Creating a digital twin of the archaeological landscape at Þingvellir, Iceland

Research Project Plan

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Background and Motivation

Norse settlement of Iceland started around 870 AD, and within one generation an estimated 20 000 people settle in the previously untouched landscape (Schmid et al. 2021). These settlers would have encountered a landscape very different to what we can observe today, with much of the vegetation disappearing after Landnám (land take), due to anthropological and environmental factors.

Much of our knowledge and understanding of Icelands settlement goes back to the 12^{th} century when stories and songs previously transmitted orally were written down (Hartman et al. 2017, Smith 1995). Sources such as the Book of Icelanders (íslendingabók), Book of Settlements (Landnámabók) and sagas of Icelanders (Íslendingasögur) recount the history of individual families, farms, their land claims and the environment in rich detail. These have been geo-referenced as part of the Iceland Saga Map Project (Lethbridge & Hartman 2016)(sagamap.hi.is). Smith (1995) cautions against the use of them as primary data sources, as they may be influenced by 12^{th}-14^{th} century politics and contain exaggerations of events hundreds of years prior. One example is the description of Iceland as fully forested at the time of settlement in the Book of Settlement, whereas modern estimates put it between 15-39% (Dugmore et al. 2009, Traustason & Snorrason 2008, Trbojevic 2016).

It is through the use of tephrochronology and radiocarbon dating that a settlement and environmental change timeline can be established. In particular the Landnám tephra layer (LTL) which has been dated to 871-877 AD, can distinguish the pre-Landnám landscape from that of post-Landnám, through the presents of pollen or settlement evidence below/above the tephra band (Gathorne-Hardy et al. 2009, Schmid et al. 2021).

The archaeological landscape at different points of time have been recreated for other studies from the Icelandic Forest Research, Iceland Institute of Natural History and academia (Church et al. 2007, Shotter 2022, Traustason & Snorrason 2008, Trbojevic 2016), however they created 2D polygons on a modern day map. By adding a third dimension to maps the study of the past landscape can be improved (Murphy et al. 2018, Stewart 2019), as the settlers would have seen the land at eye height, not on a map. Settlement decisions and the creation of networks across an archaeological landscape become more meaningful when considering what environment they would have faced.

Through technological advances we no longer depend on 2D maps to study archaeological landscapes, the advances within Geographic Information Systems (GIS) and game engines are driving 3D mapping. This is creating the potential for improved analysis and immersive visualisation for end users. Allowing for a better understanding the past landscape and the potential to better adapt to future changes. The use of computer-aided design (CAD) in GIS is not new (Stewart 2019), neither is the use of game engines (Mat et al. 2014), but these approaches can be time and computationally intensive or behind license barriers. However, with modern open source programs modifying or populating a model with procedurally generated vegetation to create a digital twin for analysis shows promise.

To achieve this, a multidisciplinary approach will be used to collate and validate data from the different fields: archaeological, tephrochronological, environmental and literary research data will be used with modern GIS tools to recreate, analyse, and visualise the Icelandic landscape, its resources, and the networks developed across it.

Aims and Objectives

This project aims to create a digital twin of the archaeological landscape around the Þingvellir at the start of the norse settlement, through a multidisciplinary approach using literary texts, archaeological and environmental data to layer on top of a DEM.

This digital twin will enable a better understanding of the landscape early settlers would have encountered, the settlement decisions taken and consequent resource use. This can then improve the analysis of networks they created.

To that end, the following objectives are set:

O1 Re-imagine the archaeological landscape in the Þingvellir depression at the time of first settlement 870 AD.

O2 Create a digital twin of the landscape in a 3D environment.

O3 Evaluate the capabilities of the digital twin for the analysis of qualitative networks.

The evaluation of this project will address the following research questions:

RQ1 To which degree do multidisciplinary data sources agree on the pre Landnám landscape?

RQ2 What are the opportunities and limitations of creating and using digital landscape twins for spatial analysis?

Methodology

The 2x2m DEM from ArcticDEM (Porter 2018) will be used as a base for this study. The Þingvellir depression, around the Þingvallavatn (the Lake of the Fields of Parliament) was chosen due to the cultural and historical importance of the Alþingi assembly site (Sanmark 2022). It is situated in the south west of Iceland and the surrounding hills formed by volcanoes will be the natural boundary for the study (Figure 1) (Sæmundsson 1992). Archaeological finds from the early settlements in the area will be used, as described by Schmid et al. (2021).

