipalities we came to the following conclusions.

- As input for the predictive models, the following datasets have been used:
  - Soil maps from 1947 until 1975 (as images rather than vector data, often manually vectorised in the context of the model)
  - Geomorphologic maps from 1975 until 1988 (as images rather than vector data, often manually vectorised in the context of the model)
  - The Dutch Elevation model (Actueel Hoogtebestand Nederland; AHN) (slope class maps have been derived from them)
  - The depth of sandy layers (The Zanddiepte-attentiekaart)
  - Historical topographic maps, older than 150 years
  - Information of known archaeological sites (find spots, archaeological monument maps from the National Heritage Agency RCE)
  - Local knowledge from local experts and amateurs
- The data sets used as input are not always available. Companies that developed these models are not eager to share the data sets, since they consider these to be commercially valuable;
- The models have not been reported in a transparent manner, making it difficult to reproduce and verify them;
- In some cases, we have noticed that the same models were applied to areas with the same characteristics, but resulting in different estimates for the chances to find archaeological sites (e.g. for the municipalities of Groesbeek and Ubbergen a moraine landscape that is located in both municipalities is assigned different expectations. Although the landscape in both municipalities is classified evenly, the archaeological expectation is classified differently.);

Like the IKAW, the municipal predictive models are mainly focused on the relationship between human settlement and the physical aspects of the landscape, without taking into account socio economic, political, and religious dimensions of human relations to the landscape.

Finding the Limits if the Limes – principal investigator: Dr. Philip Verhagen

"The project aims to apply spatial dynamical modelling to reconstruct and understand the development of the cultural landscape in the Dutch part of the limes zone during the Early and Middle Roman period (15 BC – 270 AD). It will focus on modelling economic and spatial relations between the Roman army and the local population, in particular the interaction between agriculture, animal husbandry and wood management, and the related development of settlement patterns and transport networks in the area.

The ambition is to develop quantified spatio-temporal palaeo-economic scenarios of agrarian production in a complex context. The study area and period offer two challenges in this respect. Firstly, the Roman Empire developed macro-economic policies concerning taxation and land ownership that strongly influenced the local agrarian economy. Furthermore, the Dutch part of the limes zone is located in the Rhine-Meuse delta, a dynamic fluvial environment in which the Romans developed a sophisticated water management infrastructure. An integral analysis of the socio-economic system in that area therefore has to consider all the local, regional and supra-regional factors involved in economic development. The interaction of environmental, economic and socio-cultural factors must also be examined. The Dutch limes zone is one of the archaeologically best researched areas in the world (Willems, 1986; Kooistra, 1996; Roymans, 2004; Groot et al., 2009; Vos, 2009; Heeren, 2009). Consequently, a rich set of archaeological and palaeo-environmental data has been collected over the past decades. It is therefore an ideal laboratory area to construct new models of the development of the cultural landscape." (Verhagen, 2013; https://limeslimits.wordpress.com/full-project-proposal/)

The Dark Age of the Lowlands in an interdisciplinary light: people, landscape and climate in the Netherlands between AD 300 and 1000 – principal investigator: Prof. Esther Jansma

"This research programme focuses on a period of severe pan-European economic and demographic change: the Late Roman Period (AD 300-500) and Early Middle Ages (AD 500-1000). Physical-geographical and bio-geological data point at marked climatic variability and changing landscapes during this time interval. In geomorphologically sensitive regions such as river deltas and coastal areas these changes must have had a noticeable impact on the location and lay-out of urban centres and rural settlements, land use and subsistence strategies, and connections of population centres to their economical "hinterland". Recent developments in digital infrastructure in the Humanities and Geosciences in the Netherlands for the first time enable us to study these phenomena from an interregional and interdisciplinary perspective" (Jansma et al., 2013).

4.3.3 Proposed methodology to be implemented as part of D2.3

What has become clear from the IKAW and the municipal archaeological predictive models is that the biggest challenges lie in integrating socio-economic, political, and religious dimensions of the landscape. The two research projects mentioned above attempt to fill this knowledge gap by applying spatial dynamic modelling techniques. For HERCULES WP2, we have connected with these research teams and formulated the strategy to confront the outcomes of the Land Use Scanner simulations with the outcomes from these projects. The results will relate the projects to each other and attempt to extrapolate the results to a longer time span.

