Mapping Wilderness Quality in the Central Highlands of Iceland

A report by the Wildland Research Institute

For Náttúruverndarsamtök Íslands, Samtök um náttúruvernd á Norðurlandi, Skrauti and Ungir umhverfissinnar

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Contents

Executive Summary

Uninhabited wilderness areas (the Icelandic legal term: *óbyggð víðerni*) are key characteristics of many parts of Icelandic landscapes including large areas of the Central Highlands. The Post-2020 Global Biodiversity Framework of the Convention on Biological Diversity places "retaining wilderness areas" as the first of 21 action-oriented targets for 2030. Previous studies for the European Union Wilderness Register have shown that Iceland retains approximately 43 percent of Europe's top one percent wildest areas.

This report builds on these, together with the Icelandic Nature Conservation Act No 60/2013 and the definition of wilderness in Article 5(19), to produce the most accurate maps of wilderness areas in Iceland's Central Highlands and surrounding areas to date.

Wilderness quality is mapped for the Central Highlands of Iceland and used to define 17 core wilderness areas meeting International Union for Conservation of Nature (IUCN) Category Ib wilderness criteria and Wild Europe Working Definition for wilderness areas, with the caveat that winter off-road driving and grazing issues can be resolved. Together these cover over 47 percent of the Central Highlands area of interest (55,400 km^2) and three wilderness areas outside of AOI, of which 19,500 km^2 is public land and 8,970 km^2 privately owned. This analysis is carried out using internationally recognised methods at high resolution, using the best available data supplied by national and international mapping agencies.

Mapping is performed using multi-criteria modelling of the three principal factors influencing wilderness quality in Iceland; (1) remoteness from mechanised access (measured as walking time from roads usable by the public), (2) lack of visual impact from modern human artefacts (measured as number and magnitude of human features visible in the landscape such as roads, buildings, pylons etc.), and (3) perceived naturalness of land cover (measured as proportion of land under different vegetation and land use types). Combining these three wilderness attributes into a single map shows the patterns and variation of wilderness quality along a spectrum from least to most wild. Statistical methods are used to analyse the distribution of wilderness values across the entire Central Highlands and split the area into distinct zones using IUCN Category Ib "Wilderness" guidelines and the Wild Europe Working Definition as a guide.

Three wilderness zones are defined based on these internationally recognised criteria and minimum area thresholds. These are the core (including deep core areas), buffer and transition zones. Areas outside of these zones are defined as non-wild. The core wilderness areas identified mainly consist of ice caps and their surrounding landscapes plus several large ice-free areas of remote and wild volcanic landscapes and wide-open gravel plains with freshwater springs that are characteristic of Central Highland landscapes.

Seventeen separate wilderness areas are identified in this study; 14 inside the Central Highlands Area of Interest, and 3 outside, totalling 28,470 km^2, of which 26,404 km^2 is inside and 2,066 km^2 is outside the area of interest. It is recommended here that these meet the requirements for IUCN Cat Ib "Wilderness" areas and the Wild Europe Working Definition for wilderness areas and as such are appropriate for consideration as new designated wilderness areas in the Central Highlands.

The mapping and analysis in this report represents a significant improvement on existing maps in terms of detail and methods used. A key advantage over existing studies is the use of internationally recognised methods which use direct measurement of spatial factors determining wilderness quality

supplemented by wilderness character assessments based on supplementary mapping of spatial factors affecting the individual wilderness landscapes and their unique character.

Ágrip/Samantekt

Óbyggð víðerni (e. wilderness) eru einkennandi fyrir umtalsverðan hluta íslensks landslags. Á það meðal annars við um stór landsvæði á miðhálendinu. Það að standa vörð um og viðhalda óbyggðum víðernum er efst á lista útfærðra markmiða Rammasamnings Sameinuðu þjóðanna um líffræðilegan fjölbreytileika fyrir árið 2030. Víðernaskrá Evrópusambandsins frá 2013 sýndi fram á að tæp 43 prósent af „villtustu" víðernum Evrópu eru á Íslandi.

Í skýrslunni sem hér er sett fram er gerð grein fyrir nákvæmustu kortlagningu á óbyggðum víðernum á miðhálendi Íslands sem fram hefur farið. Kortlagningin byggir á náttúruverndarlögum nr. 60/2013 og skilgreiningu þeirra á óbyggðum víðernum.

Greind eru víðernagæði (e. wilderness quality) fyrir miðhálendi Íslands og sú greining notuð til að skilgreina alls 17 víðernasvæði sem uppfylla skilgreiningu Alþjóðanáttúruverndarsambandins (IUCN) á óbyggðum víðernum (flokkur Ib) sem og skilgreiningu Wild Europe fyrir víðerni, sem útfærir og lagar fyrrnefndu skilgreininguna að Evrópu. Þetta er sagt með þeim fyrirvara að tekið sé á beit og utanvegaakstri á snjó og ís á svæðunum sem skýrslan tilgreinir. Samanlagt taka víðernasvæðin til um 47 prósenta af miðhálendinu (eins og það er skilgreint í skýrslunni, 55.400 km^2) og þriggja víðernasvæði utan miðhálendisins, þar af eru 19.500 km^2 þjóðlendur og 8.970 km^2 sem lúta einkaeignarrétti. Í rannsóknunum sem hér liggja til grundvallar er alþjóðlega viðurkenndri aðferðarfræði beitt með hárri upplausn og byggt á bestu fáanlegu gögnum frá innlendum og alþjóðlegum stofnunum.

Í víðernagreiningunni eru gerð líkön byggð af þremur meginþáttum sem áhrif hafa á víðernagæði á Íslandi; (1) fjarlægð frá vélknúnum aðgangi (mældur sem göngutími frá vegum sem eru opnir almenningi), (2) sjónræn áhrif af mannlegum vegsummerkjum (mæld sem fjöldi og umfang mannvirkja sem sjást í landslaginu, svo sem vegir, byggingar, loftlínumöstur o.s.frv.), og (3) náttúrulegt yfirbragð lands (mælt sem hlutfall mismunandi gróðurþekju og tegunda landnotkunar). Með því að leggja þessa þrjá eiginleika víðernasvæða saman í eitt og sama kortið sést breytileiki víðernagæða allt frá minnstu til mestu víðernanna. Tölfræðilegum aðferðum er síðan beitt til að greina dreifingu víðernagildanna á öllu miðhálendinu og skipta því upp í víðernasvæði með víðernaleiðbeiningar verndarflokks Ib hjá IUCN og skilgreiningu Wild Europe að leiðarljósi.

Lágmarksstærð víðernasvæðis er ákvörðuð út frá þessum alþjóðlega viðurkenndu aðferðum og svæðunum skipt upp í þrennt. Þetta eru í fyrsta lagi ósnortnustu kjarnasvæðin („kjarni", e. „core") þ.m.t. djúpkjarnasvæði, í öðru lagi þau sem yst eru, n.k. jaðarsvæði víðernanna („jaðar", e. „transition zones"), og svo hjúpurinn sem þar er á milli („hjúpur", e. „buffer"). Allt landsvæði utan þessara svæða er skilgreint utan óbyggðra víðerna. Kjarnasvæðin eru mest jöklar og aðliggjandi svæði auk nokkurra stórra svæða utan jökla sem samanstanda af afskekktu eldfjallalandslagi og víðfeðmum sléttum með ferskvatnslindum sem eru einkennandi fyrir landslag miðhálendisins.

Sautján aðskilin víðernasvæði koma út í þessari greiningu; 14 innan miðhálendisins eins og það er skilgreint í þessari skýrslu, og þrjú utan þess. Alls eru þetta 28.470 km^2 af víðernasvæðum og þar af eru 26.404 km^2 innan miðhálendisins og 2.066 km^2 utan þess. Byggt er á því að öll þessi svæði geti

uppfyllt kröfur verndarflokks Ib hjá IUCN og skilgreiningu Wild Europe og sem slík geti þau hvert og eitt verið grundvöllur formlegrar verndunar með friðlýsingu.

Nákvæmni greininganna sem kynntar eru í þessari skýrslu er mun meiri en hingað til hefur tíðkast á Íslandi og aðferðin við víðernakortlagningu þróaðri. Beitt er alþjóðlega viðurkenndri aðferðafræði með beinum mælingum á staðbundnum þáttum til að ákvarða víðernagæði landsvæða, eiginleikar víðernanna eru metnir og matið byggir á staðbundnum áhrifaþáttum á víðernalandslag. Sú kortlagning víðerna sem hingað til hefur verið gerð á miðhálendi Íslands er ekki byggð á samsvarandi aðferðum.

List of Figures

1. Introduction

1.1 Uninhabited wilderness areas (the Icelandic legal term is *óbyggð víðerni*) are key characteristics of many parts of Icelandic landscapes including large areas of the Central Highlands. This report details both the legal and geographical definitions of wilderness in the Icelandic context, building on international, European, and other local definitions. The principal aims of the report are to map core wilderness areas in the Central Highlands using internationally recognised techniques and approaches and demonstrate how this could be expanded to fulfil requirements in recent legal developments in relation to the Nature Conservation Act No 60/2013, to map wilderness across the whole of Iceland by June 2023 [1].

1.2 This work acknowledges the Post-2020 Global Biodiversity Framework of the Convention on Biological Diversity that places "retaining wilderness areas" as the first of 21 action-oriented targets for 2030[2]. It has been shown that Iceland retains approximately 43 percent of Europe's top one percent wildest areas (Figure 1.1)[3]. Together these provide a strong justification for the interest in wilderness areas in Iceland and the need to reliably map their current extent using internationally recognised methods and approaches.

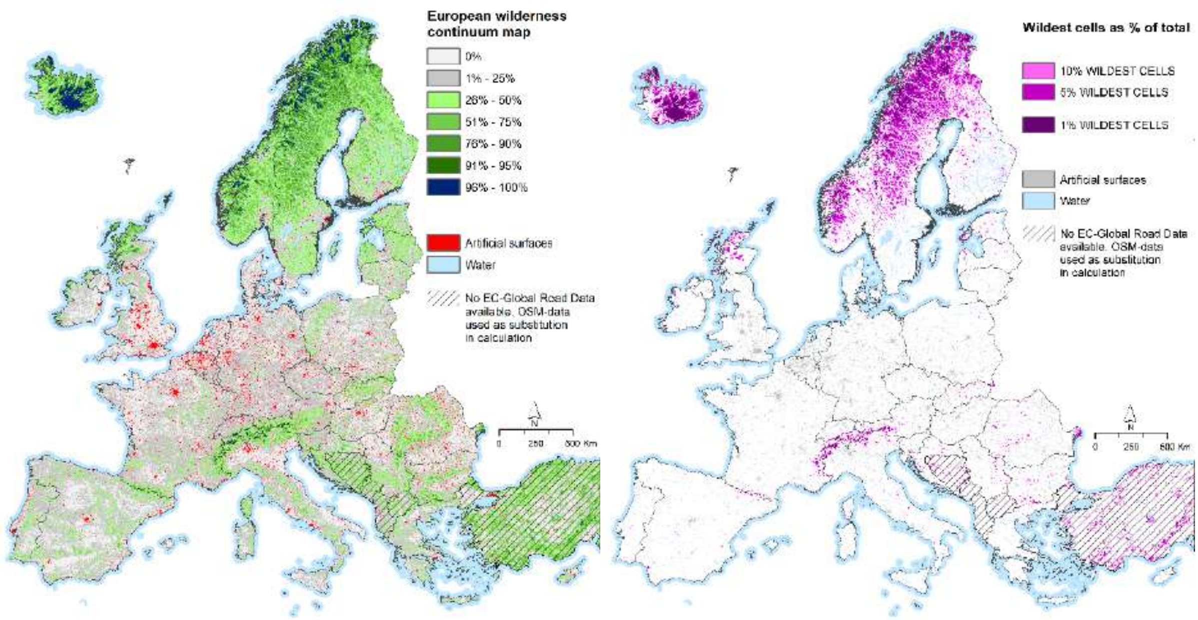

Figure 1.1 Wilderness in Europe (After Kuiters et al., 2013)

1.3 Mapping wilderness areas requires consideration of the impacts on landscape qualities of wildness from human land use and development using established methods and available

[1] Nature Conservation Act No 60/2013 as later amended https://www.althingi.is/lagas/nuna/2013060.html
[2] Comments on the survey from headline indicators. Post-2020 Global Biodiversity Framework of the Convention on Biological Diversity https://www.cbd.int/doc/c/e068/9905/299212eac8dc52bac49de7ba/sbstta-24-inf-29-en.pdf
[3] Wilderness Register and Indicator for Europe (2013) https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf

digital spatial datasets. These models provide geographical interpretations of established wilderness definitions to map variations in wilderness quality and character resulting from spatial patterns of human settlement, roads, infrastructure, and land use.

1.4 The work presented here is based on lessons learnt from previous work by the authors in both Iceland and elsewhere including Europe[4], North America[5] and China[6] together with the work of other key researchers including Anna Dóra Sæþórsdóttir, Rannveig Ólafsdóttir, Þorvarður Árnason and David Ostman. The basic model involves mapping wilderness quality attributes describing variations in spatial patterns of remoteness and naturalness. Principal wilderness attributes mapped and modelled here include remoteness from mechanised access, visual impact from modern human artefacts, and naturalness of land cover. These are combined using multi-criteria models to create a composite wilderness quality index (WQI). This is then classified using statistical methods into wilderness cores, buffers, transition zones and non-wild areas. Area thresholds based on the Wild Europe Working Definition[7] are then applied to define a final wilderness areas map and cross-referenced with IUCN (International Union for Nature Conservations) Category Ib wilderness definition and guidelines[8]. The resulting areas are characterised using additional data on openness, ruggedness, accessibility from centres of population, mobile phone coverage and livestock grazing.

1.5 Historical threats to wilderness in Iceland include impacts from geothermal and hydro power infrastructure, tourism, recreational 4x4 driving and off-road driving. These have resulted in the steady attrition of wilderness areas over the last 80 years[9]. Many of these threats are ongoing with further expansion of electrical power generation and associated transmission infrastructure. Of particular concern are proposals to expand hydropower generation and to generate electricity from extensive geothermal areas (including *Fremrinámar* and *Hágöngur* areas) in the Central Highlands together with planned wind energy installations, all capable of vastly impacting wilderness qualities[10]. Data on existing impacts are included in the mapping and conclusions drawn.

