Chapter 6

Conclusions and Discussion

In this dissertation the implications and opportunities of the digital revolution in science for the research into the archaeological, historical and heritage dimensions of landscape have been studied from a GIScience perspective. This research has identified four challenges in landscape research for which GIScience methods and tools are hypothesised to offer innovative solutions and create new research opportunities. These challenges concern:

i. the growing corpus of spatial information generated by the digitalisation of historical sources and archaeological research;
ii. inter- and transdisciplinary interactions for heritage planning purposes;
iii. the analysis of complex and multi-layered landscapes;
iv. the analysis of the processes at work in long-term landscape change on a regional scale.

The challenges have focussed on topics that are related to methods that produce, process, analyse and visualise Big Data. These form the core topics of this dissertation and have been thoroughly researched by means of four case studies. The cases are best practices that provide valuable insights on how to apply, develop, and evaluate GIScience methods and tools. The dissertation evaluates the opportunities of Big Data for landscape research, and stresses the importance of a Spatial Data Infrastructure (SDI) in that context. It provides a solid framework for a user-centric approach, stimulates the use of Free and Open Source Software (FOSS), and advocates the development of a (national) SDI for academic landscape research. The research has been approached through the GIScience framework proposed in Chapter 1. In this framework, GIScience is seen as a combination of four components: the organisational, the data, the analytical, and the visualisation and communication.

1. Overview of chapters

The dissertation began in Chapter 2 with a qualitative analysis of the development and implementation of an SDI for the research on the archaeology, history, and heritage of the landscape. This chapter provided an overview of the diverse types of researchers involved, and stressed the importance of users’ GI-literacy consisting of the spatial-thinking skills and technical skills necessary for handling geospatial information to perform a specific task. Moreover, it emphasised the importance of clear governance and leadership in SDI development and maintenance. Furthermore, it prescribes a user-centric approach in which a top-down (expert-driven) analysis forms the first step in an iterative development
process. In Chapters 3 to 6 the insights from the qualitative analysis led to a conceptual technological architecture of an SDI which forms the basis for the specific case studies. Chapter 3 has introduced and evaluated a method to facilitate inter- and transdisciplinary knowledge exchange between various landscape researchers. By translating the Biography of the Landscape approach (Kolen et al., 2015) into a retrospective cartographic reconstruction, and by implementing this reconstruction in an interactive geospatial app for a tablet, a digital research instrument – the Digital Cultural Biography (DCB) – was developed that extends the heritage management arrangement tools recommended through Historic Urban Landscape (HUL) (UNESCO, 2011). To evaluate the DCB approach, a group of architects was given the task to design an open area in the neighbourhood Testaccio in Rome which is amidst various prominent archaeologically and historically significant features. Their task was to integrate the multiple historical dimensions in their design, and to allow visitors to experience that as such. By letting half of the participants use the DCB and the other half work without it, the impact of the DCB tool and method could be measured systematically. To do so, the chapter introduced an evaluation framework using a combination of established methods on technology acceptance – in which a distinction is made between usefulness and ease of use – and appreciation by looking at stated preference and revealed preference methods and ex-post and ex-ante examinations to measure knowledge. Furthermore, the resulting designs have been qualitatively analysed with respect to how the temporal dimension was included, and which design methods have been used to inform visitors explicitly about the historical and heritage dimensions.

Chapter 4 described the opportunities provided by geospatial technologies for 3D Big Data on multi-layered and complex landscapes. Based on a user-requirement analysis, a workflow was developed to obtain a reliable virtual 3D landscape. A data infrastructure was implemented to use this virtual 3D landscape for various analytical and visualisation purposes. From a technical point of view, the core of the developed instruments is a central server that contains the data and processing services. On top of this server, a web application was developed which users with low IT literacy can use to visualise and analyse the virtual landscape. Furthermore, a desktop application was developed with which the 3D data can be added and adjusted. The latter is meant to be used by more advanced Geospatial technology users. Finally, the data can be downloaded in order to use them in standard 3D software packages.

