Exploring Uncharted Lands: Recreating Iceland's Lost Forests

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Abstract - As Norse sailors settled in Iceland, they were faced with a land of ice, fire and forests. Yet Iceland's landscape is now well-known for lacking trees, a situation which only amplifies the negative effects of climate change and soil erosion. To reverse this situation, efforts are made to plant and grow new forests, but a drop in funding has slowed the progress considerably. To stimulate public engagement, this work therefore proposes to develop a land cover model of Iceland's past landscape, visualising its natural forests to promote afforestation efforts. This paper first reviews the previous attempts at recreating the pre-Landnám landscape (land take phase of the settlement). Using literature describing the factors contributing to the landscape changes in Iceland, these attempts are discussed to highlight their strength and understand their limitations. Then, using a novel methodology that incorporates soil, wetness and vegetation, a model of the potential current-day land cover of the wider Thingvellir area is developed. This model is then reviewed against official land cover datasets, to highlight key findings. Finally, by incorporating archaeological and historic data, the model is revised to generate a new pre-Landnám land cover model. Several insights were made, despite the model's limitations. First, the current-day model, and the comparison with official land cover, permitted the identification of areas where afforestation efforts could be successful and prioritised. Second, the pre-Landnám model suggests a more diverse landscape compared to those previously described in the literature.

***Keywords* –** Iceland, settlement, landscape recreation, land cover model, forest

1 Introduction

The landscape one encounters in Iceland today impresses with its majestic and vast openness, but the Iceland the Norse settlers encountered 1150 years ago would have been vastly different. It seems almost unimaginable today, with only 1.5% of its land covered in forests (Traustason and Snorrason, 2008), that the country was once "covered with woods between the mountains and the seashore", as Ari Þorgilsson claimed in the early 12^{th} century (2006). These landscape changes have led to large scale erosion, increased wind speed and dust storms, with continuous loss of arable land and destruction of native habitats (Shotter, 2022). Iceland has potentially lost up to 30% of soil since Landnám (land take phase of settlement), leading to over 40% of Iceland now being classified as barren desert, despite their efforts to slow down erosion (Arnalds, 2015).

As the global climate is warming, Iceland is facing its warmest summer temperatures during the Holocene. Understanding the natural habitat in the area could improve the management and restoration efforts, for example, by deciding on areas that have the highest potential for reclamation. With the increase of forest cover, Icelandic Forestry (Skógur) is trying to rebuild what was lost in a way that will benefit the country, by improving the ecosystem resilience, preventing further soil erosion and decreasing dust storms, while also creating a carbon sink, areas of recreation, and a sustainable forest industry (Eysteinsson, 2017).

But at the current rate, the forest cover is expected to only rise by 1% within the next 70 years, putting the target of 12% by 2100 out of reach (Eysteinsson, 2017). To generate the necessary funds, public engagement must be improved, particularly that of the large number of tourists travelling to Iceland every year (2.2M predicted for 2023 (Bjarnadóttir, 2022)). This study aims to create a model that will support a better understanding of the landscape early settlers would have encountered, to improve current landscape recreations and visualisations for the wider public and increase engagement.

Past studies have researched the environmental and human impact on Iceland's environment, through diverse approaches in the fields of archaeology, tephrochronology, and pollen studies, but thus far the research has been lacking detailed studies of what the archaeological landscape might have looked like. Reconstructions have been largely siloed into their respective disciplines and are limited by their simplification, scale, location or focus on a single species. Country-scale models often overestimate the forest cover while underestimating the diversity of the landscape, particularly in wetland and mountainous areas. Whereas farmstead-scale studies are too narrow to develop a picture of the wider landscape. This paper is attempting to overcome these issues by creating a region-scale model that combines past research with current environmental data and historic documents to fill in knowledge gaps when creating a landscape recreation.

Research Question

The evaluation of this project will address two research questions:

RQ1 What are the strengths and limitations of pre-Landnám landscape recreations in the literature?

RQ2 How well can current-day environmental data sets, with the addition of archaeological data and historic documents, support a new model of the pre-Landnám landscape?

To that end, this paper will:

- Review the literature on factors contributing to landscape changes in Iceland and use this knowledge to assess the landscape recreation models previously developed.
- Critically evaluate environmental datasets about the wider area surrounding Thingvellir and the capabilities in merging those into a current-day model of the potential land cover.
- Re-imagine the pre-Landnám landscape in area surrounding lake Thingvallavatn at the time of settlement by including historic and archaeological data to the current-day model.

2 Background

This section highlights the existing literature relevant to this paper. After presenting the specificities of the Icelandic landscape, it pays particular attention to the wider area around lake Thingvallavatn – the chosen area for this study. It then discusses previous attempts made to model the archaeological landscape in Iceland.

The Icelandic Landscape

Iceland has a harsh environment, isolated in the north Atlantic, it took time for plants to established themselves after the end of the last Ice Age, 10,000 years ago. At the time of settlement the temperature and vegetation had just reached its maximum (Erlendsson and Edwards, 2009; Gathorne-Hardy et al., 2009), before it slowly dropped towards the 13^{th} century and reached its post settlement lowest in the 15^{th} century (Hartman et al., 2017; Gathorne-Hardy et al., 2009). The boreal climate, with little snow cover in the lowlands (below 400 m above sea level (m asl)), and lack of permafrost, in addition to the absence of grazing animals allowed for the vegetation to adapt to this specific environment (McGovern et al., 2007).