1.6 It should be noted that the mapping presented here is based on the Icelandic legislation in force at the time of writing, principally the Nature Conservation Act No 60/2013, and is applied to the Central Highlands and surround areas as shown in Figure 1.2. The term Central Highlands in this report refers to the boundaries as shown in this figure, if not otherwise stated. This Area of Interest is defined for the purpose of this report and for the practical purposes of the analysis contained therein. It follows the natural character of the Highland landscape rather than patterns of ownership or municipal boundaries and

[4] Carver, S., Comber, A., McMorran, R. and Nutter, S., 2012. A GIS model for mapping spatial patterns and distribution of wild land in Scotland. Landscape and urban planning, 104(3-4), pp.395-409. https://doi.org/10.1016/j.landurbplan.2011.11.016

[5] Carver, S., Tricker, J. and Landres, P., 2013. Keeping it wild: Mapping wilderness character in the United States. Journal of environmental management, 131, pp.239-255. https://doi.org/10.1016/j.jenvman.2013.08.046

[6] Cao, Y., Carver, S. and Yang, R., 2019. Mapping wilderness in China: Comparing and integrating Boolean and WLC approaches. Landscape and Urban Planning, 192, p.103636. https://doi.org/10.1016/j.landurbplan.2019.103636

[7] https://www.europarc.org/wp-content/uploads/2015/05/a-working-definition-of-european-wilderness-and-wild-areas.pdf

[8] https://www.iucn.org/news/protected-areas/201612/wilderness-protected-areas-management-guidelines

[9] https://skemman.is/handle/1946/9876

[10] Reference is made to the work according to Act No 48/2011 on the Master Plan for Nature Protection and Energy Utilization, see https://www.ramma.is/english and the plan currently debated in the Parliament; https://www.althingi.is/altext/152/s/0468.html

planning jurisdictions. This is contrary to all previous work published, which applies boundaries which are perhaps unsuitable in the context of nature conservation. It is centred around the existing UNESCO World Heritage Site Vatnajökull National Park[11], and recent efforts to create a wider Central Highlands National Park[12], more recently replaced by the government's strategy for the expansion of Vatnajökull National Park instead, to cover all glaciers and already protected areas within the central highlands[13]. Consideration is given to the need to recognise IUCN guidelines and protected area categories in defining core wilderness and associated areas in line with explanatory notes to the Icelandic legal acts in force in the field of nature conservation[14].

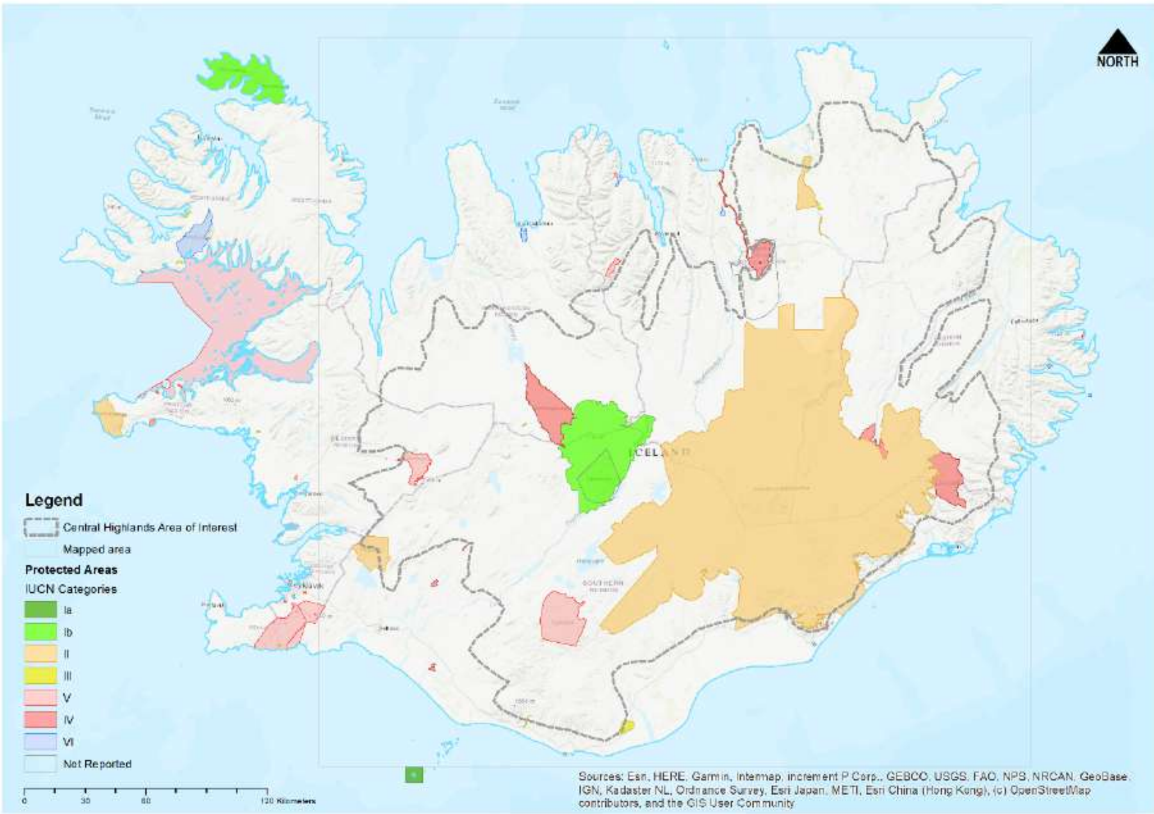

Figure 1.2 Central Highlands Area of Interest and Protected Areas (After World Database on Protected Areas, WDPA)[15]

1.7 The report highlights the need for more robust and repeatable approaches for mapping wilderness quality and character in support of planning decisions regarding protected

[11] https://whc.unesco.org/en/list/1604/
[12] https://www.government.is/topics/environment-climate-and-nature-protection/national-parks-and-protected-areas/plans-for-a-new-highland-national-park/
[13] https://www.stjornarradid.is/rikisstjorn/stjornarsattmali/
[14] https://www.iucn.org/theme/protected-areas/about/protected-area-categories and Act No 60/2013 as read in the light of its preparatory work and context.
[15] https://www.protectedplanet.net/country/ISL It should be noted that the two areas demonstrated on the WDPA map as IUCN Category Ib areas, are in fact not designated as such. Only one area has to date been designated according to Article 46 of Act No 60/2013 (IUCN Category Ib). This is a privately owed area in the north west, Drangar, formally designated in December 2021 and not yet added to the WDPA database.

area designations and their legal boundaries. The ability to reliably map and model the impacts from human land use and infrastructure in an accurate and detailed manner is essential in providing baseline information on which such decisions can be made and assess the impact of any future proposed developments.

1.8 This report has been prepared by the Wildland Research Institute (WRi) working for a national initiative, Óbyggð kortlagning. WRi is an independent academic institute with specialist knowledge in wilderness, geographical information systems (GIS) and landscape assessment[16] and Óbyggð kortlagning is a collaboration of local experts and four Icelandic environmental NGOs aiming at the first wilderness mapping of the central highlands in line with current national legislation.

1.9 WRi have detailed, in-depth knowledge of the wilderness mapping processes. WRi are the originators of the original wilderness mapping methodology developed for the two Scottish National Parks[17] and have acted as technical advisors to Scottish Natural Heritage (SNH) and the Scottish Government during their original Phase I mapping process[18]. In addition, WRi have been contracted, together with partners Alterra and PAN Parks, by the European Union Environment Agency (EEA) to extend the methodology to the whole of the Europe[19]. This approach has also been adopted in a modified form for use in mapping wilderness character by the US National Park Service within national park wilderness areas in the United States[20] and has also been applied in China[21]. WRi are also the authors of the much-cited report on "The Status and Conservation of Wildland in Europe" commissioned by the Scottish Government[22]. WRi are currently working for IUCN France to develop a map of Haute Naturalité (High Naturalness) based on modifications to the mapping approaches developed in Scotland[23].

1.10 Óbyggð kortlagning[24] is a project initiated by local experts with in-depth knowledge in the field of wilderness and nature conservation and four environmental associations in Iceland during 2021[25] for the purpose of mapping Icelandic wilderness areas in line with national legal definitions in force and compatible with internationally recognized methodology; in particular IUCN management category Ib, and for general awareness raising locally in the field of wilderness protection. Several experts in natural sciences and law together with university students worked on the Óbyggð project during 2021. In addition, two local experts, Sif Konráðsdóttir, lawyer, and Snæbjörn Guðmundsson, geologist, provided extensive expert knowledge in preparing the mapping and drafting of this report, in their respective fields of expertise.

[16] http://www.wildlandresearch.org/
[17] https://www.lochlomond-trossachs.org/park-authority/publications/wildness-study/
[18] https://www.nature.scot/guidance-mapping-scotlands-wildness-and-wild-land-non-technical-description-methodology
[19] https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf
[20] Tricker, J. and Landres, P., 2018. Mapping threats to wilderness character in the National Wilderness Preservation System. Biological Conservation, 227, pp.243-251. https://doi.org/10.1016/j.biocon.2018.09.010
[21] Cao, Y., Yang, R., Long, Y. and Carver, S., 2018. A preliminary study on mapping wilderness in mainland China. International Journal of Wilderness, 24(2). https://ijw.org/2018-mapping-wilderness-in-mainland-china/
[22] http://www.self-willed-land.org.uk/rep_res/0109251.pdf
[23] https://www.wildeurope.org/final-stage-for-mapping-wild-france/
[24] https://www.facebook.com/obyggdkortlagning and https://www.instagram.com/obyggdkortlagning/?hl=en-gb
[25] The four associations are: Náttúruverndarsamtök Íslands, Samtök um náttúruvernd á Norðurlandi, Skrauti náttúruverndarsamtök og Ungir umhverfissinnar.

2.Defining wilderness and approaches to mapping

Background

2.1 Wilderness is a widely discussed and hotly debated topic in conservation and environmental protection. We instinctively know what we mean by it, but the actual definition used varies depending on the individual or organisations involved. At its most basic, the term wilderness applies to uninhabited landscapes without obvious human modification or intrusion where we might expect to find and experience wild nature. While there are few (if any) wholly wild landscapes remaining in the world, where they still exist, they tend to be in areas that are too harsh and remote to offer much by way of human interest for agriculture or industry. However, in recent years new sources of energy and recreational interests have created threats to even these landscapes.

2.2 The current climate and biodiversity crisis has led to calls for stronger protection of the world's remaining wilderness areas to help preserve important wildlife habitats and protect global life-support systems. To this end, the Post-2020 Global Biodiversity Framework of the Convention on Biological Diversity places "retaining wilderness areas" as the first of 21 action-oriented targets for 2030[26]. The European Parliament recognised the importance of protecting Europe's wilderness areas in February 2009[27] with a subsequent paper calling for wilderness to be defined, mapped, and protected at all levels[28]. The resolution gave rise to two key reports: the first dealing with definitions and guidelines[29], the second creating a register of protected wilderness areas and a European scale wilderness index[30] as shown in Figure 1.1.

2.3 Wilderness definitions can be divided roughly into two camps: perceptual and ecological. In terms of landscape perceptions, a sense of wilderness may be found where landscapes are remote and obvious forms of human impact are absent. Such places may be a long way from the nearest road and have no agriculture and no buildings or infrastructure and so engender a feeling of wildness. In terms of ecological wildness, the habitats and species present are natural and have not been significantly modified by human activities such that the land cover and wildlife present are as close to what would be considered wild, and that key processes of ecological succession and disturbance occur naturally and shape the form, pattern, and trajectory of ecosystems present.

2.4 Wilderness is also a contested concept with some people questioning its validity citing long histories of human modification of nature and the cultural significance placed on some apparently wild landscapes by indigenous people and cultures. In Iceland specifically, there are contested views on the need to exploit the island's sustainable energy resource and possible conflicts with its developing tourism-based economy[31] and national parks[32].

[26] https://www.cbd.int/doc/c/e068/9905/299212eac8dc52bac49de7ba/sbstta-24-inf-29-en.pdf
[27] https://www.europarl.europa.eu/doceo/document/TA-6-2009-0034_EN.html?redirect
[28] https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/proceedings_wildlife.pdf
[29] https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf
[30] https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf
[31] Sæþórsdóttir, A.D. and Hall, C.M., 2019. Contested development paths and rural communities: Sustainable energy or sustainable tourism in Iceland?. Sustainability, 11(13), p. 3642. https://doi.org/10.3390/su11133642
[32] Bishop, M.V., Ólafsdóttir, R. and Árnason, Þ., 2022. Tourism, Recreation and Wilderness: Public Perceptions of Conservation and Access in the Central Highland of Iceland. Land, 11(2), p.242. https://doi.org/10.3390/land11020242

2.5 Appropriate legal mechanisms are required to provide such protection in national policy and law. Despite the difficulties associated with the word "wilderness" in general[33], careful and tight definitions are required if legal protection is to work[34]. Wilderness statutes must *(i)* define which lands would be wild enough to qualify as wilderness, and *(ii)* define which uses would be permissible on those lands to ensure that the wilderness resource is preserved[35].

National wilderness legislation

2.6 The Icelandic Nature Conservation Act No 60/2013 gives the definition of wilderness in Article 5(19) as "*An uninhabited area […] that is in principle at least 25 km^2 in size or in such a way that one can enjoy solitude and nature there without disturbance from man-made structures or the traffic of motorized vehicles and in principle at least 5 km away from structures and other technical traces, such as power lines, power plants, reservoirs and built roads*."[36] This definition is closely interlinked with the provision outlining the conditions for designating lands as wilderness protected areas, Article 46, which again in its explanatory note in the Bill of Law refers to one of the stated objectives of the Nature Conservation Act: to retain the wilderness, *i.e*. Article 3(e). "*Large areas, in principle untouched by human activities, where nature can evolve independently, may be legally designated as wilderness protected areas*" according to Article 46, which further reads: "*The designation shall aim at protecting the characteristics of the areas, for example to maintain diverse and unique landscape, openness and/or protecting large ecosystems; and to ensure that present and future generations can enjoy solitude and the nature without disturbance from man-made structures or the traffic of motorized vehicles*", the part underlined here containing the exact same wording as the subjective part of the definition in Article 5(19) cited above, which is further discussed below. All legal provisions cited above are in force as of November 2015 and were a novelty at the time. No wilderness designation as referred to in the national legislation has yet taken place within the Central Highlands.

2.7 There are two operational definitions from the Nature Conservation Act No 60/2103: one objective and the other more subjective. The objective definition states that "*in principle"* wilderness areas should meet a minimum size requirement of 25km^2 and, also "*in principle",* be more than 5km from infrastructure, including but not limited to certain electricity infrastructures and roads. The more subjective definition suggests wilderness or *óbyggð víðerni* is a place where "*one can enjoy solitude and nature […] without disturbance from man-made structures or the traffic of motorized vehicles*."[37] The Explanatory Note to a Bill of Law 2015 providing for this part of the definition, goes on to

[33] Casson, S.A., Martin V.G., Watson, A., Stringer, A., Kormos, C.F. (eds.). Locke, H., Ghosh, S., Carver, S., McDonald, T., Sloan, S.S., Merculieff, I., Hendee, J., Dawson, C., Moore, S., Newsome, D., McCool, S., Semler, R., Martin, S., Dvorak, R., Armatas, C., Swain, R., Barr, B., Krause, D., Whittington-Evans, N., Gilbert, T., Hamilton, L., Holtrop, J., Tricker, J., Landres, P., Mejicano, Gilbert, T., Mackey, B., Aykroyd, T., Zimmerman, B., Thomas, J. (2016). Wilderness Protected Areas: Management guidelines for IUCN Category 1b protected areas. Gland, Switzerland: IUCN, 2-4 pp. https://portals.iucn.org/library/sites/library/files/documents/PAG-025.pdf
[34] Bastmeijer, K., (ed) 2016. Wilderness Protection in Europe: The Role of International, European and National Law. Cambridge University Press.
[35] Kormos, C.F. (ed.) 2008. A Handbook on International Wilderness Law and Policy. Fulcrum Publishing, Golden, Colorado, p. 21.
[36] Translation of national legal texts is our informal translation, see original text: https://www.althingi.is/lagas/nuna/2013060.html
[37] Article 1(c) of Act No 109/2015, amending Act No 60/2013 https://www.althingi.is/altext/stjt/2015.109.html

suggest such a subjective definition is needed because "*[i]f the definition was only based on minimum size, there would be few wilderness areas left in Iceland today"*, thus highlighting one of the key problems with objective size or distance thresholds common in discrete Boolean analyses that rely on buffer zones and minimum size thresholds. *"It is proposed that experience is an explicit part of the wilderness definition, as this is an important part of the wilderness concept"*, the Explanatory Note further states[38]. The approaches presented in this report rely on this legal background and context.