Chapter 5 introduced a simulation modelling framework to analyse long-term land-use change on a regional scale. The modelling framework combined social and physical environmental aspects by integrating knowledge from the economic domain with knowledge from the archaeological, historical and palaeo-environmental domains. The framework was applied to test hypotheses for the land use in the western part of the Lower Rhine Delta during the early and middle Roman periods. For this, a simulation tool was configured, which allocates the land use according to various demographic and other scenarios for long-term causation. By working with multiple scenarios, the simulations deal with uncertainties in understanding past spatial dynamics and processes.
2. Answers to the research questions

The central research question in this dissertation is: *What significant contributions can recent methods and technologies from GIScience make to innovate the research on the archaeological, historical and heritage dimensions of landscape in light of the digital revolution in academic research?* In order to answer this main question, four research questions were formulated which formed the basis for the case studies presented in the different chapters.

**Q I:** *How can a Spatial Data Infrastructure be developed to facilitate the research of the historical, archaeological and heritage dimensions of landscape in order to enhance transdisciplinary and interdisciplinary research, taking into account different disciplinary backgrounds, objectives and IT- and geospatial skills?*

Chapter 2 presented a user-centric approach to the development of an SDI for the research on the history, archaeology and heritage of European landscapes. It highlighted that successful SDI development requires a clear understanding of the researchers involved. They should be characterised in terms of their research goals and methods, their spatial thinking, and their technical skills. Together, these considerations should determine the development and application of appropriate geospatial technological solutions. Furthermore, the chapter demonstrated that geospatial technologies are currently rapidly developing, this generating innovative opportunities to approach landscape research. The tools should therefore be approached as separate components which can be reused and built upon to develop new functionalities. The chapter advocates that, from a sustainability perspective, the various data services should be interoperable with different clients, making standards an essential component as well. In order to ensure this, the leadership or governance in the process of developing and maintaining an SDI is essential too. Without clear leadership and understanding of sustainability and contingency plans, SDIs are deemed to fail.

**Q II:** *How can innovative landscape approaches be translated into digital GIScience interaction tooling for transdisciplinary and interdisciplinary knowledge exchange? How can these be developed and how can these be systematically evaluated?*

Three chapters contributed to answer this question. Chapter 2 provided the framework on how to do this from a conceptual point of view, placing the user’s technological and spatial thinking skills at the centre. In Chapters 3 and 4, this framework was applied by developing two different types of the geospatial interaction instruments in the context of two case studies. This research question can be split into two parts. The first deals with how landscape approaches can be translated into digital GIScience tooling, and the second with how the tooling can be evaluated.
For the first part of QII, Chapter 3 developed a digital knowledge exchange method and instrument: the DCB. The presented method aimed at facilitating various interactions between multiple stakeholders. However, it has been applied and thoroughly analysed specifically for the exchange of knowledge derived from past-oriented research, like history and archaeology, by future-oriented architects. The research shows that the DCB has been adequately developed according to the usability and content needs of the users. Furthermore, it shows that most of the participants would be willing to allocate a part of their budget to develop a DCB tool in new projects. Most architects are positive about the DCB tool and experienced added value. They expressed the opinion that this innovation would aid their work process. Looking at the designs themselves shows that most of the architects incorporated diachronic long-term history. As for the methods to represent the historical narratives, most of the designs referred to past spatial patterns. This outcome is in line with the core concept of the DCB method, which leads to the conclusion that the DCB method meets a general concern amongst the architects that participated. The research demonstrates that the method has much potential for enhancing inter- or transdisciplinary interactions, providing a solid starting point for the further development of such research instruments.

Chapter 4 demonstrated how 3D geospatial technologies can successfully be developed for analysing complex and layered archaeological and heritage landscapes. The tools developed in this case are in line with the SDI approach presented in Chapter 2. The interaction tooling developed offers a technological solution to deal with complex and layered landscapes, and allows researchers with multiple backgrounds to analyse complex structures in their spatial context. Regarding Big Data, this case offers a technical solution to process and visualise a complex data set. Furthermore it offers a method for inter- and transdisciplinary knowledge exchange of complex multi-layered landscapes between differently skilled researchers.

Considering the second part of QII, Chapter 3 proposed an evaluation framework to systematically analyse the impact of trans- and interdisciplinary knowledge exchange tooling. The evaluation framework combined multiple established evaluation methods. The presented research demonstrated that the evaluation framework is useful, but requires improvements when applied in future contexts. The methods for measuring the knowledge and appreciation of the tool must be further enhanced. In addition, it is clear that the evaluation framework must be improved by paying attention to the timing of the survey and by enlarging the sample size.