The grazing animals and agricultural practices the settlers introduced after A.D. 870 changed this landscape from an estimated forest cover between 15% and 40% (Ólafsdóttir et al., 2001; Dugmore et al., 2009; Smith, 1995; Trbojevic, 2016) to 1.5% today (Traustason and Snorrason, 2008). The total vegetation cover changed from 54%-65% (Arnalds, 1987; Ólafsdóttir et al., 2001) to 28%-45% today, depending on the classification (Dugmore et al., 2009; Arnalds, 2015).

Vegetation cover is crucial to stabilise and trap the fragile andisols, which make up 89% of Iceland's soils (Arnalds, 2004). But due to the lack of large vegetation with sufficiently deep roots, erosion of large portions of soil has led to large scale landscape changes, with 15%-30% of soil lost since settlement, and over 40% of the country now being classified as a desert (Arnalds, 2015).

For better comparison between European countries the CORINE land cover classification was used to update Icelandic classifications. The CORINE classification however limits forests to trees that reach a minimum height of 5 m, Iceland received an exemption and it was lowered to 2 metres (Traustason and Snorrason, 2008). Following the classification in Table 1: 59% of Iceland's forests are Moors and heathland, 19% Transitional woodlands shrubs and 15% actual Broad-leaved forests.

Table 1: *Icelandic to CORINE land cover classification comparison.*

Icelandic	CORINE	Height
Natural birch woodlands	Broad-leaved forests	>2m
Natural birch woodlands	Moors and heathland	<2m
Transitional woodlands shrubs	Young forest plantation	<2m
Mixed forest	Mixed plantation and birch woodland	>2m

The low size of the only native forest forming species – Downy Birch *(Betula pubescens)* – is due to hybridisation, unfavourable environmental conditions and/or grazing which leads to low, multi branch "shrubs" that reach 2 metres in height, rather than reaching 12 metres with a single trunk (Smith, 1995; Shotter, 2022).

Study Area

Early settlers were attracted by the natural resources along the west coast, which was followed by a spread inland for farming and grazing, particularly along river valleys and in the south (Hartman et al., 2017; Vésteinsson et al., 2006). This early period of the settlement is referred to as Landnám, the time of land take. Their survival depended on strong collaboration within the community, which was often made out of family and kin, and the formation of economic trade networks (Pálsson, 2018; McGovern et al., 2007). According to traditions they formed regional gathering sites, assemblies known as *Thing* which were created in areas around settlement concentrations, near water courses, islands or peninsulas (Sanmark, 2022).

In A.D. 930 the parliament – *Althing* – was created at *Thingvellir* (eng.: fields of parliament), it marks the end of the Landnám period. Unlike the regional *Thing* sites, the chosen site had to be accessible to everyone across Iceland, while also being unclaimed, at a distance from farms and arable land to ensure safety and equality for the attendees (Sanmark, 2022).

Due to its historic, cultural and political importance, Thingvellir is now a protected National Park, and one of the first stopping point for many visitors. Its popularity and proximity to Reykjavik makes it ideal to reach people and increase engagement, which is why it was chosen for this study. The area was extended to approximately 45x45 km to include known areas of settlements, current forests and different vegetation types (Figure 1). Reykjavik and the coast were not included as there is too much uncertainty about the coast line at the time of settlement and modern large urban expansion provided difficulties for this study.