2.8 In the Nature Conservation Act in force since November 2015, and in subsequent amendments to the Act, there is a new trend towards broader recognition and application of IUCN management categories and internationally recognized methods in mapping landscape qualities and character including wilderness[39]. While this provides the basis of a local definition, this can be placed in the wider international context not only to the IUCN management category Ib but by reference to the Wild Europe definition, discussed below.

2.9 A recent legislative change saw amendments to the Icelandic Nature Conservation Act No 60/2013 making the mapping of wilderness mandatory with a suggested completion date of June 2023. This report presents both a method and approach by which such a programme of mapping could be accomplished using the Central Highlands as an example.

IUCN Protected Area definition and legal designation in Iceland

2.10 A protected area under IUCN guidelines is defined as: *"a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values."*

2.11 All these cumulative criteria must be satisfied for an area to qualify as a protected area in Iceland and are a precondition for areas to be classified under the IUCN management categories and in an international context, including the World Database of Protected Areas[40] [41].

2.12 The designation of protected areas under national legislation is made by ministerial decree. Historically, two out of three existing Icelandic national parks were however established by way of legal acts adopted by the Icelandic Parliament. Statutory acts pre-dating the Nature Conservation Act No 60/2013 are also in place in some designated protected areas, such as Mývatn and Breiðafjörður[42]. The Nature Conservation Act in force allows now for all such designations to be established by way of ministerial decree, including national park designation according to Article 47. No national park has been established since the entering into force of the Nature Conservation Act No 60/2013.

[38] See explanatory note to Article 1 in Bill of Law amending Act No 60/2013 https://www.althingi.is/altext/145/s/0140.html

[39] Reference is made to general comments in the Explanatory Note attached to the Bill of Law put forward to the Parliament in 2012 and lated adopted as Act No 60/2013, more spcifically comments to Chapter VIII of the Bill and to Article 46 in particular, see https://www.althingi.is/altext/141/s/0537.html, and to the preparatory work in 2011 White Paper on Nature Conservation (Hvítbók um náttúruvernd) https://www.stjornarradid.is/media/umhverfisraduneyti-media/media/PDF_skrar/Hvitbok_natturuvernd.pdf

[40] http://www.rogercrofts.net/files/iceland/Heart%20Iceland%20NP%20recommendations.pdf

[41] https://www.protectedplanet.net/en/thematic-areas/wdpa?tab=WDPA

[42] Gazetted 1995, see Act No 54/1995 and https://ust.is/nattura/natturuverndarsvaedi/fridlyst-svaedi/vesturland/breidafjordur/

IUCN Wilderness Protected Areas and Wild Europe Working Definition

2.13 IUCN Category Ib, wilderness protected areas, is set out in the IUCN Best Practice Guidelines series[43]2008 IUCN Management Guidelines, Series No 21[44], and more in-depth guidance is provided in the more recent 2016 Wilderness Protected Area Guidelines, Series No 25[45]. The IUCN definition reads "*protected areas that are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition*".

2.14 The 2013 Wild Europe Working Definition adapts IUCN Category Ib to European circumstances, and is now adopted by the European Union. This states "*A wilderness is an area governed by natural processes. It is composed of native habitats and species, and large enough for the effective ecological functioning of natural processes. It is unmodified or only slightly modified and without intrusive or extractive human activity, settlements, infrastructure or visual disturbance.*"[46]

2.15 The Wild Europe Working Definition provides further interpretation of the IUCN wilderness definition by outlining specific criteria and size thresholds within "*a standardized and practical definition of wilderness and wild areas that can form the basis for effective protection, restoration or rewilding initiatives across a range of geographic and cultural circumstances in Europe*."[47] Here the criteria are focused on minimum size thresholds for core, buffer and transition zones, biodiversity, natural processes, settlement, infrastructure, access and various forms of human land use including foraging, livestock grazing, forestry, hunting, fishing, crop agriculture, tourism and recreation, etc. The working definition has been adopted by the EU Wilderness Register[48], the EU Guidance on Wilderness and Wild Area Management in the Natura 2000 Network[49], the German Federal Government[50], the Austrian National Parks Association[51], IUCN France, Fundatia Conservation Capathia[52], The European Wilderness Society[53] and Sumava National Park.

2.16 International approaches have tended more towards continuous mapping methods that allow for the fact that definitions and perspectives on wilderness qualities and character found in wild landscapes are more subjective and thus require more subtle and nuanced mapping that takes the fuzzy and highly variable nature of wilderness attributes into account. The factors affecting wilderness quality and character are universal and based largely around concepts of remoteness and naturalness. How they are modelled and

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[43] IUCN WCPA Best Practice Guidelines for Protected Area Managers Series, see https://www.iucn.org/theme/protected-areas/resources/iucn-wcpa-best-practice-guidelines-protected-area-managers-series

[44] https://portals.iucn.org/library/node/30018
[45] https://www.iucn.org/news/protected-areas/201612/wilderness-protected-areas-management-guidelines
[46] https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/WildernessGuidelines.pdf
[47] https://www.europarc.org/wp-content/uploads/2015/05/a-working-definition-of-european-wilderness-and-wild-areas.pdf. With 2020 clarifications https://www.wildeurope.org/wp-content/uploads/2020/07/WEI-defs-200720-1.pdf
[48] https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf
[49] https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/WildernessGuidelines.pdf
[50] https://www.bfn.de/themen/biotop-und-landschaftsschutz/wildnisgebiete/qualitaetskriterien.html
[51] https://www.wildeurope.org/model-wilderness-area-in-alps-based-on-wild-europe-definition/#more-3068
[52] https://www.carpathia.org/
[53] https://wilderness-society.org/european-wilderness-definition/

mapped has a marked influence on the results with most approaches across a range of scales from global to local using the wilderness continuum concept as a guide to understanding where an example landscape sites along a spectrum from least to most wild. This is shown in Figure 2.1.

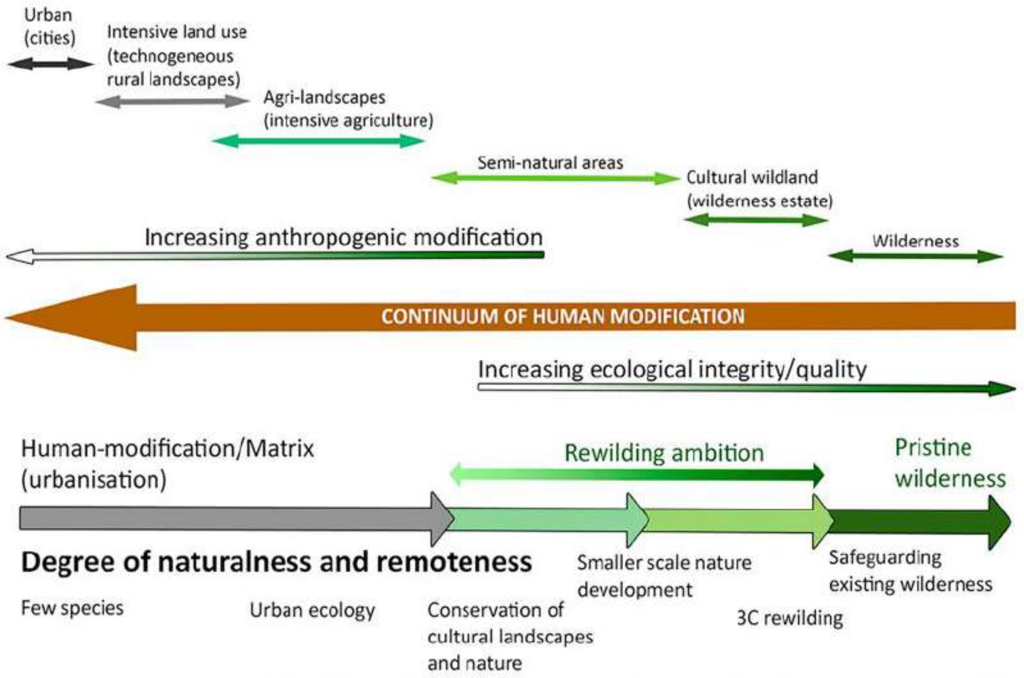


Figure 2.1 The Wilderness Continuum (After Lesslie and Taylor, 1985)

2.17 As discussed above, nature conservation legislation in Iceland entails directly comparable designation categories to those in IUCN management categories. The background is a 2011 White Paper on Nature Conservation[54] and the approach later taken when adopting new designation categories in the Nature Conservation Act No 60/2013, put forward as a Bill of Law in 2012, adopted in 2013 and entering into force in 2015.

2.18 The legislative changes as regards wilderness areas in Iceland making their way into statutory rules during the last decade or so may appear subtle on the surface and when exclusively observing the wording of the definition (as opposed to the previous Nature Conservation Act from 1999). However, the changes are fundamental. *First*, protecting wilderness is now one of the stated objectives of the Nature Conservation Act (as per Article 3(e)), and all legal provisions, decisions and actions must be made and interpreted in that light; *second*, legal designation of wilderness as a protected area can now be made explicitly and according to Article 46; and *third*, the designation conditions and objectives of wilderness areas shall be in line with IUCN Category Ib, the definition and designation of wilderness in Article 5(19) and 46 having a direct reference to this.

2.19 To date, local literature has been sparse as regards the content, meaning and effect of the legislative novelties. Legal analysis is sparse and administrative practice and precedents non-existent nationally. As set out by dr. Aðalheiður Jóhannsdóttir in her 2016 article on

[54] https://www.stjornarradid.is/media/umhverfisraduneyti-media/media/PDF_skrar/Hvitbok_natturuvernd.pdf

wilderness in Iceland[55], a fourth item can be added to the list provided above, strengthening the wilderness protection, namely the adoption of certain environmental principles in the Nature Conservation Act in 2015. Amongst others, this includes the precautionary principle, Polluter-Pays-Principle and adopting a scientific basis for decisions. However, while legal provisions are in place, the absence of wilderness mapping in line with the legal provisions discussed above and subsequently legally designating the areas selected, constitutes a significant limitation to the objectives of protecting wilderness in Iceland.

2.20 Against this background, the mapping and recommendations put forward in this report are based on the assumption that IUCN management categories and Nature Conservation Act designations categories are in principle comparable. In this report, the focus is on mapping wilderness areas in the Central Highlands and identifying those suitable to be considered and legally designated and managed as wilderness areas within the meaning of IUCN Category Ib and Article 46 of the Nature Conservation Act. However, provided offroad winter driving and other incompatible human activities are addressed, other categories could be easily defined in the process of further work and be informed by the type of mapping described here.

2.21 This report is not the first addressing different categories for legally designating areas in the Central Highlands. Rogers Crofts, who has a long-standing role as an advisor to the Icelandic government on nature conservation, touched upon the management categories in a report to the Icelandic authorities in 2010[56] in relation to the then newly established Vatnajökull National Park, during the preparation of its first management plan. He further provided detailed recommendations in his latest recommendations to the Icelandic authorities. In the latter report, dated January 2018[57], he discussed the option to legally designate areas in the Central Highlands, dividing them into different areas and appropriate IUCN management categories (see Chapter 7 of his report). Crofts' recommendations do not refer to any examples of IUCN Category Ia, Strict Nature Reserve, within the Central Highlands. For IUCN Category Ib[58] he suggested Þjórsárver[59], while Vatnajökull ice cap could be designated as a Category II National Park, and some of the waterfalls and the lava formation mentioned in his suggestions could be included as Category III Natural Monument or Features. Several examples of such designation opportunities are indeed located within the Central Highlands area of interest in this report, for example Dettifoss[60], Gullfoss[61] and Hveravellir. His recommendations for designated areas are highly relevant and worth looking into for nature conservation purposes, regardless of the approaches taken by the Icelandic authorities, to designate areas within the Central Highlands as protected areas under all management and governance types. It is however outside the scope of this report to recommend designations option other than wilderness areas within the meaning of Articles 5(19) and

[55] Jóhannsdóttir, A.: Wilderness protection in Iceland, in Bastmeijer, K., (ed) 2016. Wilderness Protection in Europe: The Role of International, European and National Law. Cambridge University Press, pp. 360.
[56] http://www.rogercrofts.net/files/iceland/IcelandVisitReportJuly2010.pdf
[57] http://www.rogercrofts.net/files/iceland/Heart%20Iceland%20NP%20recommendations.pdf
[58] Further reading of IUCN management categories: https://www.iucn.org/theme/protected-areas/about/protected-area-categories
[59] https://ust.is/nattura/natturuverndarsvaedi/fridlyst-svaedi/sudurland/thjorsarver/
[60] Privately owned land, gazetted 1996 as Natural Monument, managed by Vatnajökull National Park, see https://ust.is/nattura/natturuverndarsvaedi/fridlyst-svaedi/nordurland-eystra/dettifoss-og-fossarod/
[61] Gazetted in 1979, see https://ust.is/nattura/natturuverndarsvaedi/fridlyst-svaedi/sudurland/gullfoss/

46 of the Nature Conservation Act and IUCN Category Ib though opportunities for Cat II areas are highlighted in the maps and methods used.

Governance types internationally and locally

2.22 The governance of protected areas, according to IUCN guidelines refers to: who decides the protected area objectives, and how these are implemented; how those decisions are taken; who holds power, authority, and responsibility; and who is (or should be) held accountable for successes and failures of management. The IUCN acknowledges four governance types as shown in Table 2.1.

Table 2.1 IUCN governance types

	Type	Description
A	Governance by government	Federal or national ministry/agency in charge Sub-national ministry/agency in charge Government-delegated management (e.g. to NGO)
B	Shared governance	Collaborative management (various degrees of influence) Joint management (pluralist management board) Transboundary management (various levels over frontiers)
C	Private governance	By individual owner By non-profit organisations (NGOs, universities, cooperatives) By for-profit organisations (individuals or corporate)
D	Governance by indigenous peoples and local communities	Indigenous peoples' conserved areas and territories Community conserved areas – declared and run by local communities

2.23 The situation where most protected areas have traditionally been owned and managed by governments has been changing internationally. Privately protected areas (governance type C) can provide the opportunity for voluntary contributions to conservation, complementing the role of governmental agencies. In particular, they can contribute to achieving the Convention on Biological Diversity (CBD) Aichi Biodiversity Target 11[62] on completing ecologically representative protected area networks around the world. Against this background, IUCN has in recent times advocated for privately protected areas as an addition to areas governed solely by governments or NGOs on their behalf[63]. In fact, a large part of protected areas within certain regions of the world have traditionally been privately owned and governed, as is the case in South Africa. In the UK many protected areas are governed by NGOs and in the Netherlands one third of protected areas are subject to private governance. However, this has not happened in Iceland. The Nature Conservation Act exclusively provides for government governance, regardless of ownership of the designated land. An example is Geysir, which was not a protected area

[62] https://www.iucn.org/news/protected-areas/201905/enhancing-progress-towards-aichi-target-11
[63] https://www.iucn.org/commissions/world-commission-protected-areas/our-work/privately-protected-areas-and-nature-stewardship

while under private ownership and was only designated in 2020[64] following the transfer of title to the Icelandic state. The most recent designation is a privately owned area gazetted in December 2021 as the first national wilderness area designation, is governed by the state as is the case with all designated protected areas in the country[65].