The conceptual diagram in Figure 2 summarises the steps taken to achieve the Objectives, which will described in detail below.

To achieve the first objective (**O1**) the following work is proposed:

1. Using altitude, erosion and geological data, create a base layer for the model. This includes changing the model to reflect river flow changes, volcanic eruption, divergence along the fault line, addition and removal of soil due to erosion. Additionally, removal of man-made structures present in the DEM will be necessary.

2. Add the vegetation in the landscape through archaeological finds, literary descriptions and tephrochronological studies to create a 2D archaeological landscape. This work will include an analysis of how close literary sources and environmental/archaeological evidence agree.

3. Finally, creating 3D polygons by adding z values to create a 3D model.

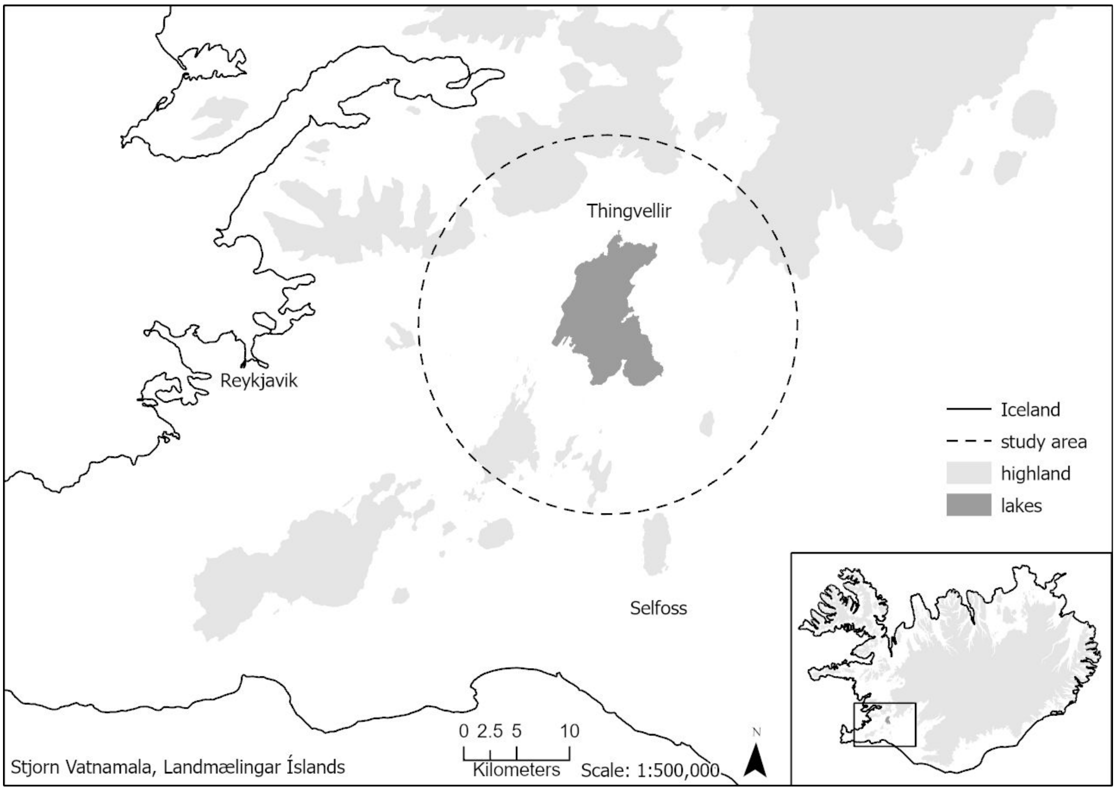

Figure 1: Map indicating the study area in the Þingvellir depression surrounded by hills (400m a.s.l. lines indicated) forming a natural boundary.