Q III: How can a useful 3D application be developed allowing landscape researchers to share and analyse complex and layered historical, archaeological and heritage landscapes?

Chapter 4 demonstrated the potency of 3D technologies for the study of complex and layered landscapes. By using these technologies, the landscape researchers can now analyse their study area differently, potentially leading to new knowledge. Furthermore,
the researchers are provided with a method to share their research results with other scholars. As the research of the Via Appia is still ongoing, the full impact of the 3D technologies cannot yet be determined; however, the preliminary results are already highly promising (see De Hond, 2014). From a technical point of view, the research in Chapter 4 demonstrated opportunities of web-services for processing large data sets and dealing with issues concerning versioning. Since most of the tools have been developed as FOSS, they can be reused by other research teams or for other purposes. The openness makes the method and produced data more resilient to technological advances. The point cloud web viewer has, for instance, already been reused to visualise the massive point cloud for the Netherlands (Martinez-Rubi 2015). As identified by Von Schwerin et al. (2013) and Forte et al. (2012), 3D digital research tools are highly difficult to develop without significant budgets and the participation of skilled software and database engineering researchers. By using FOSS, this obstacle can potentially be overcome and provide a way ahead for other research teams. 3D geospatial technologies to analyse complex sites are maturing, but are expected to still remain relatively experimental in the upcoming years.

Q IV: How can long-term spatial developments be analysed using simulation methods and models that integrate cultural and natural factors through multiple scenarios?

Chapter 5 proposed a simulation modelling framework that integrates cultural and natural factors. Considering long-term change, the framework included causalities between various periods. Due to the many uncertainties, the modelling framework has foremost been developed and has demonstrated its value as a tool to test hypotheses and inform new hypotheses. From the case study in which the modelling framework was applied, interesting leads for future research directions emerged. The chapter thus showed the potency of the simulation framework and tool as a research instrument to integrate knowledge from multiple disciplines in order to test hypotheses, and to generate geospatial information that potentially could inform new research questions.

3. Conclusions

To answer the main research question of this dissertation: What significant contributions can recent methods and technologies from GIScience make to innovate the research on the archaeological, historical and heritage dimensions of landscape in light of the digital revolution in academic research?, five aspects are identified.

- First, this dissertation has provided an answer to how methods and technologies from GIScience can aid the research on the history, archaeology and heritage of the landscape. The research has shown that the opportunities of 3D technologies for the analysis of complex sites are promising, that these are still relatively new and that, especially from a technological perspective, more developments need to take place. Furthermore, the research has demonstrated that a simulation modelling framework and tools that include social-cultural factors to analyse long-
term spatial processes is an upcoming field, but that the impact of this type of research is still limited due to its complexity. Finally, it has shown how an innovative landscape approach, i.e. the landscape biography, can be translated into a geospatial instrument to facilitate trans- and interdisciplinary knowledge exchange interactions.

- Considering the growing corpus of spatial information in landscape research, all chapters have provided valuable insights into the technological innovations related to the concept of Big Data. The research has demonstrated that new methods and tools are required and that an infrastructural approach is inevitable. The DCB approach presented in Chapter 3 anticipates a data-rich situation for landscape research. The changing data landscape will allow methods such as the DCB approach to be applied in a more extensive and standardized way. The study has thus not only demonstrated the potential value of the DCB approach to foster trans- and interdisciplinary knowledge exchange, but also the potential for GIScience SDI tooling. Chapter 4 has offered a strategy for 3D data landscape information which exceeded the available technological capabilities. It offers a technological solution by developing different visualisation and analysis interfaces to handle these large and complex datasets.

- This dissertation has also demonstrated how to develop geospatial technologies for different users with heterogeneous disciplinary backgrounds and various IT- and geospatial-skill levels, by applying a user-centric approach. The theoretical framework for this has been provided in Chapter 2 and implemented in Chapters 3 and 4, for which geospatial tools were developed in close collaboration with the users. In Chapter 3 this led to the use of innovative geospatial technological instruments, i.e. mobile tablets. In Chapter 4 a data infrastructure was set up with various clients for different purposes aimed at different types of users.