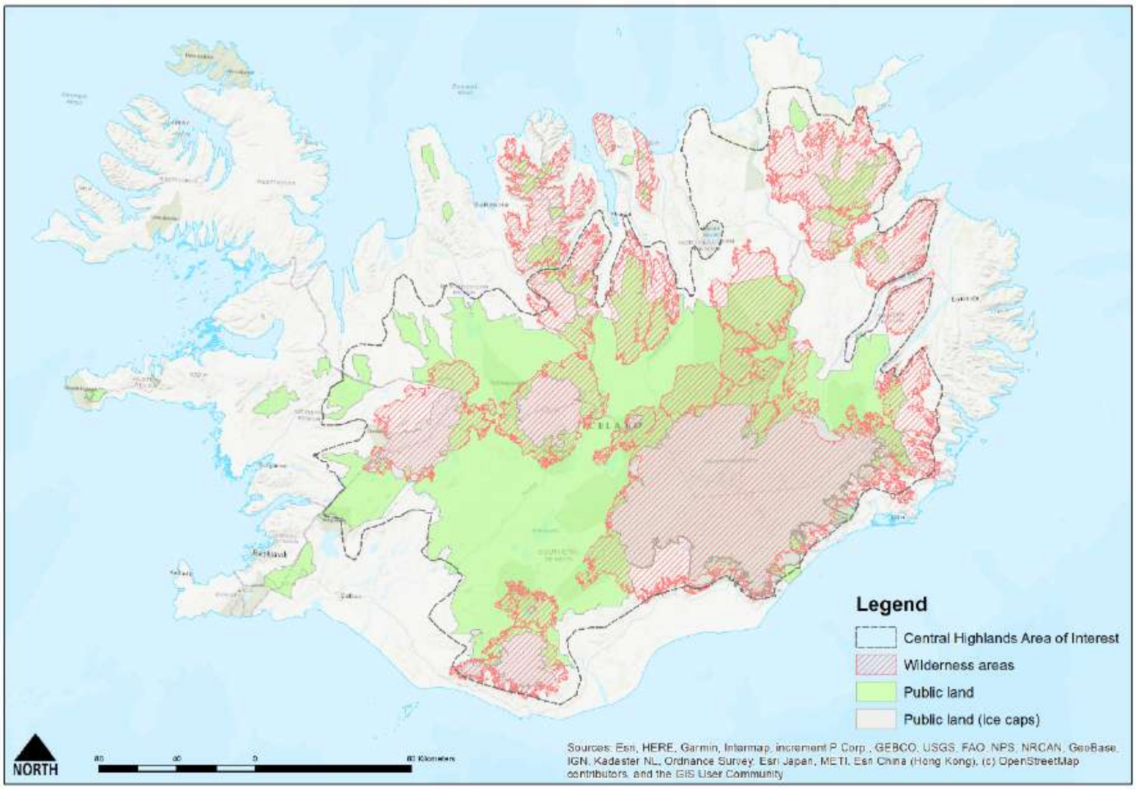


Figure 2.2 Public lands and wilderness areas in the Central Highlands (After Óbyggðanefnd[66])

2.24 The designation and governance of Vatnajökull National Park is somewhat unique. It was gazetted by way of a regulation issued on a ministerial level. Its legal basis is *lex specialis;* statutory law concerning exclusively the protected area assigned, and managed by a board of directors, the majority of which are members nominated by the relevant municipalities and may be regarded as a form of shared governance. Governance types C (private governance), and D (indigenous peoples and local communities) do not exist in protected areas in Iceland. It is interesting to note that early mapping of wilderness areas in the Central Highlands[67] shows as much as 85 percent of Vatnajökull National Park is wilderness, also referred to in Iceland's nomination of the National Park as UNESCO World Heritage Site[68]. The work presented here suggest a similar figure but puts this at 78 percent based on measurement of wilderness attributes.

[64] https://www.stjornarradid.is/efst-a-baugi/frettir/stok-frett/2020/06/17/Geysir-fridlystur-a-thjodhatidardegi-Islendinga/ https://ust.is/nattura/natturuverndarsvaedi/fridlyst-svaedi/sudurland/geysissvaedid/
[65] Drangar wilderness area, see https://ust.is/nattura/natturuverndarsvaedi/fridlyst-svaedi/vestfirdir/drangar-a-strondum/
[66] https://obyggdanefnd.is/
[67] In Þ Árnason, D Ostman, and A Hoffritz. 2017. Kortlagning víðerna á miðhálendi Íslands: Tillögur að nýrri aðferðafræði. Höfn í Hornafirði https://www.skipulag.is/media/pdf-skjol/Kortlagning_Viderna_Web2.pdf
[68] See Fig 2.36 in 2018 UNESCO Nomination Text at https://whc.unesco.org/en/list/1604/

2.25 The report found a considerable share of the wilderness areas identified to be privately owned. While most of the land within the Central Highlands is owned by the state, either directly or as public lands (*þjóðlenda*) according to Act No 58/1998 on Public Lands, the wilderness areas within the Central Highlands area of interest in this report contain large areas outside public lands[69], see Figure 2.2. This is also the case in large parts of wilderness areas identified in this report outside the Central Highlands, see Chapter 5 below, but also *Heljardalsfjöll* in the Northeast (see Area 2 in Appendix to this report) and *Nýjabæjarfjall* in the Central North (see Area 7 in Appendix to this report), together with parts of several other areas (public land designation procedures has not yet taken place in East Iceland). In total, almost one third of the wilderness areas identified in this report are outside public lands. Whereas Article 47 designation, National Park, requires in principle public ownership of the land designated according to national legislation, this is not a requirement for any other national designation category. It is worth considering whether the absence of alternative governance types recognised by national legislation when assigning protected areas is best serving the objectives of the Nature Conservation Act, and nature conservation in Iceland in general.

Previous attempts to map wilderness in Iceland and international examples

2.26 Previous attempts to map wilderness in Iceland have tended towards mapping the objective criteria based around the minimum size requirement of 25km^2 using buffer zones of more than 5km from roads and buildings[70]. Application of such thresholds needs to be done with great care as the results can be misleading. For example, a small shepherd's hut can have the same effect as a geothermal powerplant, or a rough gravel road can have the same effect as a paved and elevated dual carriageway road. Adjustments to how these are counted in Boolean analyses can be made by simply tallies or applying viewshed analyses to determine which and how many human features are visible[71]. Example maps are shown in Figure 2.3. The differences seen are largely due to which roads are selected for mapping. Excluding unpaved roads from the second of these maps results in much more wilderness areas within the interior of the country despite these having a similar impact to paved roads in terms of remoteness from motorized access and visual impact.

2.27 Other attempts have taken an entirely different approach by looking at public perceptions of wilderness using online methods of data capture[72]. Here an online map is used together with a spray can tool to allow users to define their own wilderness areas by spraying directly on the map. An example is shown in Figure 2.4. This can be compared against the maps in Figure 2.3 and serves to demonstrate that perceptions, while important and of interest, are no substitute for direct mapping based on full use of the available data.

[69] https://obyggdanefnd.is/wp-content/uploads/thjodlendur-kort.pdf
[70] Ólafsdóttir, R. and Runnström, M.C., 2011. How wild is Iceland? Wilderness quality with respect to nature-based tourism. Tourism Geographies, 13(2), pp.280-298. https://doi.org/10.1080/14616688.2010.531043
[71] https://www.ramma.is/media/rannsoknir/OstmanEtal2021_WildernessIceland.pdf
[72] Ólafsdóttir, R. and Sæþórsdóttir, A.D., 2020. Public Perception of Wilderness in Iceland. Land, 9(4), p.99. https://doi.org/10.3390/land9040099

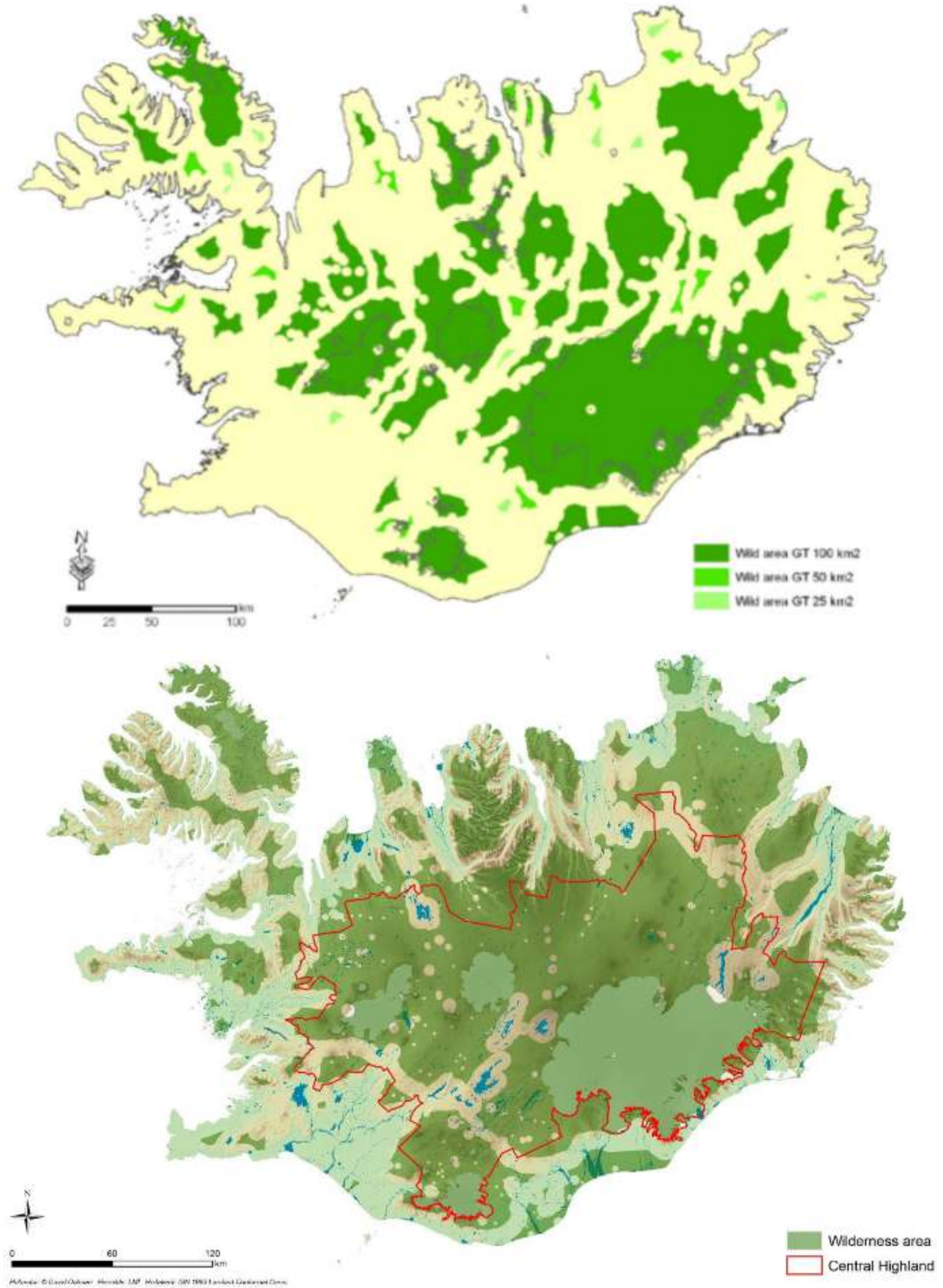


Figure 2.3 Comparison of reconnaissance level maps of wilderness in Iceland. (a) After Ólafsdóttir and Runnström, 2011 (b) After Árnason and Ostman, 2021

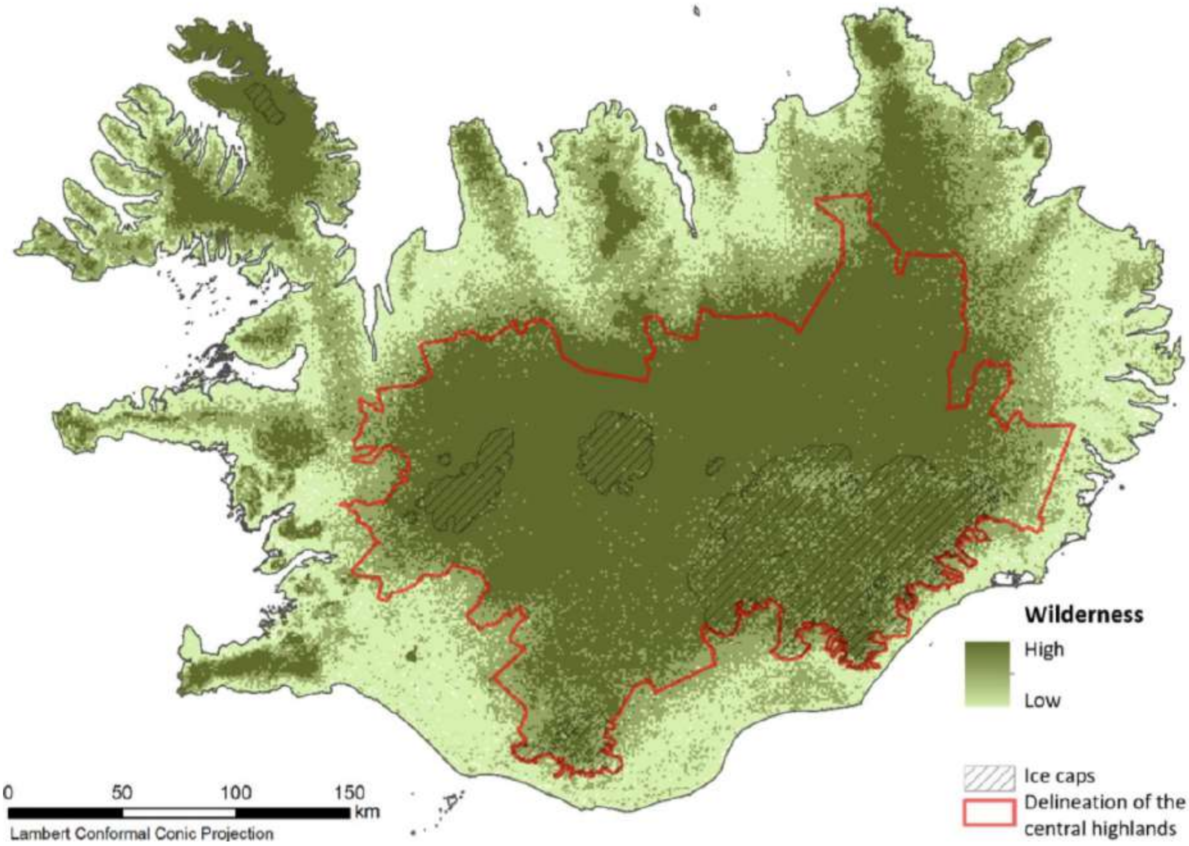


Figure 2.4 Public perceptions of wilderness in Iceland (After Ólafsdóttir and Sæþórsdóttir, 2020)

2.28 Recent local mapping projects in Iceland have focused on demonstrating the projected impact on wilderness quality from proposed developments. These include the proposed Hvalávirkjun hydropower plant in the Drangajökull Peninsula[73], and the proposed four-wheel drive vehicle route in Vatnajökull National Park[74]. Both projects adopt and adapt internationally recognised mapping approaches based on continuous data models and the wilderness continuum concept and acknowledge objective and subjective parts of national legal definition in force. These allow for the mapping of wilderness attributes along a sliding-scale from least to most wild based on direct measurement of critical factors such as remoteness and visual impact. Example WQI maps are shown in Figure 2.5. "What if?" modelling allows before and after maps to be drawn with and without the proposed development in place within the digital landscape model to enable calculations of the amount of wilderness lost should the development go ahead. The example of the Hvalávirkjun hydropower plant is shown in Figure 2.5.