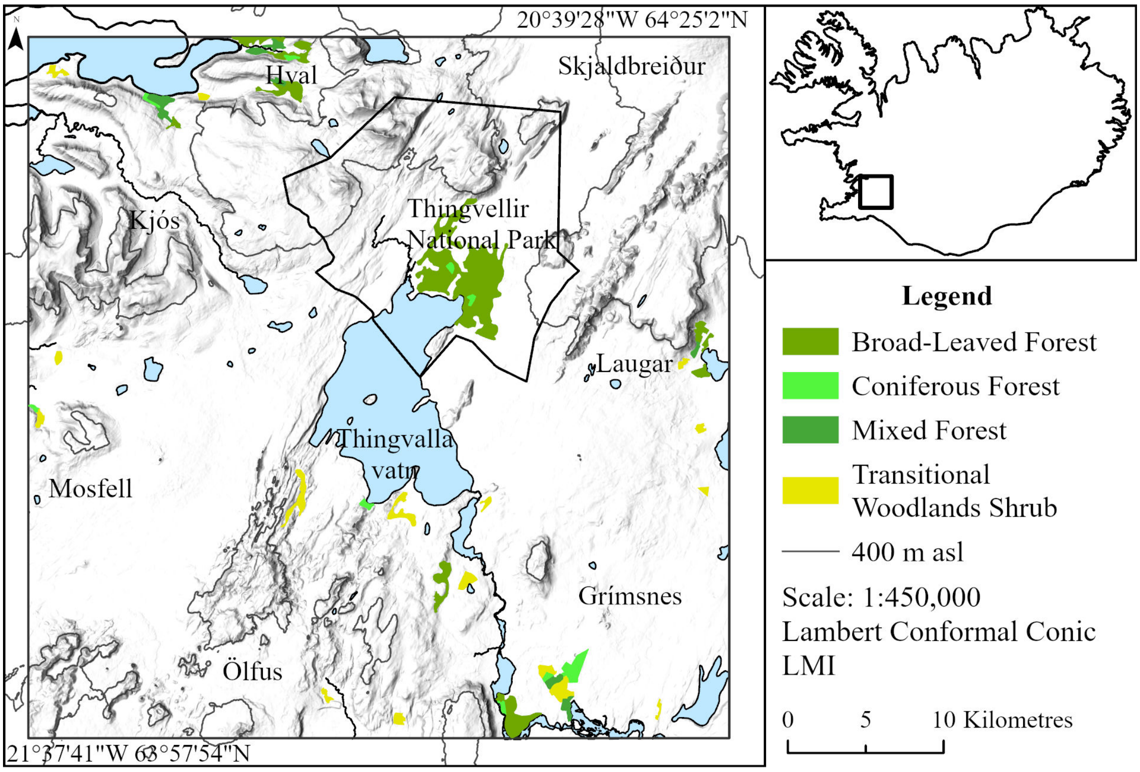

Figure 1: *Left: map depicting the chosen study area, with lake Thingvallavatn in its center and Thingvellir National Park north of it. Also indicated are current forest cover (Landmælingar Íslands, 2023), and generalised area names for orientation purposes. Right: overview of the study area within Iceland.*

Forests models

There is no consensus on the settlement landscape or methodology, which is the reason why the estimated forest cover varies so widely between studies. Trbojevic (2016) conducted an extensive literature review of past attempts, starting from early recreations based on historic descriptions stating that all of the lowlands were covered in forests. As the climate was similar to today, the tree line can be calculated as altitude temperature limit, but even this changes between studies: 300 m asl (Streeter et al., 2015), 400 m asl (McGovern et al., 2007; Dugmore et al., 2005; Traustason and Snorrason, 2008) and 600 m asl (Trbojevic, 2016). Basing a landscape recreation on the absence or presence of Birch forests has proven to be flawed and the assumptions used for it are usually based on political and economic reasons to further an agenda (Trbojevic, 2016).

The first attempts at a detailed vegetation map based on modern research where that of Eysteinsson at the Iceland Forest Service 2009, which distinguishes the forest limits in the boreal southern from that in the arctic north but did not distinguish vegetation types beyond a generalised Birch forest. This creates an overestimation of forest cover and misrepresents the landscape. Another attempt was by Einarsson and Gíslason, at the Icelandic Institute of Natural History (Talbot, 2012) which is commonly used in other studies (e.g. Shotter 2022). Even at a country-scale it differentiates woodland, dryland and wetland vegetation types into small patches. It has however been criticised for its mistakes, which led to an overestimation of the forest cover. The use of country-scale models of the landscape for regional or farmstead scale studies leads to over estimations of forest cover and a poor representation of the past landscape.

The Icelandic landscape is changing, and has changed since settlement, due to human activity and changes in the climate. While previous research has looked at country and farmstead scales separately, it appears that targeting a regional model between these scales could prove useful to better comprehend the diversity of its landscape, as well as including a wider selection of vegetation types. This study will attempt such a model by looking at the wider area around lake Thingvallavatn and the Thingvellir national park for its historical, cultural and political importance, and proximity to Reykjavik.

3 Data and Methodology

This section presents the data and methodology used to develop and validate the current-day land cover. The current-day model was created using environmental data from the Geodesy of Iceland, referred to as LMI (*Landmælingar Íslands*) and validated with current land cover data. These then formed the basis for the development of the pre-Landnám landscape model, adjusted through the use of archaeological and historic data.

Current-Day Model

Vegetation in Iceland depends on the soil, its wetness and its drainage capabilities (Arnalds, 2004), which several models reviewed for this study either lack or are overgeneralised. The model created in this study therefore adds – to the altitude already used in the other models – soil, wetness and slope as key indicators for the land cover classification.

For the purpose of this study, soil types are based on information from Thorsteinsson et al. (1971) and Arnalds (2004):

- *Histic / Gleyic and Brown Andolos*: fertile soils that feature wetlands in poorly drained areas, but shrubs and trees in temporarily wet areas, dry areas only support shrubs and smaller species;

- *Leptosols*: soils with limited vegetation;
- *Vitrisols*: upland desert soils.

Areas of young lava fields ($< 10,000$ years old) in the study area were classified separately. From direct observations in the field, it was noted that wet lava fields with Brown Andosols can support trees, whereas dry lava fields, usually associated with Leptosols, have limited vegetation.

To create areas of wetness, the data for both permanent and temporary wetness was extracted from the wetness dataset (Landmælingar Íslands, 2023). Other areas outside water bodies were considered dry. Due to the high diversity within the study area, and the purpose of a simple model, it was generalised to a cell size of 300.

The ArcticDEM (Digital Elevation Model) of 2 metre resolution was used to analyse the slopes in the study area (Porter et al., 2018). Due to the complexity of the landscape, the slope was calculated at a 30 metres resolution and re-classified into groups of: low slope (below 10°); moderate slope (below 30°); and high slope (above 30°). Wetlands were limited to the low slope areas. Altitude limits were set to 400 m asl for birch forests and 600 m asl for vegetation in general.