The Land Use Scanner (LUS) 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 (Hilferink & Rietveld, 1998; Koomen et al., 2011). 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. The LUS models are based on the understanding that land use is primarily influenced by socio-economic developments. This concept can also be applied with relative ease to situations in the past. 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 paleo geographic reconstructions for the area over long periods of time.

4.3.4 The data and functionality the SDI should provide to facilitate WP2

As stated in chapter 4, the functionality the SDI should provide for the study landscape can be divided in three. First, as a repository to store and share the information between the project members, especially the modellers; second, as a platform to share insights with local professionals; and, third, as knowledge dissemination platform.

As input for the LUS for HERCULES WP2, we can distinguish three types of data input:

1. Ddatasets about the physical landscape to allow producing suitability maps. For this, we will combine the paleo geographical reconstructions with datasets of the current physical landscape such as LiDAR (and slope class), soil, geomorphology as input for suitability maps for past land use. Producing the suitability maps for the different periods will be done with input from previous studies, such as the IKAW and archaeological municipality models, and the two ongoing research projects outlined above. To deal with the uncertainties in these model outcomes, the suitability will be approached as different scenarios. For each period, a broadband of suitability maps will be provided.
2. Data that provide insight in distance relationships. Previous reconstructions of past networks (both roads and water) will be combined with shortest path analysis for known centres (to be performed as part of task 2.3) to produce different scenarios for distance

relationships through time. For this, known archaeological sites combined with settlement pattern studies will be used as input data.

3. Data related to indicators for the need for specific land types through time. For this, the available techniques and estimates of past demography will be needed as input for the modelling.

To make the religious and political dimensions and experiences and meanings of the landscape part of the modelling is challenging. For task 2.3 attempts it will be done for smaller time frames; integrating these into long term reconstructions will also be attempted.

A web viewer to visualize the data for the Nijmegen area case study landscape has been published as part of the VU University Amsterdam WP2 SDI component, Geoplaza. A preview of the data collection that will be used as input can be found here:

http://geoplaza.vu.nl/cms/maps/226-hercules-wp2-nijmegen-area

The data sources that are available are:

- Digital Elevation model (LiDAR)
- Archaeological policy maps

The viewer does not show all the data available that will be used as input for the modelling (for instance: soil maps, ground water data, geomorphology, slope class data). Due to legal issues we are, at this stage, not allowed to publish all the input data we have collected so far through our web viewer (i.e. paleogeographic reconstructions and known archaeological sites). For our interactions with local stakeholders, we have therefore made use of a web viewer protected by a password combined with password protected services. We anticipate that the legal issues will be solved in time for D2.3 and the Knowledge Hub.

4.4 Case study 2: Uppland

4.4.1 Description of case study landscape

The historic development of the landscape in Uppland is highly influenced by the marked regressive shoreline displacement after the Holocene. Today, the land is rising by about 5 millimetres per year, but since this process is slowing down it has historically been faster and has altered the character of the landscape considerably. This creates a horizontal stratigraphy in the landscape where prehistoric sites that were once water bound are now found further inland the older they are. The changing landscape also meant that the characteristics of the landscape changed, and new land with different geological characteristics became available for occupation. Since subsistence strategies changes over time, with different land use and landscape preferences, this means that long term settlement patterns become complex and an understanding of the changing shorelines are fundamental for understanding long term landscape use. Archaeological remains from different periods and of different character are distributed over the landscape in a reflection of these landscape changes. For these reasons, the Uppland case initially focuses on modelling the shoreline dynamics in relation to isostatic land rise. Understanding the changing landscape is a necessary first step for any landscape model and analysis, and for D2.2 the team working on the Uppland case study landscape has focused on calculating a set of shore lines for different BP values that are included in the SDI for further analysis for D2.3.

Topography influences communication networks, and thus the development of regions and territories, as has been discussed for Central Sweden area previously (Löwenborg, 2007; von Hackwitz, 2012; Wijkander, 1983). In order to understand the development of these topographically based regions it is necessary to account for the changes of the actual topography of the landscape over the period of study. This has not been done before, and this WP will perform the first extensive evaluation of how these regions can be compared to cultural changes.