[73] http://hdl.handle.net/10802/28566 (direct link to the Hvalá report on rafhladan.is)
[74] https://wildlandresearch.org/wp-content/uploads/sites/39/2021/09/Vonarskard-Report-v1.7.pdf

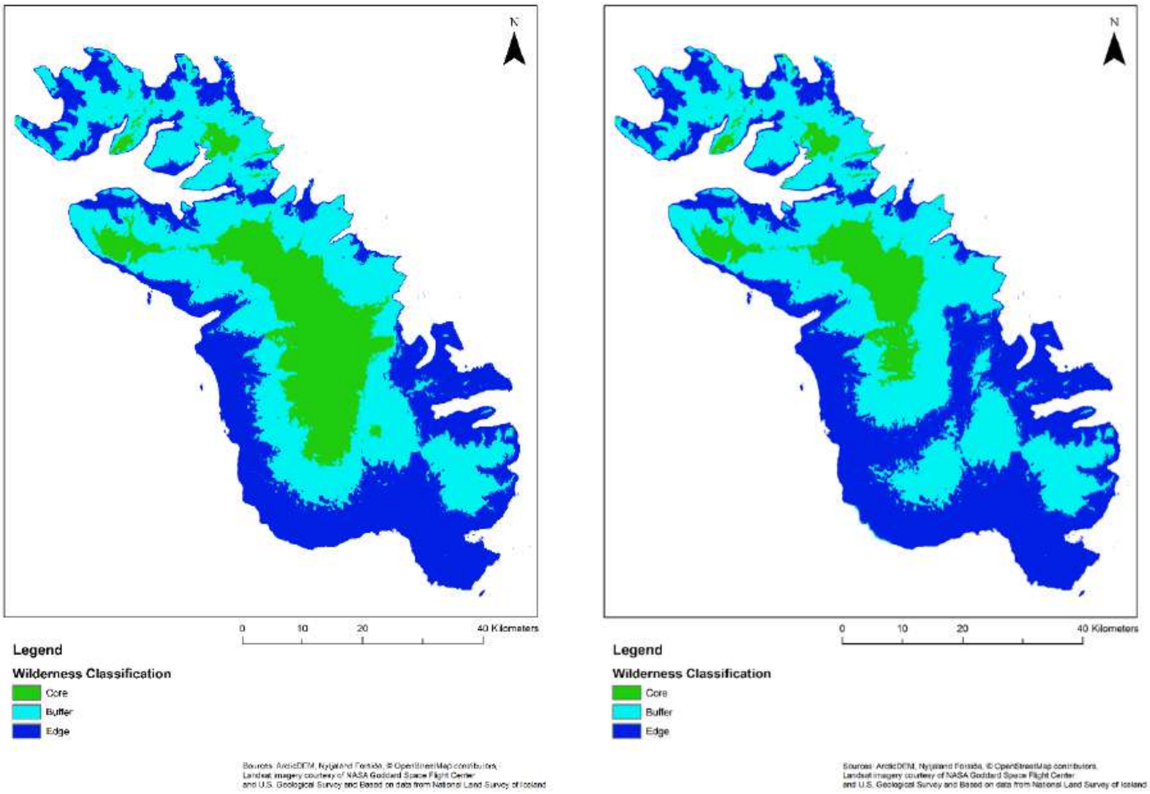
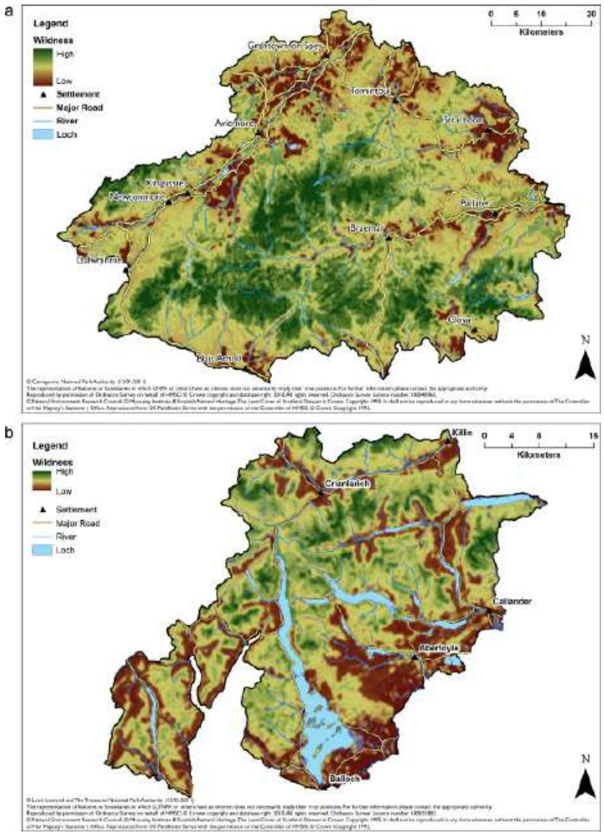


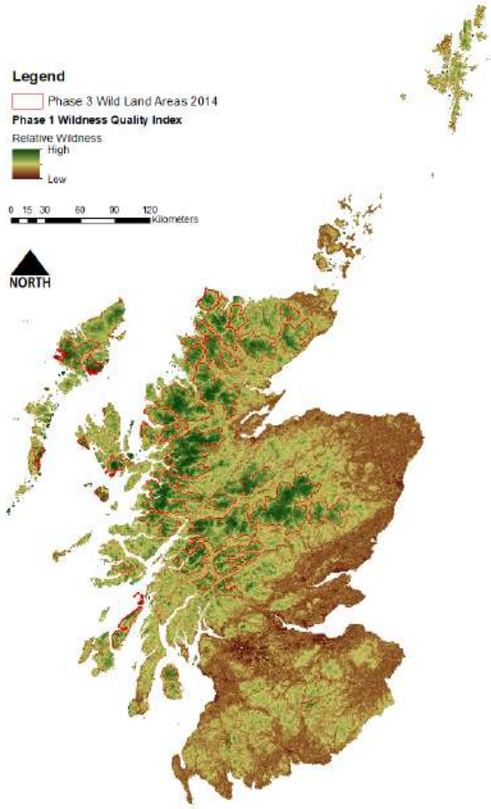
Figure 2.5 "What if?" modelling of impacts on wilderness showing before and after effects from the proposed Hvalá power plant (After Carver et al., 2019)

2.29 These models build on previous work by the authors with international partners to map and model wilderness quality and character at multiple spatial scales. Examples include mapping wildness in Scottish National Parks[75] and wild land areas (WLAs) across Scotland for NatureScot (formerly Scottish Natural Heritage)[76], mapping Haute Naturalité or high naturalness across France for IUCN France[77], and mapping variations in wilderness character in designated wilderness areas for the US National Park Service[78]. Example maps are shown in Figure 2.6.

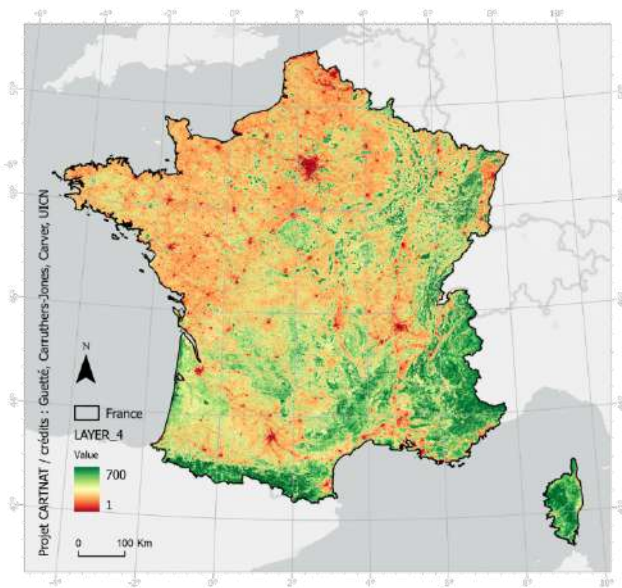
[75] https://www.lochlomond-trossachs.org/park-authority/publications/wildness-study/
[76] https://www.nature.scot/guidance-mapping-scotlands-wildness-and-wild-land-non-technical-description-methodology
[77] https://uicn.fr/aires-protegees/wilderness/
[78] https://leopold.wilderness.net/our-science/research-agenda/management-tools/character-mapping.php



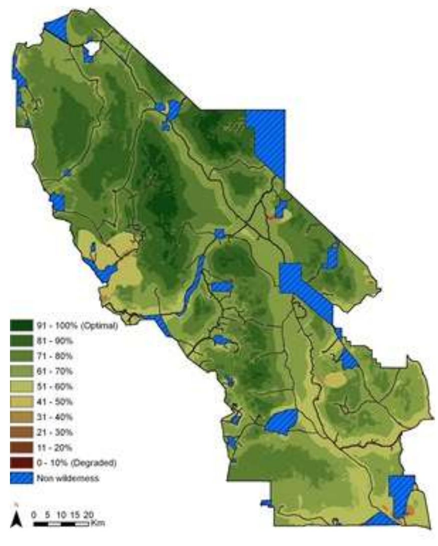
a. CNP and LLTNP (After Carver et al., 2012)



b. WLAs in Scotland Phase1 and Phase3 maps (After SNH, 2014)



c. Haute Naturalité, France (CARTNAT) 2021



d. Wilderness character in Death Valley National Park, USA (After Carver et al., 2013)

Figure 2.6 Examples of wilderness continuum mapping

2.30 Applying these approaches to modelling wilderness quality in the Drangajökull Peninsula and across Vonarskarð in the Vatnajökull National Park has made it clear that the variable nature of the Icelandic landscape, together with the relative impacts of human features in those landscapes on key attributes of remoteness and visual impact, mean that continuous mapping of wilderness quality is needed to define wilderness areas with a high degree of accuracy and reliability. These approaches are described in detail in sections 3, 4 and 5 of this report.

Off-road driving in Iceland and the register of roads in nature

2.31 Challenges regarding off-road driving/winter driving on snow and ice have been encountered during the preparation of the wilderness mapping. Winter driving on ice and snow, where the snow/ice cover allows driving without damaging the underlying ground and vegetation, is in principle allowed throughout the island and only limited in certain areas within Vatnajökull National Park. Meanwhile, a summer ice-road across the Langjökull between Langjökulsvegur in the northwest and Skálpanesvegur in the southeast exists as a tourist attraction. This creates a problem for IUCN Cat Ib designation since criteria clearly state that use of mechanical vehicles for recreation is incompatible with wilderness[79].

2.32 Wilderness mapping needs to be based on information on motorized access to roads and tracks. However, roads other than those usable by the public, both those operated by the National Road Authority and not, are to date only *de jure* and not *de facto* subject to an official and complete mapping or database. Uncertainty exists regarding many routes on more unofficial roads and tracks.

2.33 Efforts to limit persistent off-road driving have been made in the past, but recent legislative changes have addressed this more specifically. This is by way of provisions in Article 32 in the Nature Conservation Act No 60/2013 and in Regulation No 260/2018 issued on the basis of that provision; a specific chapter of the Nature Conservation Act is as of 2015 dedicated to the off-road driving issue: Chapter V. Furthermore, when accepting Vatnajökull National Park on the World Heritage list in 2019 UNESCO recommended that additional measures were put in place to discourage illegal off-road driving by visitors, and to rehabilitate any areas affected adversely by these and other visitor uses[80]. In the past, the Icelandic authorities' consultant, Roger Crofts, mentioned the challenges off-road winter driving constitute[81] and recommended to limit the off-road driving permission in protected areas[82] in his 2010 report.

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[79] Certain categories of human activity are incompatible with wilderness values and variances cannot be allowed. These categories include "Mechanical recreation—Humans use vehicles for recreational activities, including bicycles, automobiles, off-road vehicles, motorboats, and snowmobiles." Kormos, C. F., & Locke, H. (2008). Introduction. In C. F. Kormos (Ed.), A handbook on international wilderness law and policy. Colorado: Fulcrum Publishing, Golden. p25.

[80] https://whc.unesco.org/en/decisions/7364

[81] "This is an issue where I hope that progress can be made. The situation has got progressively worse in recent years with more people disregarding the long standing rule of no off roading on non snow covered ground." http://www.rogercrofts.net/files/iceland/IcelandVisitReportJuly2010.pdf

[82] "Op. Cit. "I understand that, according to the legislation article 17: "Motorised vehicles may not be driven off-road. Such vehicles may, however, be driven on glaciers, as well as off-road on snow outside of urban areas, provided that the grounds on frozen and covered by snow." The latter part of this article is too open. I have noticed damage where motorized vehicles have been driven across snow covered vegetated land. The legislation should be changed to halt or ban all off-road driving, snow covered or not in protected areas,

2.34 Article 32 of the Nature Conservation Act foresees the adoption, by each municipality, of a decision regarding which roads and tracks "in the nature", other than public roads as defined by the Road Act No 80/2007, shall be partly or fully open to motorized access, and subsequently be entered into digitized register thereof. This decision shall be made in an extensive consultation procedure with agencies, stakeholders and nature conservation associations, in parallel with the adoption of the municipalities' local planning and shall be published in the National Gazette in order to take effect. In protected areas the permission of the governing agency is a precondition. The National Road Authority is then entrusted with keeping an updated on-line database with these roads and tracks. All other roads and tracks in the nature shall be deleted from all maps, including digitized maps GPS appliances, and detailed data shall be entered into these maps informing about the road register. Deadline for the adoption of this register was by end of 2020, according to the Nature Conservation Act. To date, only one municipality appears to have adopted such a decision, however not yet published.