Based on information on the habitats of current native species (Kristinsson, Hörđur, 2017), the following vegetation land cover classes were created for this model:

- **Wetland**, which range from peat bogs, predominated by Sedge's (*Cyperaceage*), to transitional areas were Tea-leaved Willow *(Salix phylicifolia)*, Dwarf Birch *(Betula nana)* and birch shrubs are found;
- **Forest**, which are dominated by Downy Birch *(Betula pubescens)* and associated undergrowth;
- **Shrub**, which classifies exposed and dry fertile soil areas that would not support trees or wetlands, these are dominated by birch hybrids/shrubs;
- **Moss** fields, for areas that do not support larger vegetation;
- **Sparsely Vegetated**, for areas at higher altitudes and/or slopes, commonly associated with Willows and Juniper (*Juniperus communis*); and
- **Unvegetated**, for highlands and/or poor soil that mainly support Lichen.

By combining classification for the soil (including slope, altitude and wetness) with that of vegetation land cover, the final current-day model divided the study area into the typology described in Table 2.

Model Validation

The current-day model was manually adjusted before validation. This step improved the visual distinction between patterns and reduced the impact of outliers and areas of artefacts that were created as a result of combining datasets.

The current-day model was validated in two ways. Firstly, by comparing the modelled wetland cover with the protected wetlands in Iceland and wetlands classified within INSPIRE datasets (Landmælingar Íslands, 2023). Secondly, by comparing the modelled forest cover with that of INSPIRE (classified as Broad-Leaved, Coniferous, Mixed Forest

Table 2: *Land cover classification used in the model.*

Type	Description
Wetland	Permanently wet areas in Histic-Gleyic and Brown Andosols, low levels of slope
Forest	Temporary wet Histic-Gleyic and Brown Andosols, slow to medium slopes, below 400 m asl Lava fields that are permanently wet
Shrub	Dry Histic-Gleyic and Brown Andosols, below 400 m asl Lava fields that are temporarily wet
Moss	Leptosols and dry lava fields Lava fields that are dry
Sparse Vegetation	400-600 m asl slopes
Unvegetated	Leptosol above 400 m asl, Vitrosols & above 600 m asl

or Transitional Woodland Shrub), and the Forestry (Skógur) forest dataset (Landmælingar Íslands, 2023). These comparisons primarily focused on calculating the percentage overlap between areas classification.

The purpose of these comparisons is two-fold. First it aimed to identify areas of discrepancy between the created model and the classifications from official sources. Then, with these limitations established, it aimed to improve and correct assumptions made when creating the classification for the pre-Landnám model.

Pre-Landnám Model

The current-day model was manually adjusted to better align with the validation data, before secondary data was used to infer the past landscape. The recreation was made on the basis that aeolian sediment transportation of sandy Vitrosols from the highlands and Andosols from erosion in the exposed lowlands increased after settlement and would have dried out areas in the lowland (Connors, 2010; Shotter, 2022). The landscape would have been wetter and therefore supported more forest along surface water lines.

Björn Gunnlaugssons map from 1844 is the earliest detailed visual record of the landscape, as such, its key features were used to indicate land cover extent. Inconsistencies were corrected based on archaeological evidence from the Mosfell Project (Connors, 2010). As there are only a limited number of records of archaeological settlement sites in the area (Schmid et al., 2021), georeferenced settlement sites from sagas (sagamap.hi.is) were used to indicate fertile land and possible human impact leading to environmental changes.

Historic and archaeological data were used as indicator only for changes in the landscape. The resulting model therefore presents a theoretical simplification of the landscape and should be read as such.

This section described the methodological approach used to create both the current-day and pre-Landnám landscape model of the Thingvellir region. First, a dataset of the current-day soil types (including wetness, slope and altitude) was created and then used to infer the land cover classification of the area. This model was then compared with official data sources to establish its limitations. Combined with archaeological and historic information on the likely presence of settlements, these constructed the basis for the pre-Landnám model.

4 Results and Discussion

This section presents the models created using the methodology above. In the first instance, the current-day model and its validation are discussed. Then, the pre-Landnám model is considered and reviewed alongside models previously created.

Current-Day Model and Validation

Forests could cover an estimated 20% of the area according to the model. Shrubs cover the largest part of the map with 27%, and 23% of the area is either too high in altitude or has poor soil quality and can only supports little vegetation. The Hval to Kjós to Mosfell and Laudar to Grimnes areas are fertile and dense with wetland, but divided by an area of elevated hills and young lava fields that form the boundary between tectonic plates (Figure 2). The lake forms the center of large flat open areas to the east and west of it, in which there is little protection from the elements and little surface water, and therefore forms dry Brown Andosols that likely would not support forests.