4.4.2 Evaluation existing models for assessing long term landscape change in case study area

The model used for calculating historic shorelines is based on a shoreline method from archaeological sites combined with an isolation method built on analyses to determine when lakes were isolated from the sea. The benefit of using a regression equation is that the method considers both the isostatic uplift and the eustatic variations. This means that the shoreline 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 Jan Risberg et al. (2007) and further developed by Camilla 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 area of Uppland 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. While similar model have been developed by the agency responsible for the Swedish Geological Survey (www.sgu.se), they have not been published and made available, so models published by Risberg et al. and Sund are the only ones that are available for the extensive geomorphological modelling needed for this project.

4.4.3 Proposed methodology to be implemented as part of D2.3

From the set of reconstructed paleotopographies a range of analyses will be performed. Initially, a set of historic watershed catchments will be calculated for each period. 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. As part of D2.3 these watersheds will be calculated, along with prehistoric shore lines.

Water catchments can be calculated from a DEM using a set of hydrological functions in a GIS. 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 area 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. Also the quality of the DEM is important, where poor quality of the DEM might make it impossible to use for hydrological modelling. In the Uppland study area, a high resolution DEM has been produced by the Swedish Cadastral Agency (Lanmäteriet) using LiDAR technology. Since the DEM also has been edited to account for bridges this makes the data very suitable for hydrological analysis.

These datasets will then form the base for further analyses of a range of archaeological artefacts and features, and their distribution in the landscape and over the different catchment areas, interpreted as potential regions. Through a comparative analysis of historical remains a diachronic analysis of regionality will be performed. This will address questions of how these topographic regions can be traced back in time, and how they are influenced by the changing landscape that is transformed from a highly fragmented archepilago to a more homogeneous flat plain dominated by clay with extensive areas of moraine.

Using the shore line 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 4200 BC) and ending with the Viking Age (ca 1050 AD). The analyses are being conducted in GIS software.

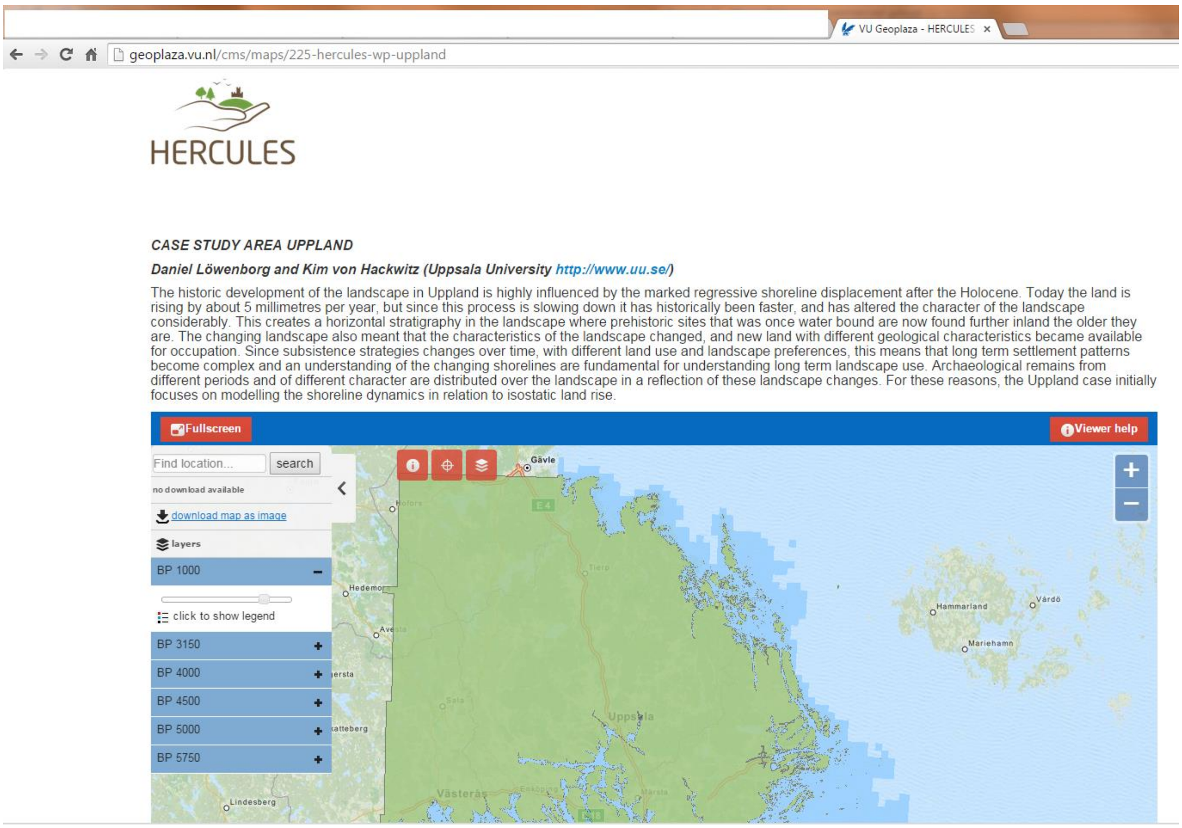
4.4.4 Required data and functionality for the SDI