2.35 Vatnajökull National Park Management Plan adopted 2011, updated 2013[83], does not include easily accessible information or maps of roads and tracks open to motorized access and no digitized data. In the absence of an official, updated and approved register of roads and tracks open to motorized access across the Central Highlands, the Landmælingar Íslands (LMÍ) database, accessed on June 2021[84], has been used as a proxy, being the best available source of data, until the Article 32 road register has been adopted.

except for legitimate research and rescue services." This rule is still in force, in Article 32(1) of the Nature Conservation Act.

[83] https://www.vatnajokulsthjodgardur.is/static/files/Stjornsysla/PDF-skjol-kort/stjornunar-og_verndar_2013.pdf

[84] https://kort.lmi.is/

3. Developing a wilderness model unique to Iceland

3.1 Different countries and cultures have different understandings of the word "wilderness" and what it means in terms of landscapes and protected area designations. In Iceland the legal term *óbyggð víðerni* (often just shortened to *víðerni*) which means "uninhabited wilderness" and corresponds to IUCN category Ib is not the word generally used to refer to wilderness in Iceland[85]. A 2016 survey suggests that words like *óbyggðir (*literally meaning uninhabited area*)* and *miðhálendi* (central highlands) are both closer to the legal term *óbyggð víðerni* in the minds of the local population. Hence, surveys and discussions on the locals' perception of "víðerni" has limited relevance, even if they can be relevant when asking foreign tourists about their perception of "wilderness"[86]. Regardless, by most international standards much of Iceland's interior may be classified as wilderness once away from roads and human development (see Figure 3.1).

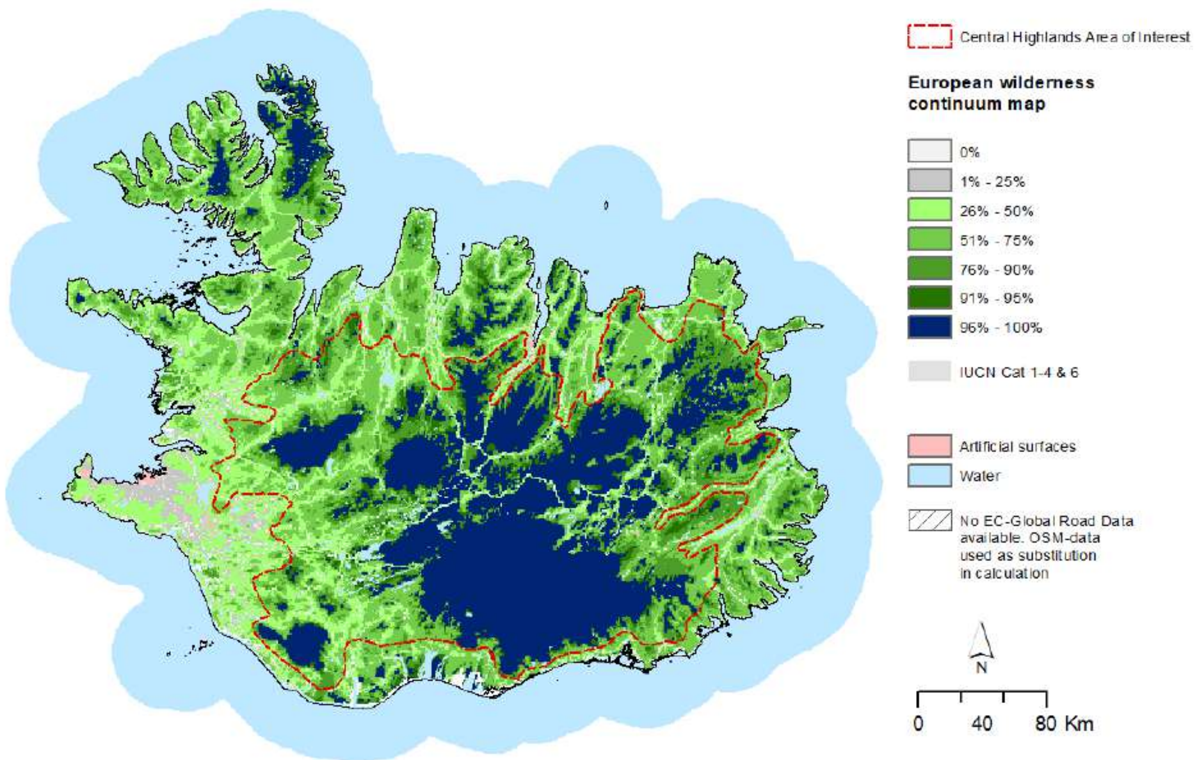

Figure 3.1 Iceland's Central Highlands (After Kuiters et al., 2013)

3.2 The uniqueness of Iceland's interior with its mix of glaciers and ice caps, wide flat gravel plains, rolling hills and rugged mountains, ice-fed rivers, lakes, freshwater springs and

[85] Ólafsdóttir R. and Sæþórsdóttir A.D.: Hálendið í hugum Íslendinga. 1. hluti: Merking hugtakanna víðerni, óbyggðir og miðhálendi. Náttúrufræðingurinn. 2020, p. 202-208. Hálendið í hugum Íslendinga. 2. hluti: Hugmyndir og viðhorf Íslendinga til víðerna. Náttúrufræðingurinn. 2020, p. 282-293 .

[86] Huijbens E.H. Ferðamennska á mannöld – Jarðsambönd ferðafólks við virkjanir og víðerni. Náttúrufræðingurinn. 2020, p. 169-180.

deep valleys are hallmarks of this wild and spectacular country (Figure 3.2). The presence (or absence) of water either in the form of snow and ice, huge glacial rivers, lakes, ponds, hot springs and gravel plains is a key landscape element that provides both interest and frequently acts as barriers to movement. Vegetation, while sparse, adds further interest and colour with Arctic/Alpine plant communities and famous moss carpets being particularly unique. Finally, Iceland's geology, often dark and in places surprisingly colourful, with a myriad of forms characterising this young landscape with its lava flows and different formations, cinder cones, geothermal areas and active volcanoes.

a. Hofsjökull and Þjórsárver

b. Vonarskarð

c. Nýidalur

d. Ingólfsskáli

Figure 3.2 Landscapes of the Central Highlands

3.3 It is this variety in surface form and geographical context that creates the need for a two-part model; one that can firstly model variations in wilderness quality and secondly categorise individual areas depending on their landscape character and human features affecting perceptions of wilderness (Figure 3.3). The first part is a more traditional WQI based on just three attributes: (1) remoteness from mechanised access (or time taken to walk from a motorised vehicle); (2) lack of visual intrusion from modern human artefacts; and (3) naturalness of land cover, which used together can map the variation in wilderness quality and used with area thresholds help define wilderness core, buffer and transition zones. The second part of this model focuses on wilderness character using further detail on models of openness, ruggedness and accessibility (time taken to drive from human settlements), with further information provided from maps of mobile communications, livestock grazing and landscape character.

3.4 This two-part model provides detail and nuance in the mapping of wilderness attributes and overall quality, while providing further information about the character of each of the resulting core wilderness areas. At the same time, the approach developed here meets the need for reliable, rigorous, robust, and repeatable methods that can be used to confidently inform decisions about policy on protected areas.

a. Power lines

b. Interior roads

c. Mountain huts

d. Hydro reservoirs and dams

Figure 3.3 Impacts on wilderness quality

3.5 The WQI approach is **reliable** because it uses best available data at high resolutions that work well at both national and local scales. The approach is **rigorous** because it models all the key aspects of wilderness in detail using Internationally recognised state-of-the-art methods. The models are **robust** in providing direct measurements of key wilderness attributes such as remoteness (time taken to walk) and visual impact (proportion of the landscape view occupied by human features taken partial visibility and distance decay into account). The approach is **repeatable** meaning that the same results are achieved each time the model is run and can be used to accurately predict the impact from proposed developments and changes on wilderness quality.

3.6 The WQI outputs can be used to delimit boundaries for IUCN Category Ib areas based on the criteria used in the Wild Europe Working Definition and EU Wilderness in Natura2000 Guidelines and provide additional information of possible Cat II areas. The approach used here mirrors the work of NatureScot in defining core wild land areas in Scotland, by using statistical methods to define classes of wildness based on examining the overall distribution of wildness values in the WQI.

4. Attribute mapping

4.1 In the classic wilderness quality mapping developed by Lesslie and Maslen (1995)[87] for the Australian National Wilderness Inventory (ANWI) and adapted by Carver et al (2012)[88] for Scotland's national parks, four wilderness attributes are used to create a combined map of wilderness or "wilderness quality index" (WQI). In areas such as Scotland wild areas are often characterised by their rugged nature, but this is often not the case (such as in the low-lying Flow Country in the far northeast of the Scottish mainland) leading to bias in mapped wildness towards mountainous areas or rugged coastlines. This is very much the case in Iceland, where wild areas are represented in a variety of guises, including the many wide open gravel plains and ice caps commonly found in the Central Highlands, while enclosed and rugged valleys are found locally in other areas such as Nýjabæjarfjall in the north and Torfajökull/Fjallabak area in the south. Variations in topography thus have a marked influence on sense of space and openness as well is impacting on patterns of visual impact from modern human artefacts.

4.2 To control for this only remoteness from mechanised access, perceived naturalness of land cover and absence of modern human artefacts are used to map wilderness quality, so avoiding possible bias by inclusion of a ruggedness layer at this level. These attributes, the data sources and approaches used to map them are described in Part 1 below.

4.3 Potential wilderness areas are defined by classifying the WQI into core, buffer, transition and non-wild zones using statistical methods. Here a Jenks Natural Breaks model is applied as per the Scottish Wild Land Area mapping carried out by SNH (2014)[89].

4.4 These areas are then described using additional information (including ruggedness, openness, accessibility to centres of population, etc.) to create a Part 2 analysis of wilderness character building on the work and experience of the US National Park Service 'Keep It Wild' wilderness character mapping[90].

Part 1: Wilderness Quality

Remoteness

"Distance, 10 miles; total climb, 6,300 feet; time, six and a half hours (including short halts). This tallies exactly with a simple formula, that may be found useful in estimating what time men in fair condition should allow for easy expeditions, namely, an hour for every three miles on the map, with an additional hour for every 2,000 feet of ascent." Naismith (1892)[91]

4.5 Given the varied and challenging nature of the terrain found within the Central Highlands it is essential to include terrain as a principal variable governing remoteness across the peninsula. Remoteness is mapped in the Central Highlands based on a GIS implementation of Naismith's Rule (see above) using detailed terrain and land cover

[87] Lesslie, R.G. and Maslen, M (1995). National Wilderness Inventory: Handbook of Procedures, Content and Usage. 2nd edn. Australian Government Publishing Service, Canberra.
[88] https://doi.org/10.1016/j.landurbplan.2011.11.016
[89] https://www.nature.scot/doc/wild-land-areas-map-and-descriptions-2014
[90] https://leopold.wilderness.net/our-science/research-agenda/management-tools/character-mapping.php
[91] Naismith, W. W. (1892) Scottish Mountaineering Club Journal. II: 136

information to estimate the time required to walk from the nearest point of mechanised access be that a road or track.

4.6 The DEM used is taken from the ArcticDEM resource Tile data set and processed such that any major artefacts are removed, and missing data filled/replaced[92].

4.7 Maps showing remoteness from roads usable by the public and hill tracks are included in the SNH policy document 'Wildness in Scotland's Countryside' (SNH, 2002)[93]. These are based on linear distance from the nearest road usable by the public or track taking barrier features such as lakes, reservoirs and large rivers into account. Work by Carver and Fritz (1999)[94] has developed anisotropic measures of remoteness based on a GIS implementation of Naismith's Rule incorporating Langmuir's corrections[95]. This has been subsequently applied in modelling the historic trends in wild lands in the Highlands of Scotland (Carver and Wrightham, 2003) and wild land quality in the Scottish national parks (Carver et al., 2012)[96].

4.8 This is an anisotropic approach to modelling remoteness[97] and is based on the relative time taken to walk into a roadless area from the nearest point of mechanised access taking the effects of distance, relative slope, ground cover, and barrier features such as open water and very steep ground[98] into account. This assumes remoteness to be directly proportional to the time taken to walk from A to B across varied terrain and is therefore analogous to the concept of the long walk in which is a long-established principle in Scottish mountaineering and could equally be applied to the terrain of the Central Highlands of Iceland with some modifications for river crossings and the various icecaps and any heavily crevassed areas. The implementation of this model of remoteness requires a detailed terrain model and ancillary data layers that are used to modify walking speeds according to ground cover (e.g. Naismith's approximation of 5 kilometres per hour on the map can be reduced to 4 kilometres per hour or less when walking across open

[92] These flaws were split into two groups which were repaired with two separate methods. If the flaw was small and or contained at glacial and or coastal area, the Elevation Voidfill Tool within ArcGIS was used to generate the missing data using a contour algorithm. All other of flaws were fixed using ARCDEM Strip Data and the DEMCOREG script. Where available the best strip file was co-registered using python script from https://github.com/dshean/demcoreg. The outputted strip files and tiles were then mosaicked into a new 2m Raster and clipped to the Central Highlands study area.

[93] https://www.nature.scot/wildness-scotlands-countryside-policy-statement

[94] Carver, S. & Fritz, S. (1999) Mapping remote areas using GIS. in M.Usher (ed) Landscape character: perspectives on management and change. Natural Heritage of Scotland Series, HMSO.

[95] Langmuir, Eric. (1984) Mountaincraft and leadership: a handbook for mountaineers and hillwalking leaders in the British Isles. Edinburgh: Scottish Sports Council, 1984. This model assumes a person can walk at a speed of 5km/hr over flat terrain and adds a time penalty of 30mins for every 300m of ascent and 10mins for every 300m of descent for slopes greater than 12 degrees. When descending slopes between 5 and 12 degrees a time bonus of 10mins is subtracted for every 300 metres of descent. Slopes between 0 and 5 degrees are assumed to be flat.

[96] Carver, Steve, Alexis Comber, Rob McMorran, and Steve Nutter. "A GIS model for mapping spatial patterns and distribution of wild land in Scotland." Landscape and Urban Planning 104, no. 3-4 (2012): 395-409.

[97] Anisotropic models do not assume equal ease of travel/movement in all direction, rather movement is either aided or restricted by other factors such as steepness of slope and the presence of impassable barriers such as lochs such that the cost of movement is not-directly proportional to horizontal distance. Isotropic models are much less realistic because they do assume equal ease of movement in all directions and therefore oversimplify the concept of remoteness in this context.

[98] NoData or null values in a raster grid contain no data and so are disregarded in most calculations unless the model explicitly references these. NoData values are useful in building access models in that they can be used to describe the locations of barrier features that cannot be crossed.

heath or tundra), and include barrier features as null values which force a detour to find a safe and suitable crossing point.

Data sources

4.9 Calculating remoteness based on Naismith's Rule requires a range of data including a detailed terrain model, land cover data and information on the location of rivers, open water, roads, tracks and other access features. These are all sourced from readily available datasets including the AUI Farmland Database and the National Land Survey of Iceland (LMÍ).