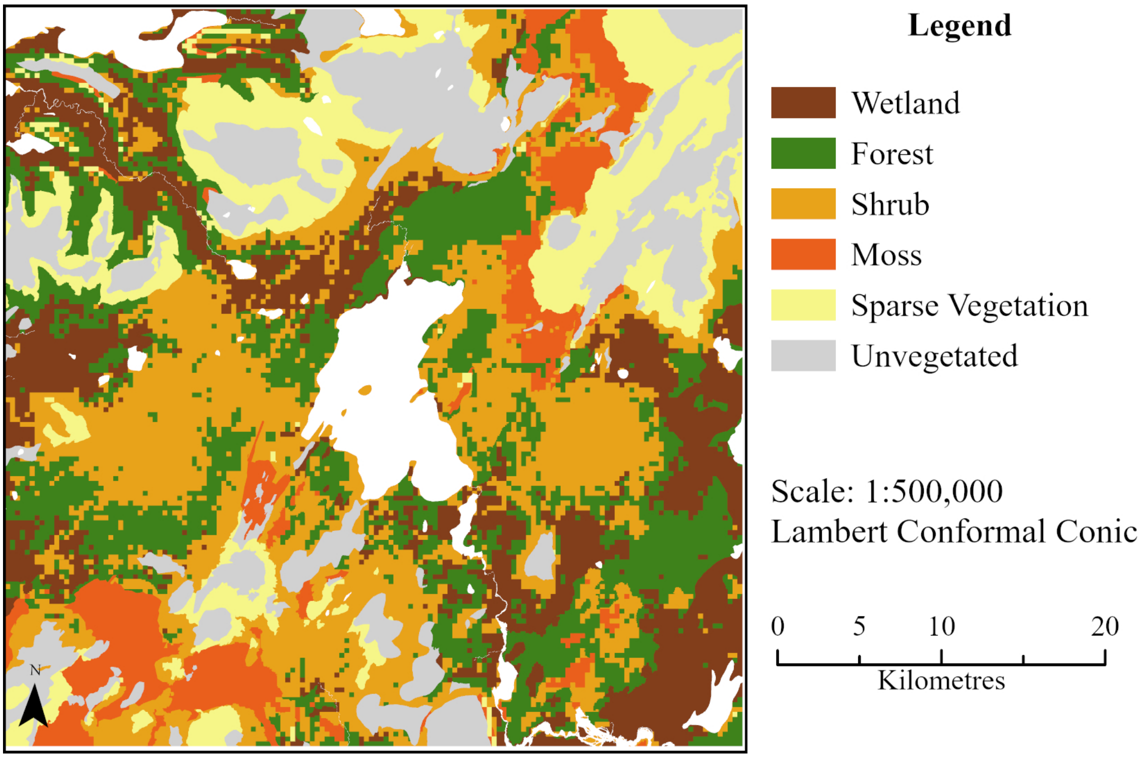

Figure 2: *Map of the current-day land cover model of possible vegetation extend, based on current-day environmental data.*

Despite being located south west of the Langjökull glacier, lake Thingvallavatn receives majority of its water through groundwater. The glacier discharges instead into the Hvitarvatn catchment, with the main river flowing through Laugar and Grimsness (Flowers et al., 2007). This could be the reasons for the wetness and fertility of that area compared to the area surrounding lake Thingvallavatn. Similarly, the protected river valleys along the Kjós and Hval coast are rich in vegetation, however salinity was not taken into consideration, these results should therefore be treated with caution.

Despite the two classes covering four to five times the area, the model missed 37% of current Wetlands and 61% of current Forests (Table 3). The Forest was underestimated in particularly wet areas of the wetland along the coast, Mosfell, Laugar and Grimsnes, as well as the lava field north of lake Thingvallavatn (Figure 3, left). The model also predicts larger forest cover in valleys along Mosfell, Kjós and Hval as well as the large drier areas east and west of lake Thingvallavatn. Highlands and young lava fields in Ölfus were low in vegetation, as expected.

Table 3: *Validation outcome comparing the current-day model to official land cover data for forests and wetlands.*

Land Cover	Predicted (km^2)	Official (km^2)	Accurate (km^2)	Missed (km^2)	Potential (km^2)
Forest	381	71	28 (39%)	43 (61%)	310
Wetland	324	78	49 (63%)	29 (37%)	246