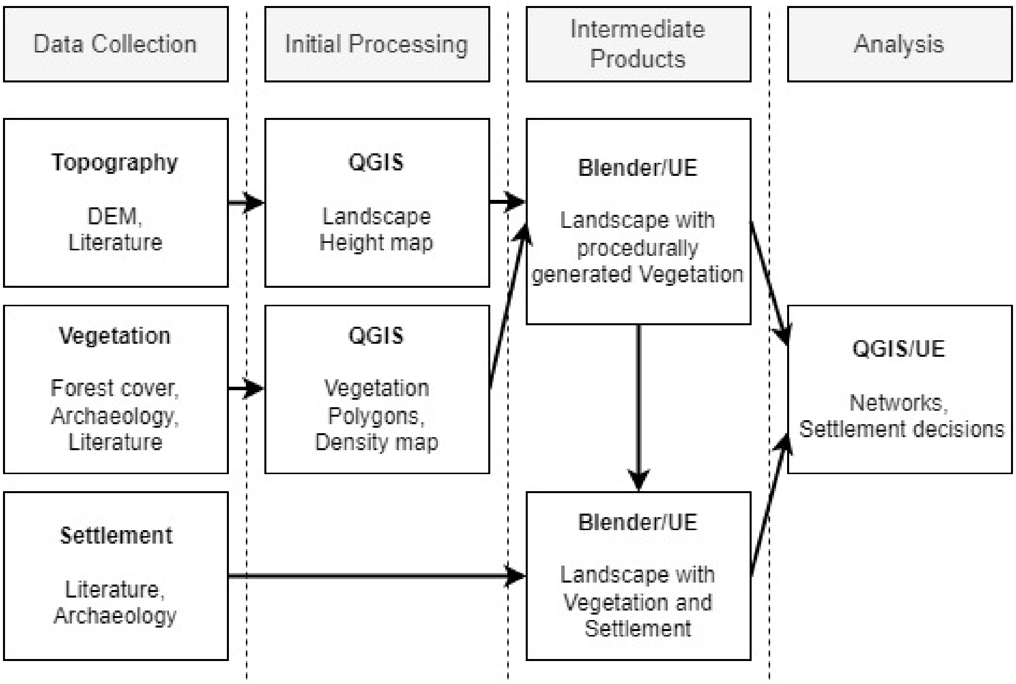

Figure 2: Workflow diagram for creating a digital twin of the archaeological landscape.

The numerous studies available on the Viking settlement should provide enough information to recreate the archaeological landscape. ArcGIS will be the limiting factor and challenge in actually creating it, especially the changes along the fault line. Regarding the recreation of vegetation, studies such as Church et al. (2007) have demonstrated how the study of charcoal pits can help infer the presence of forests; similarly Gathorne-Hardy et al. (2009) and Shotter (2022) have shown how the distribution of pollen below the Landnám Tephra Layer can help understand the evolution of vegetation in volcanic regions.

Throughout this work, the source materials listed above with be cross-referenced, highlighting agreements and discrepancies, in order to address **RQ1**.

The second objective (**O2**) requires the archaeological landscape DEM, 2D and 3D maps (created in **O1**) to be imported into the chosen the chosen tool to create the digital twin. Then, in order to complete the landscape, the area will be populated with procedurally generated vegetation. If possible, the steps to create the DEM (870 AD) will be replicated to compare ease of use.

The height maps and models need to be transferable from ArcGIS/QGIS into the digital twin tool and vice-versa, in order to consider the use of digital twins valuable for this type of spatial analysis. Comparing the creation of the maps, models and interoperability will address **RQ2**.

This closely relates to the third objective (**O3**) where the game engine model would be imported into ArcGIS/QGIS, and archaeological data (Schmid et al. 2021) will be integrated into the map in order to create a network that takes the archaeological landscape into consideration.

Tools

The GIS tools considered are the ESRI product ArcGIS Pro 3.0 and the open source QGIS 3.29. Blender (blender.org), Unity 3D (unity.com) and Unreal Engine 5.1 (unreal.com) are the tools under consideration for creating the digital twin.
The choice of tool is yet to be determined but factors to consider are:

- interoperability,
- ease of use,
- repeatability,
- availability of documentation,
- programming language and
- it should be accessible, free and/or open source.