Methods

4.10 Remoteness is calculated here using a GIS implementation of Naismith's Rule incorporating Langmuir's Correction based on the PATHDISTANCE function in ArcGIS. This estimates walking speeds based on relative horizontal and vertical moving angles across the terrain surface together with appropriate cost or weight factors incurred by crossing different land cover types and the effects of barrier features such as lakes, large rivers, heavily crevassed areas and very steep ground (cliffs). Remoteness is calculated considering access over land and ice only. The outputs from these remoteness models were combined to produce a total remoteness map. The theory and practical application of this model is described by Carver and Fritz (1999). The walking model is applied using the following conditions:

4.11 *Source grid:* This is taken to be those **roads and tracks** that provide vehicular access via private car.

4.12 *Cost surface:* This is assumed to be *5km/*h for all land cover types except heathland which is 3km/hr and wetland which is 2km/hr. Fords across rivers were deemed to take 20mins to which equates to approximately *0.06km/h* as the pixel size was 20m.

4.13 *Barriers to movement:* These are taken to include rivers that appear as polylines in the OSM data, and slopes that were identified as unpassable using data from ArcticDEM. Local knowledge was used to mark the rivers that are known to be too deep or strong to be crossed on foot. These are mostly the main glacial rivers of the highlands and are deemed impassable, especially further down from the outlet glaciers where they have merged into one large channel. Closer to the outlet glaciers the smaller tributaries can often be crossed on foot. Sections of river are assumed to be crossable where there is a bridge or where these rivers are crossed by a path and so can be assumed to be passible at these locations with a time delay as described above.

4.14 The inputs to the remoteness modelling for the current conditions existing within the Central Highlands are shown in Figure 4.1.

4.15 The current remoteness from mechanised access as modelled using these methods and data is shown in Figure 4.2. To account for the great variances that occur in the fluvial landscape in Iceland over the summer and winter periods, several separate remoteness calculations were conducted to better appreciate the effects that the different seasons have on the remoteness in the Icelandic central highlands. During the summer, vehicles are restricted to established roads with off-roading specifically prohibited. However, during the winter these rules are not in place, and (outside of some designated out-of-bounds areas) vehicles may travel anywhere in Iceland on snow and ice. The difference in relative remoteness in winter between walking and driving 4x4 “super jeep” vehicles is very noticeable with these vehicles being able to cover greater distances in shorter times as seen in Figures 4.2b and 4.2c when drawn using the same scale as summer walking.

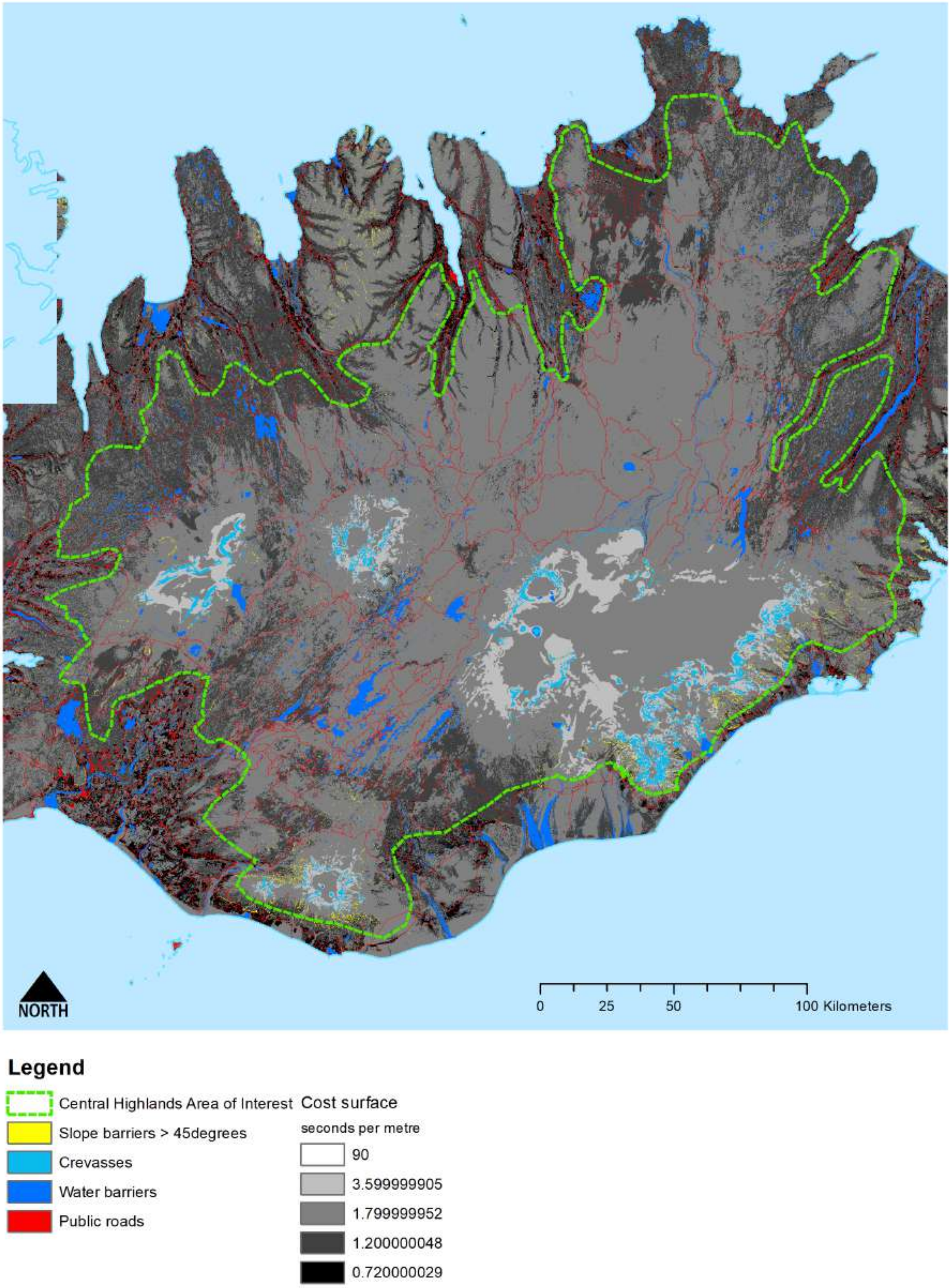

Figure 4.1 Inputs to remoteness model

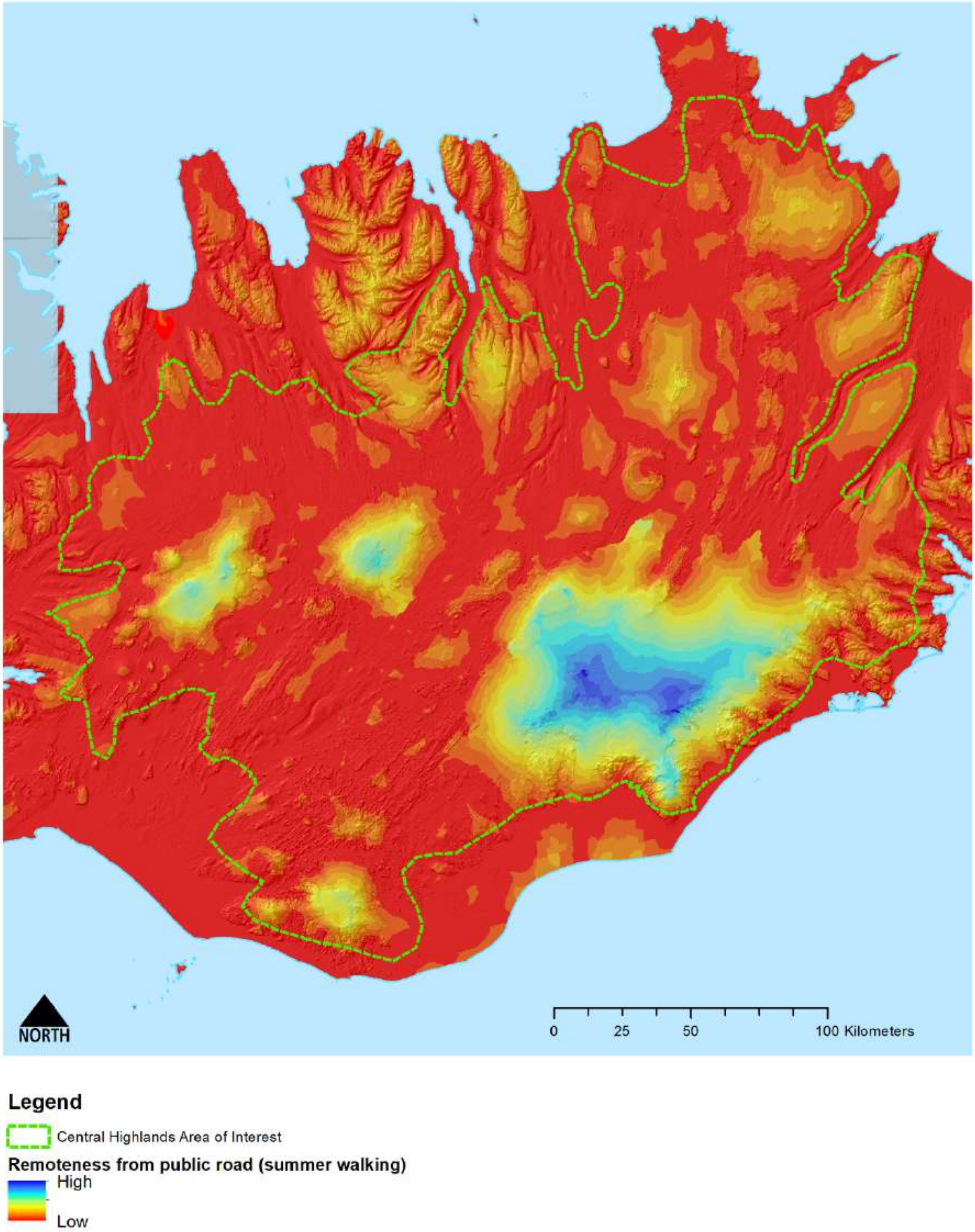

Figure 4.2a Remoteness from roads usable by the public (summer walking)

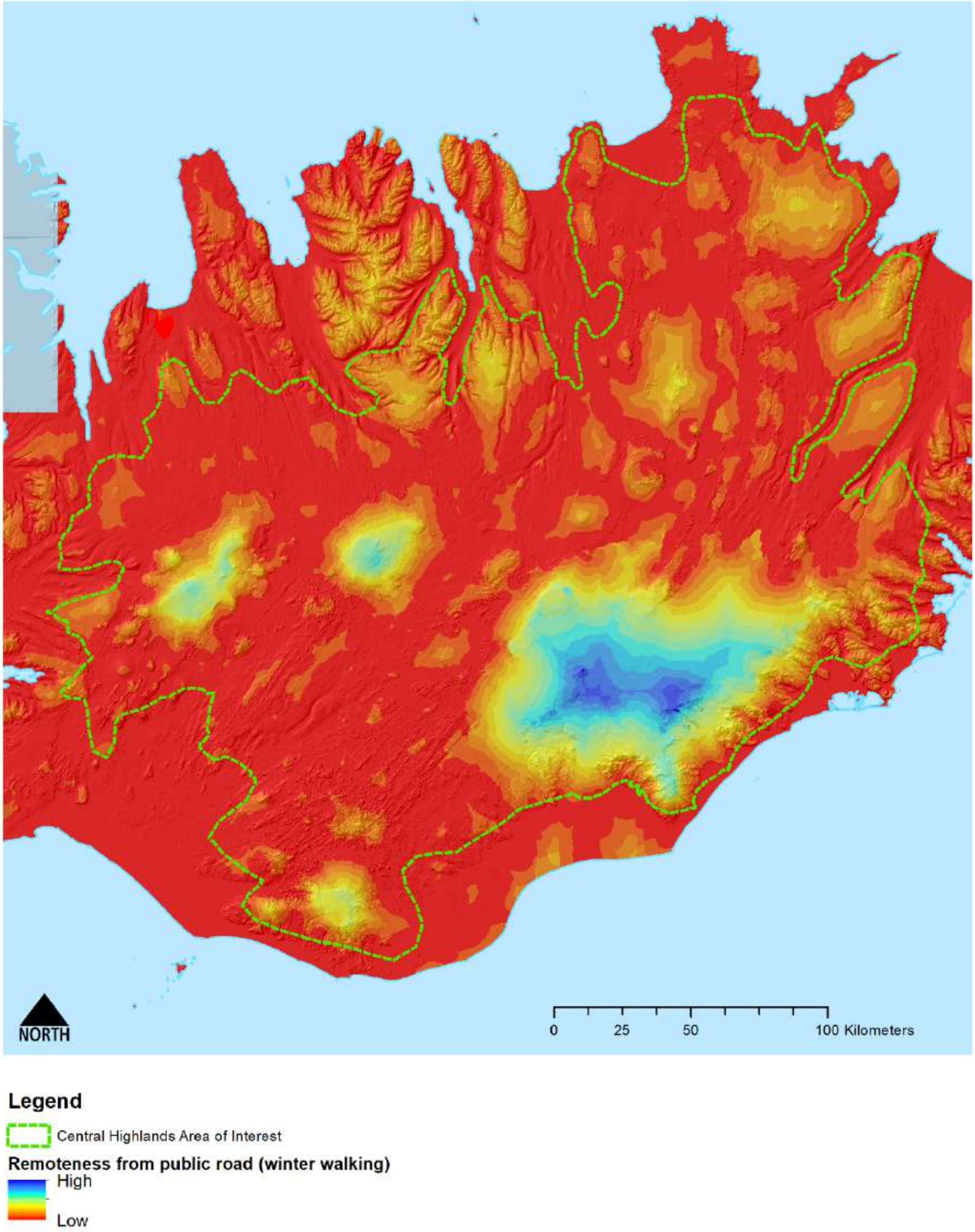

Figure 4.2b Remoteness from roads usable by the public (winter walking)