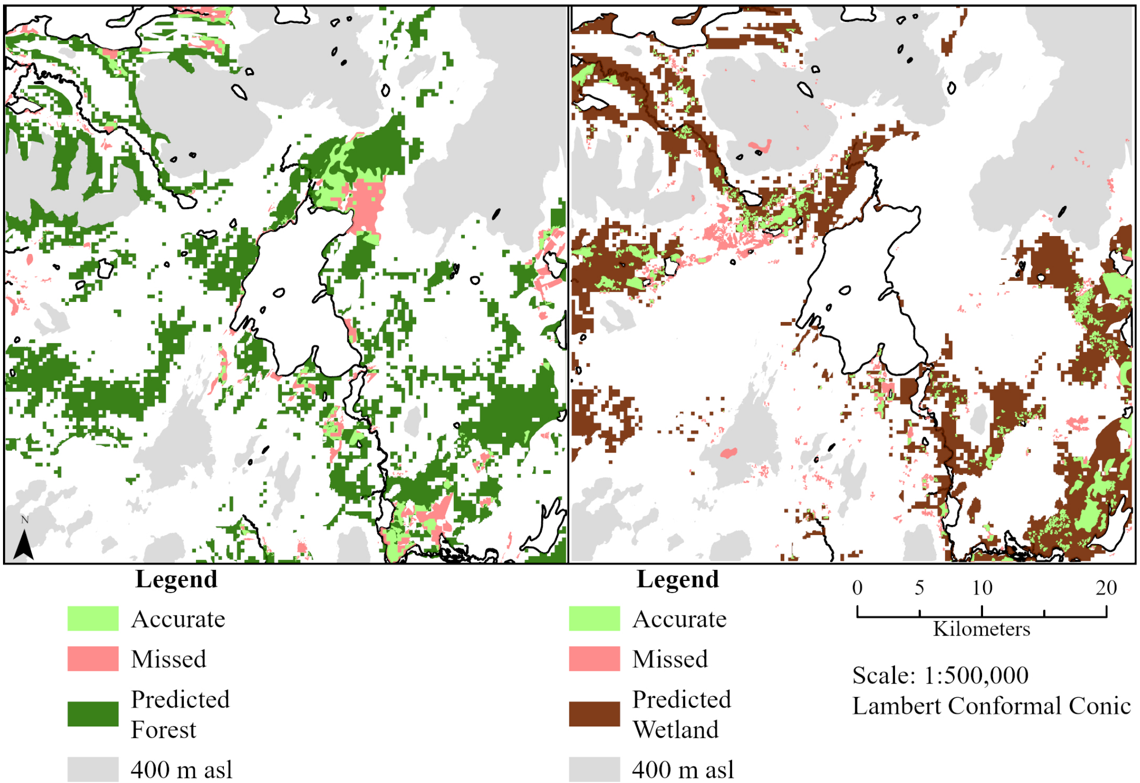

Figure 3: *Maps of the predicted Forest (left) and Wetland (right) areas, compared to the validation data. In light green are areas where the model accurately predicted the cover and in pink areas that were missed by the model.*

Wetness of the area between Mosfell-Kjós and lake Thingvallavatn, as well as the area surrounding the river south of lake Thingvallavatn was underestimated (Figure 3, right). Overall the predicted wetlands appear to be densest close to rivers and Histic-

Gleyic Andosols, Brown Andosol was less suitable than expected. However, they are also found in highlands and areas that do not currently support trees.

Two factors could explain the discrepancy between the current-day model predictions and official land cover data. First, the validation data is at a higher resolution, while many of the small areas were lost in the model due to the chosen resolution, and other areas became overestimated during the simplification process. Second, the model is predicting vegetation cover under natural modern environmental factors. The low overlap could simply be due to the fact that human activities regulate where forest can grow, rather than what would naturally support it. However, this highlights large areas that could be potentially used for afforestation efforts.

The current-day model also shows interesting differences between the young lava fields in the area. While the fields south of lake Thingvallavatn have low predicted vegetation, the lava fields north of the lake and at Grimsnes both have high shrub and forest cover (Figure 4). There could be several reasons, the main candidate being the soil accumulation and wetness coming from the glacial river north-east of Grimsnes, along with different land management. This demonstrates the uncertainty associated with predicting land cover of lava fields with the data used in the model.

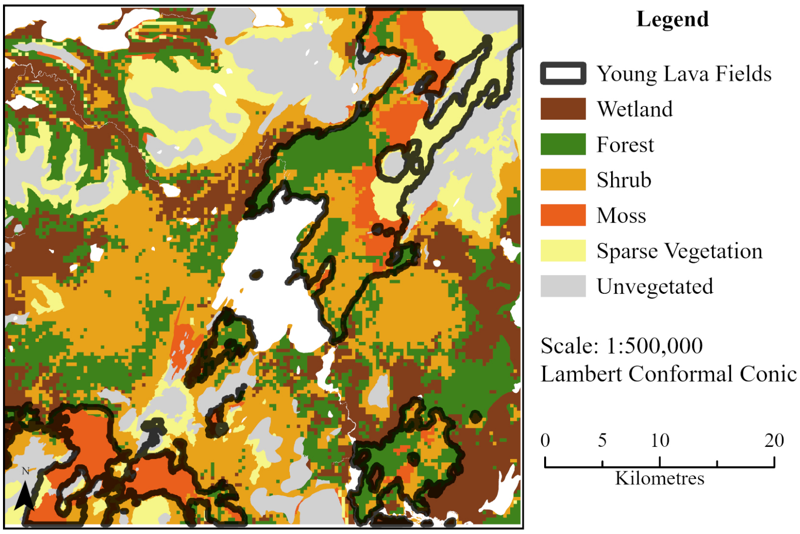

Figure 4: *Young lava fields (post glacial) in the area.*

Moreover, direct observations of the lava field north of the lake have revealed that, while officially classified as forest, much of the area is in fact covered by moss and dwarf birch with some shrubs (Figure 5). On the other hand, areas with forests are not labelled as such in the official land cover data. This shows the limits of using such dataset as ground-truth for validation and further explain the contrast observed between the current-day model and official data.

Pre-Landnám Model

The coastal areas are largely unchanged, apart from smoothing out the granularity of the current-day model (Figure 6). Wetland areas along the coast and Laugar and Grimsnes have a large number of saga settlement locations, suggesting fertile wet soil (Figure 7). As the area south of lake Thingvallavatn has four settlements, wetland areas were expanded to as large an area as the data would support, however they were reduced surrounding the

Figure 5: *Thingvalla lava field (10,200 years old), at Thingvellir National Park, covered by moss and dwarf birch, with birch shrub on larger flat areas in the background. ©Maria Maily*

young lava fields north of the lake and south of Mosfell. The largest change was the conversion of Sparse Vegetation areas east and west of the lake to forests. In Gunnlaugsson's map, those areas are overestimating lava fields and otherwise heaths, indicating shared grasslands used for sheep grazing. This continuous human impact on top of sand build up was taken as indication that it could at one point have supported forests.