Numerous tutorials demonstrating QGIS and Blender promote their use of open (non proprietary) file formats which helps interoperability. Both tools also allow the integration of custom python code. The recently released ArcGIS Maps SDK for Unreal Engine (developers.arcgis.com/unreal-engine) could also be a solution for 3D analysis. However being a proprietary ESRI product limits user uptake due to license fees. Unreal engine is also known for requiring significant resources.

After consulting game engineers access to the MSCGIS group research datastore was requested and granted, as the models are likely to require storage in excess of 50GB. Additionally, technical support was consulted about the required software. Once the decision has been made, as to which to use for the project it will be installed on one of the departmental computers which has a graphics card.

Goals and Risks

The goals for this project are presented in Table 1, prioritised according to the MoSCoW method:

- Must have - critical for the project's success
- Should have - core to the project's scope
- Could have - optional
- Won't have - out of scope

Must have	DEM (870 AD) using environmental changes 2D and 3D vegetation maps Digital twin of the landscape
Should have	Network analysis extending to coast (Reykjavik or Selfoss)
Could have	Extend the network analysis to other settlements
Won't have	Viewshed analysis of 3D landscape Temporal network changes (100yr time step)

Table 1: MoSCoW prioritisation of the project's goals.

Figure 3 depicts the workflow and milestones that need to be followed to ensure the delivery of Must have goals on time.

This project will be utilising specialist software (GIS and 3D modelling), and will necessitate access to high performance hardware. Beyond this and the potential loss of data this project does not include major risks. Hardware and software requirements have been discussed with the departments technical advisors as well as access to datastore to backup all data.

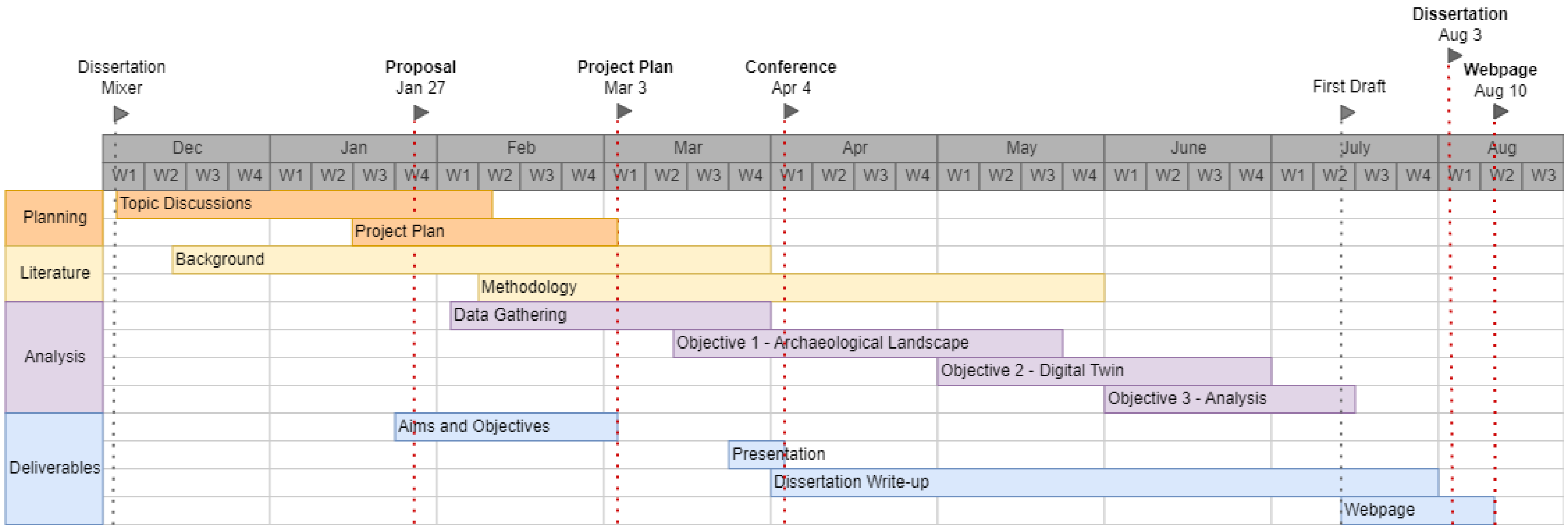

Figure 3: Gantt chart for the research project, with important dates and duration of tasks.

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