The set of paleo topographical surfaces will form the base for further topographical and hydrological analyses. These are based on high resolution LiDAR data that has been corrected for hydrology and resampled to facilitate large scale analysis. The methods for calculating historic elevation, describes above, has been applied to this high resolution LiDAR data.

The regions calculated from paleo topography will be analysed in relation to a set e.g. archaeological data of find spots, archaeological features and historical boundaries. The analysis and modelling will be performed on local desktops and workstations. The SDI will function as a repository and showroom for the data, initially this will be done using Geoplaza components, at a later stage of the WP these will be integrated with WP7. Since WP2 has applied standardized protocols for the mapping services published, the services will be interoperable with the mapping interfaces developed for the Knowledge Hub (WP7). A decision on where the data sets acquired and generated in the context of WP2 will be stored at the end of the project has not yet been made. Ideally all the data will be integrated in the WP7 repository. This decision will be made towards in the context of D2.3 and will be depending on legal issues and service performance.

The web viewer for the Uppsala case study area has been published as part of the VU University Amsterdam WP2 SDI component, Geoplaza. A preview of preliminary modelling results can be found here:

http://geoplaza.vu.nl/cms/maps/225-hercules-wp-uppland



Due to legal issues the elevation models which lie at the basis of this modelling are not published as part of the viewer.

The web mapping services URL is:

http://54.228.203.57:6080/arcgis/services/HERCULES_WP2/Uppland_Shorelines/MapServer/WMSServer?request=GetCapabilities&service=WMS

(Please note that the services have not been fully tile cached yet since at this stage this is not needed. This optimisation will take place in at a later stage in the project.)

5 Relationship to other WPs of HERCULES

Firstly, the WP2 SDI has taken into account the definitions related to heritage landscape analysis and management defined in WP1.

Secondly, the WP2 SDI is closely related to the WP7 Knowledge Hub. To date, within WP2, components of the Geoplaza platform have been used to present and share preliminary modelling output with the local professionals. However, the final output and the creation of a showcase interface will be done making use of the Knowledge Hub. Since WP2 has applied standardized protocols for the mapping services published, the services will be interoperable with the mapping interfaces developed for the Knowledge Hub. Furthermore, a decision on where the data sets acquired and generated in the context of WP2 will be stored at the end of the project has not yet been made. Ideally, however, all the data will be integrated in the WP7 repository. To this end, the WP2 SDI has adopted standardized data and metadata standards to facilitate such transfer to the Knowledge Hub servers. The final decision on this will be made in the context of D2.3 and will be depending on legal issues and service performance.

Thirdly, the WP2 case studies Voorema and Rhine-Meuse are subject to local workshops organised in collaboration with WP8. The data management and modelling visualisation conducted with the help of the WP2 SDI provides important input for the workshops. In these workshops, the WP2 researchers not only seek to validate the data and models used, but also explore with local heritage professionals the added value of the visualisation tools. Such tools with include a biographical-historical ecology presentation of landscape change through a cartographic reconstruction.

6 Conclusions

This second D2.2 of WP2 has outlined the progress to date with the development of an infrastructure that supports interdisciplinary research of long term cultural landscape change. An innovative methodology has been presented that underpins the user-centric development of the infrastructure, taking full account of the needs of the researchers in terms of data and functionality needs. This tool supports the modelling activities within the WP2 (Task 2.3), advances the interactions with local stakeholders (in collaboration with WP8) and the dissemination that will take place as part of the WP7 Knowledge Hub.

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