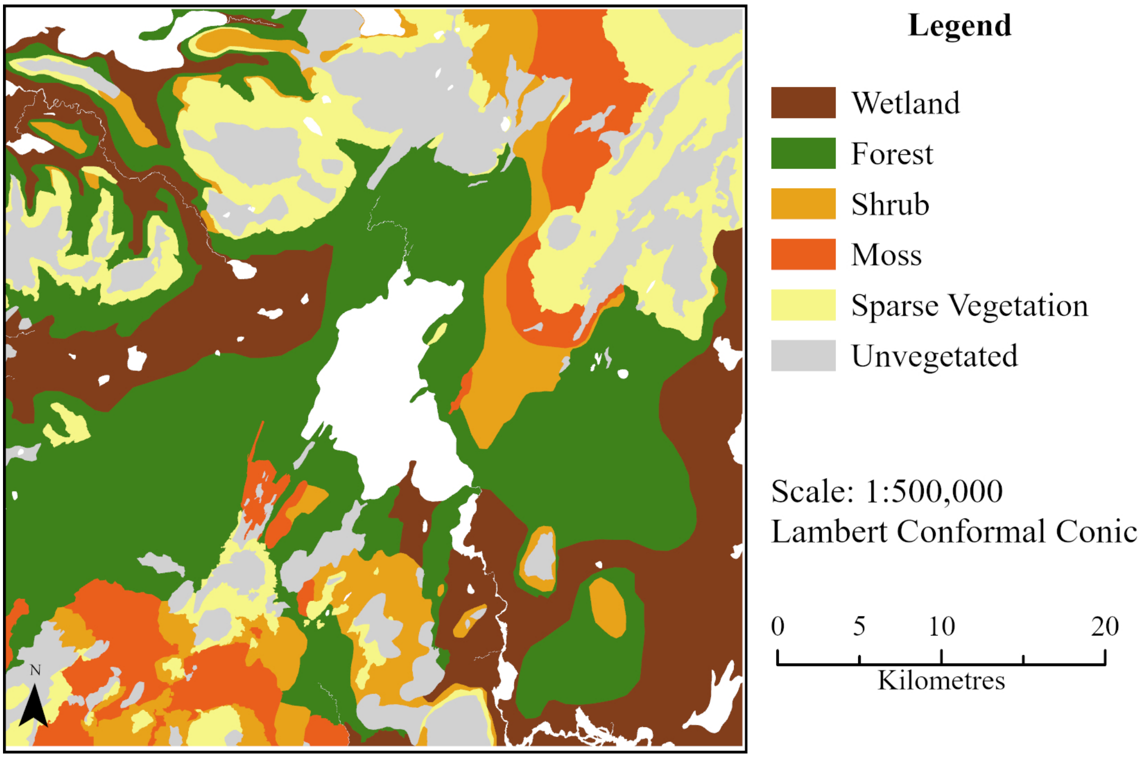

Figure 6: *Model of the pre-Landnám landscape.*

The lack of settlements at Thingvellir could be a sign of a prohibition to establish farms in proximity to the parliament, rather than based on environmental factors, which made the reconstruction difficult. The modern day forest cover in the area suggests that it could have supported larger forests at one point. Large sections of young lava fields were left at Shrub or Moss cover classification due to the lack of soil and wetness data limiting the likelihood of any difference.

Comparison to the Eysteinsson estimation (2009) was limited due to his model limit-

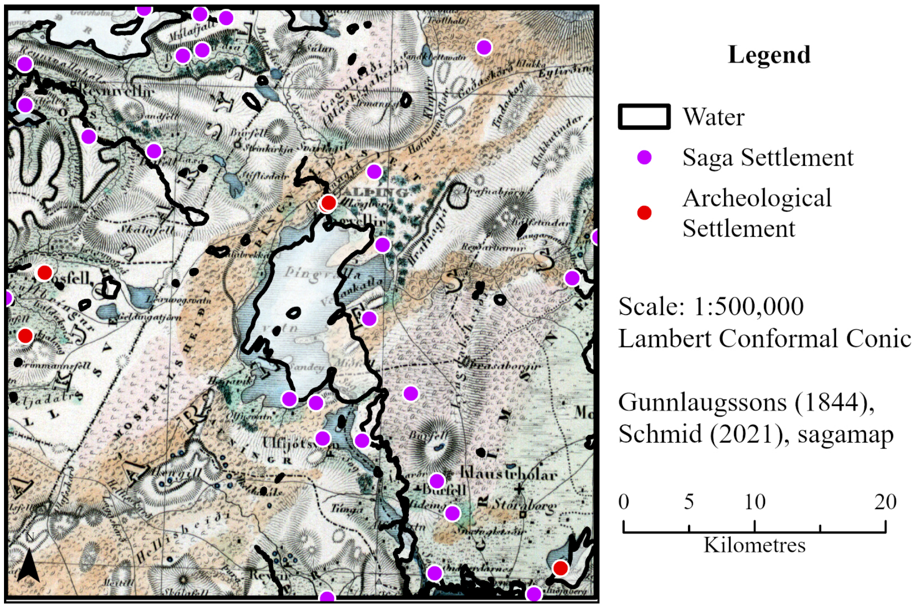

Figure 7: *Historic map by Gunnlaugssons of 1844, alongside archaeological and saga farm sites. Due to the inaccuracy of the historic map the current water bodies and major rivers were overlaid.*

ing the land cover to possible forest extent based on temperatures on a country scale. The 7.6 °C settlement limit largely overlaps the Wetland, Forest and Shrub areas of the model, however, his model expands the forest cover at 9 °C to cover all Moss covered young lava fields and reaches altitude limits beyond the created model.