- Fourth, the research presented in this dissertation shows the advantages of working according to an infrastructural approach. Chapter 2 provided the theoretical background, while in Chapter 3, the advances of an SDI are demonstrated by showing the type of tools that could be developed once the data structures are in place. Considering Chapter 4, the advances of complex data services which could handle complex 3D data and which allowed different users to access up-to-date information was clearly demonstrated. Also noteworthy is the application of FOSS tooling. By applying FOSS, other researchers can build upon the tool we developed, making the method more resilient to technological advances.

- Fifth, this dissertation shows how GIScience methods and technologies can be systematically evaluated, and how these evaluations can teach us how to improve them. It is interesting to point out the difference between the ease of use and the usefulness. These considerations should be taken into account when applying a user-centric developing strategy.
4. Future Developments and Perspectives

This dissertation has provided valuable insights on the role of GIScience for landscape research, addressing issues that arise from the overarching trend in academic research where the corpus of digital data is growing exponentially, which calls for new methods and technological developments. Contrary to the trend of Data Science, where the data-driven approaches are believed to be significantly changing academic research in general, this dissertation has demonstrated the value of interdisciplinary research teams to apply new methods and co-create technologies. The dissertation applies a theory-driven research approach. It advocates the embedding of GIScience, Data Science and landscape research in multidisciplinary research teams. In other words: researchers with an interdisciplinary perspective who understand the main issues in both landscape research and GIScience are necessary to innovate landscape research in the perspective of the digital revolution with respect to Big (spatial) Data.

Considering the future perspectives and directions for follow-up research, all the case studies demonstrate the added value of applying GIScience methods and digital tools. Summarizing the perspectives on future research for the individual cases, the following aspects can be identified:

- Concerning the trans- and interdisciplinary knowledge exchange tooling, the next step would be to research whether such tooling could be developed for a different interaction between, for example, heritage experts, architects, the local inhabitants and people that visit the area. In that regard, it would be interesting to do further research into participatory planning GIScience tools from the Geodesign domain. Additionally, it is worth looking into serious gaming opportunities (e.g. Scholten et al., 2016).

- For the analysis of complex multi-layered landscapes, 3D technologies are seen as valuable tools. Although they are currently still at a rather experimental stage, it is expected that these tools will develop into mature tools that could be broadly available. Furthermore, it is expected that complex 3D analysis tools will, on the one hand, become easier to use, and, on the other, will be more complex, with features such as shadow analysis, erosion modelling and movement of clouds. By using and developing various components as FOSS, other research teams would not have to start from scratch; moreover using FOSS would allow a ‘tailor-made’ user-centric approach for individual projects. This is stimulated by the trend of making 3D geospatial data sets, like the Dutch LiDar AHN data sets (https://www.pdok.nl/nl/ahn3-downloads), available as open data.

- We currently see a trend towards developing platforms which allow users to share 3D models of archaeological structures, objects and reconstructions in their spatial context (e.g. 3D Hop, 3D Icons, Sketchfab11). Currently, these models do have searchable metadata. However, the capabilities of these platforms are mostly

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limited to viewing and basic measuring of the objects. It is foreseen that defining objects in virtual 3D environments will become more important (e.g. Von Schwerin et al., 2016; Dell Unto et al., 2015). This would enable 3D reconstructions to be shared in a scientific transparent way, and to use 3D technologies to register landscapes in 3D. In that regard, it is interesting to further investigate the opportunities and capabilities of Building Information Models (BIM).

- Research on the simulation framework and tools to understand long-term spatial dynamics has demonstrated how knowledge can be integrated from different disciplinary fields. The research shows interesting leads for the case study’s specific hypotheses. The simulation modelling framework in its current form has therefore demonstrated its value for rough estimates on land use. The modelling framework proves to be a valuable instrument to test hypotheses, but also to potentially aid in constructing new hypotheses in the study of long-term landscape change – one that generates new questions for empirical landscape research.

To conclude, this dissertation has demonstrated that recent developments within the GIScience domain have a great deal to offer for landscape research. It has shown the opportunities provided by GIScience for better exploring, exchanging and combining the increasing amount of digital data and information about the archaeology, history, and heritage of the landscape. It is urgent to make use of the knowledge from this dissertation to generate additional new insights on past dynamics and the incorporation of past features in the current landscape. The results of the dissertation can be an important source of inspiration: the results are evidence of a broader breakthrough in the way to look at and think about the landscape. Landscape representations are no longer static flat-drawn but are digital, multi-layered, dynamic, and in virtual 3D.
References