The Einarsson and Gíslason model (Talbot, 2012) allows for better comparison and overlaps in many areas. However, it underestimates the wetland areas compared to the created model. Around Mosfell, Grimsnes and coastal areas the wetland is particularly limited to less than current day extents. Their model classifies large areas of the lava fields as forest covered or at least dryland vegetation, which reaches into exposed areas.

When comparing the current-day model to the pre-Landnám model, the Forest area would have been 15 % or 277 km^2 larger than would be possible today (Table 4), whereas the Shrub cover would have been 18 % or 328 km^2 smaller. This highlights the impact deforestation and grazing have had on the landscape in the area since settlement.

Table 4: *Land cover comparison between the current-day and pre-Landnám model. The difference highlights the contrast between current-day possible extend and pre-Landnám.*

Land Cover	Current-Day		pre-Landnám		Difference	
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
Wetland	324	17	370	20	+46	+3
Forest	381	20	658	35	+277	+15
Shrub	499	27	171	9	-328	-18
Moss	146	8	148	8	+2	0
Sparse Vegetation	238	13	242	13	+4	0
Unvegetated	287	15	287	15	0	0

Limitations

The model was restricted to a simplified representation of the environment, the low resolution chosen for the current-day model resulted in low accuracy because many small areas were lost. The resolution was chosen due to the high diversity over large areas, resulting in more areas than can be handled by shapefiles. Future attempts would have to reconsider the resolution, simplification methodology, or data format. The high diversity of slope in the wide open areas west of the lake, which cause the majority of issues could have been due to the presence of thurfur and rofabards which would need to be confirmed before smoothing in a model (Dugmore et al., 2009).

Additionally, the wetland classification included both peat bogs and mires, as well as areas of transitions, i.e., shrub areas between true wetlands and Downy Birch forests that would not support either. Future attempts would have to find a way to distinguish them in the model similar to Shrub areas. For example, Histic and Gleyic Andosols split and only Histic and poorly drained Gleyic Andosols were classified as Wetland, whereas wet Brown Andosols would be areas of transition. Additionally, during the preparation, areas of water and temporarily flooded areas should be classified as permanently wet, as the classification set in this model led to an underestimation of wetlands along rivers and lakes. An additional step would be including salinity along the coastline, and what effects this would have on the vegetation.

The land cover classes were limited by the few selected representative species that are large in size, which were chosen for future 3D representation of the model. However, there are many smaller species, particularly in the undergrowth that are more common and could improve the classification accuracy (Sigurdsson et al., 2005; Erlendsson and Edwards, 2009). Therefore, more research is needed to establish what would have been common at the time of settlement apart from birch, and fieldwork could improve the resolution of the current land cover to better represent the area.

Furthermore, during a site visit, Downy Birch trees above 2 metres were observed at the Almannagjá gorge, at a slope larger than 30°. Additional data is therefore needed to distinguish table mountains with poor slope stability from slopes with stable soil, as slope alone did not prove very effective in estimating the vegetation cover on uneven ground. Instead of using slope, the following datasets could be considered as alternative indicators for vegetation cover. Firstly, erosion and wind data could point to exposed and protected areas, as well as areas of soil buildup due to eolian processes. Secondly, the presence of sheep, as grazing could be the reason for shrubs in the Thingvellir National Park, or low the number of Birch shrubs in dry and mossy areas (Arnalds, 1987). Lastly, descriptive place names – such as skógur - forest, víðir - willow, birki - birch –, as well as descriptions in the Book of Settlement (*Landnámabók*) could be included to indicate forests and their management (Dugmore et al., 2005; Smith, 1995).

This section described the results of the current-day and pre-Landnám models, including the validation by comparison to official data of forest and wetland cover. The current-day model indicates large areas that have potential for future afforestation efforts. While it presents limitations, improvements are also suggested. The pre-Landnám model compared well with other models and improved on them by introducing different data and classification groups that diversify the landscape and limit the overestimation of forest cover.

5 Conclusion

By understanding the natural habitat and landscape of Iceland, this study aims to support the many afforestation and restoration efforts combating, or at least mitigating, climate change and global warming impacts in the country.

This work present a novel approach to modelling land cover, developed by reviewing past model approaches and factors that have contributed to landscape changes (RQ1). This new methodology combines vegetation typology with soil classifications (including slope, altitude and wetness), to first create a current-day model of possible vegetation cover, which was compared against official datasets describing the current land cover. The comparison highlighted the limitation of the modelling process (notably the difference in resolution), but more importantly emphasised the areas were afforestation efforts could be further supported.

To understand what land cover could be, this work also attempted to see what land cover used to be – prior to human settlement on the island. This required the multi-disciplinary analysis of environmental, archaeological and historical data. The land cover model previously created was transformed to take into account evidence of the past landscape and land management since settlement (farm sites, locations of sites in sagas, historic map). The resulting pre-Landnám model demonstrates the dense vegetation and diversity of land cover prior to human impact.

By critically reviewing the models limitations and comparing the pre-Landnám model to previous recreations, opportunities for improvement were presented, notably in their accuracy by adding to the datasets used in their development (RQ2). More importantly, they provide a stepping stone towards the development of a baseline of what the Icelandic landscape looked like before settlement, and with it, a better understanding of the impact of human activity in its environment. By seeing what it used to be, witnessing its current state, and visualising what it could be, this study hopes to stimulate public engagement in the conservation and redevelopment of Iceland's natural habitats.

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