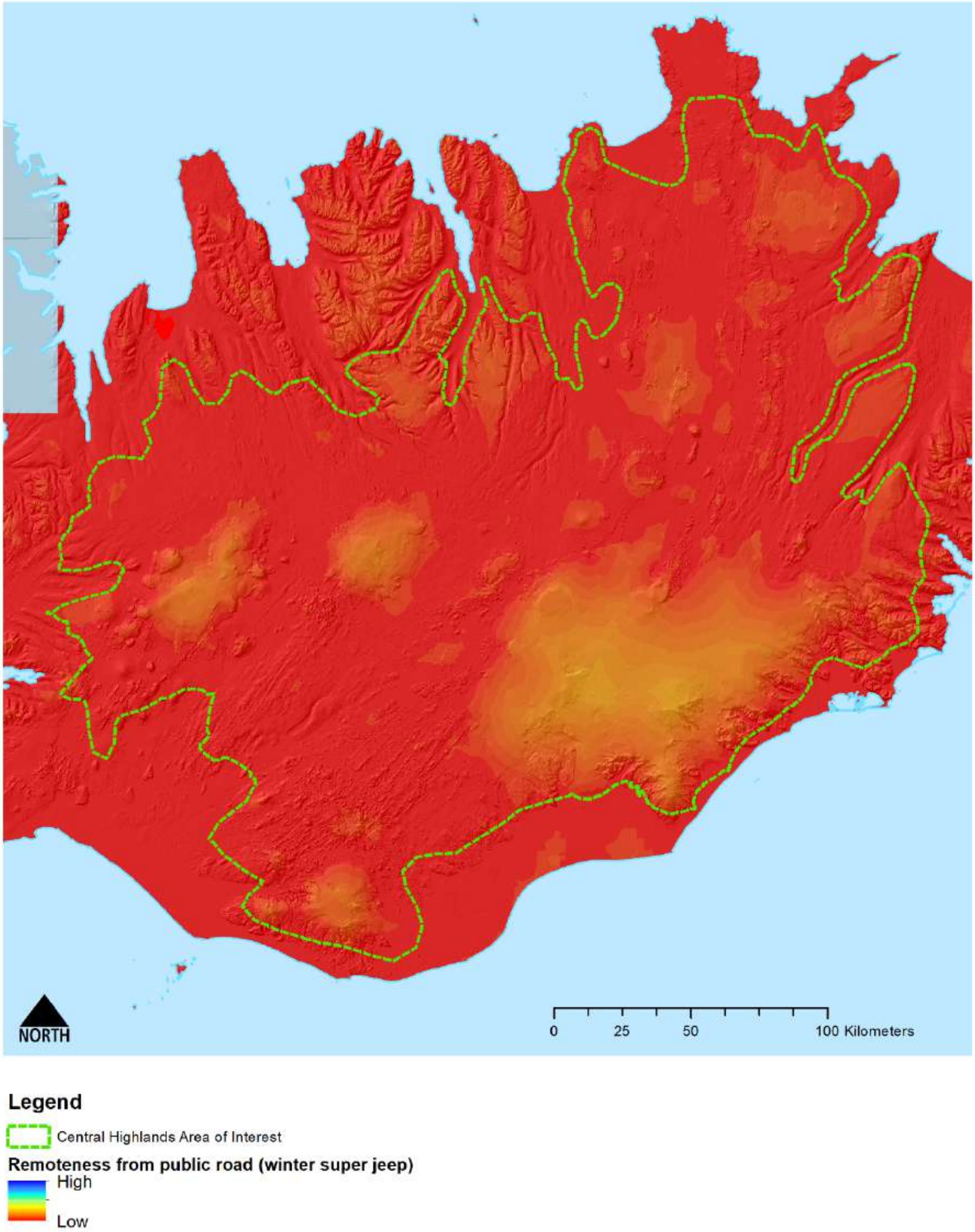

Figure 4.2c Remoteness from roads usable by the public (winter super jeep)

Caveats and assumptions

4.16 Naismith's Rule and the model used to implement it here assumes a fit and healthy individual, and does not make any allowance for load carried, weather conditions (such as poor visibility and strong head winds) and navigational skills. The model does, however, take barrier features and conditions underfoot into account as described above. Lakes and reservoirs are considered impassable on foot and are included as barrier features by coding these as NoData (null values) in the model inputs; whilst for the winter barriers, local experts were consulted as to which rivers remain barriers to foot traffic or vehicles. In the winter calculation, most reservoirs and large lakes were considered barriers for both pedestrian and vehicular traffic. This forces the model to seek a solution that involves walking around the barrier.

4.17 The model also uses a cost or friction surface that controls the walking speed according to the land cover or conditions underfoot. A speed of 4km/hr (1.389m/s) is assumed for most land cover types, while speeds of 3km/hr (0.833m/s) and 2km/hr (0.555m/s) are assumed for the heathland and wetland examples, respectively[99]. The angle at which the terrain is crossed (i.e. the horizontal and vertical relative moving angles) is used to determine the relative slope and height lost/gained[100]. These values are input into the model using a simple look up table.

4.18 The road network, both within and outside the boundary of the Central Highlands is used as the access points from which to calculate remoteness of off-road areas. In considering the effects of large rivers deemed to be barrier features, these are assumed crossable only at those points where roads, tracks or footpaths cross and only where there is a bridge or a ford.

Absence of modern human artefacts

4.19 Absence of modern human artefacts is considered here to refer to the lack of obvious artificial forms or structures within the visible landscape, including roads, vehicle tracks, pylons, dams, buildings and other built structures. The choice of which human features to include here is driven largely by what is understood to act as a wilderness detractor based on SNH wild land policy (SNH, 2002)[101], relevant sections of the perception survey and what data is available.

4.20 Previous work on the effects of human artefacts on perceptions of wilderness carried out at national to global scales has tended to focus on simple distance measures[102] [103] [104]. More recent work has used measures of visibility of human artefacts in 3D landscapes

[99] Lower walking speeds are included here based on discussion about the maximum likely speeds attainable across these two land cover types.
[100] Vertical and horizontal factors determine the difficulty of moving from one cell to another while accounting for the vertical or horizontal elements that may affect the movement, these include slope and aspect as they determine the relative angle of the slope in the direction it is crossed and hence the height gained or lost
[101] https://www.nature.scot/wildness-scotlands-countryside-policy-statement
[102] Lesslie, R. (1993) The National Wilderness Inventory: wilderness identification, assessment and monitoring in Australia. International wilderness allocation, management and research. Proceedings of the 5th World Wilderness Congress. 31-36.
[103] Carver, S. (1996) Mapping the wilderness continuum using raster GIS. in S.Morain and S.Lopez-Baros (eds) Raster imagery in Geographic Information Systems. OnWord Press, New Mexico, 283-288.
[104] Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V. and Woolmer, G. (2002) The human footprint and the last of the wild. Bioscience. 52(10): 891–904.

described using digital terrain models[105] [106].This is feasible at the landscape scale utilising viewshed algorithms and land cover datasets to calculate the area from which a given artefact can be seen. Work by Carver (2007)[107] for the Nidderdale AONB has utilised cumulative and distance weighted viewshed algorithms to give a more accurate impression of the spatial pattern of the impacts of visible human artefacts on peoples' perceptions of wilderness in guiding decisions about suitable areas for regeneration of native woodland. A similar approach to that used for the SNH work is adopted here using artefacts are deemed to have an impact on wilderness, together with more a digital surface model (DSM) derived from ArcticDEM and a novel and rapid viewshed assessment method developed for the earlier Cairngorm wildness mapping project (2008)[108].

Data Sources

4.21 Visibility analysis and viewshed calculations rely on the ability to calculate line-of-sight from one point on a terrain surface to another. It has been shown that the accuracy of viewsheds produced in GIS is strongly dependent on the accuracy of the terrain model used and the inclusion of intervening features (buildings, woodland, etc.) or terrain clutter in the analysis (Fisher, 1993)[109].

4.22 Modern human artefacts are extracted from the OSM buildings dataset[110], Icelandic Roads dataset from LMÍ[111], and datasets on Icelandic hydropower schemes and power distribution networks supplied by Landsnet. These are then assigned height values based on their prominence, with buildings assigned an average value for simplicity and powerlines represented by pylons spaced 300m apart along distribution lines and given heights based on power line type. Roads are modelled with a 3m height value used to represent an average vehicle height. Data inputs are shown in Figure 4.3.

Methods

4.23 The use of visibility analyses in GIS that incorporate both a DSM and feature data showing the location and pattern of modern human artefacts allows the creation of cumulative viewsheds that can be weighted according to artefact type and distance. These can be combined and used to describe the attribute layer showing the relative effects associated with the presence and absence of human artefacts. These are applied in the cumulative viewshed methodology. Bishop's (2002)[112] work on the determination of thresholds of visual impact, and the SNH report on "Visual Assessment of Windfarms: Best Practice" (SNH, 2002)[113], were used to help define the limits of viewsheds and the distance decay function used.

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[105] Fritz, S., Carver, S. and See, L. (2000) New approaches to wild land mapping in Europe. Proceedings of 15-VOL-2 (2000) Missoula, Montana.
[106] Carver, S. and Wrightham, M. (2003). Assessment of historic trends in the extent of wild land in Scotland: a pilot study. Scottish Natural Heritage Commissioned Report No. 012 (ROAME No. FO2NC11A).
[107] Carver, S. (2007) Regeneration of native woodland in the Nidderdale AONB. University of Leeds.
[108] https://wildlandresearch.org/wp-content/uploads/sites/39/2018/10/Cairngorm2008.pdf
[109] https://doi.org/10.1080/02693799308901965
[110] https://www.openstreetmap.org/relation/299133
[111] IS 50V, version X + date
[112] https://doi.org/10.1068%2Fb12854
[113] https://pdfs.semanticscholar.org/47b7/7e7fd1fb08fb00e05cdfb2bdd9379ce6e635.pdf

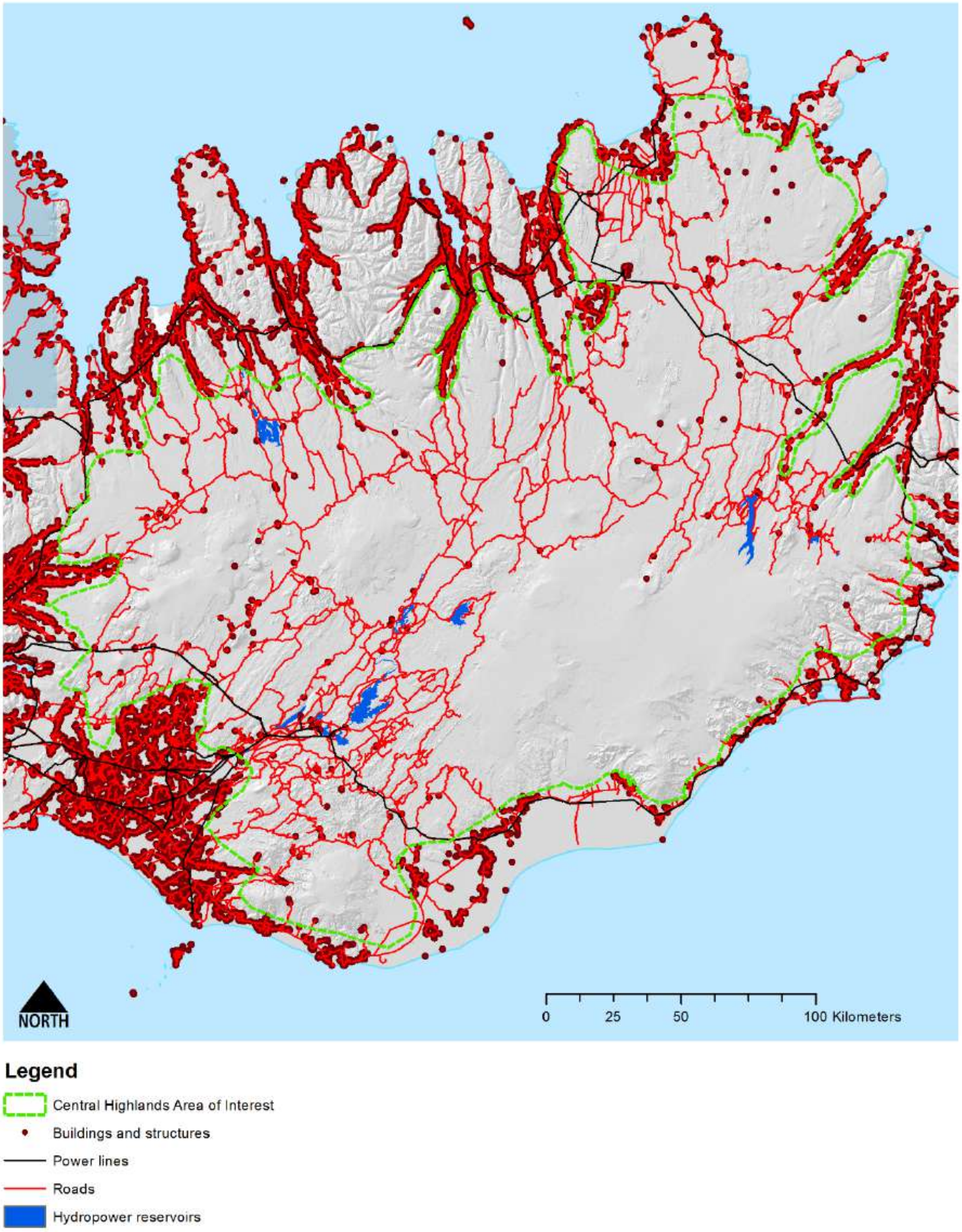


Figure 4.3 Data inputs for visual impact model

4.24 Viewshed analyses such as these are extremely costly in terms of computer processing time. Detailed analyses can take weeks, months or even years to process depending on the number of human artefacts included in the database. It is usual to reduce processing times by generalising the artefact database by aggregating the number of human features in a cell of a given size. Work by Carver (2005 and 2007)[114] used cell sizes of 500x500m and 250x250m, respectively. Subsequent work by Washtell (2007)[115] has shown that it is possible to both dramatically decrease the processing times required for GIS-based viewshed analyses and improve their overall accuracy, through judicious use of a voxel-based landscape model and a highly optimised ray-casting algorithm.

4.25 While studies exist comparing the advantages of various optimised viewshed algorithms in their own right (Kaučič and Zalik, 2002)[116] as of yet few of these seem to have percolated through into proprietary GIS packages. It is not clear whether the relative lack of sophistication of viewshed analyses sought within the Environmental Sciences (usually restricted to calculating the visibility of a handful of point features), owes itself to limitations in the pervading software, or whether the reverse is true. However, researchers in the domain have for some time been pushing the capabilities of the available tools - for example, by refining workflows for producing cumulative viewsheds (Wheatley, 1995)[117].

4.26 The algorithm used herein, which is similar to those used in real-time rendering applications and in some computer games, was designed to perform hundreds of traditional point viewshed operations per second. By incorporating this into a custom-built software tool which has been designed to work directly with GIS data, it is possible to estimate the visibility between every pair of cells in a high-resolution landscape model utilising only moderate computing resources. In this way, features of interest are no longer limited to a finite collection of points, but any set of features which can be described by a GIS data layer. This approach (called a 'viewshed transform') can be regarded as a maturation of traditional cumulative viewshed techniques. It was chosen for this project owing to the complexity of the surface and feature layers involved and the importance of applying methods that can realistically model the human perception of visual isolation in complex terrain.

4.27 The approach adopted here utilises the Arctic DEM and feature data extracted from the OSM, LMÍ road and Landsnet power line datasets to calculate a viewshed for every single human artefact, incorporate estimates of the proportional area of each artefact that is visible, and run separate viewshed calculations for each of the different categories of features listed above and combine these to create the absence of human artefacts attribute map. RARIK service powerline data was made available but not used here since most of these are along access roads and most are due to be undergrounded in future.

4.28 An inverse square distance function is used in calculating the significance of visible cells. This function gives the relative area in the viewer's field of view that a cell or feature occupies; its relationship to perceived visual intrusion is borne out by the studies

[114] Reports on mapping wild areas for North Pennines and Nidderdale AONBs

[115] Washtell, J. (2007) Developing a voxel-based viewshed transform for rapid and real time assessment of landscape visibility. Unpublished course Paper. MSc in Multi-disciplinary Informatics, University of Leeds.

[116] Kaučič, B. and Zalik, B. (2002) Comparison of viewshed algorithms on regular spaced points. In Proceedings of the 18th Spring Conference on Computer Graphics (Budmerice, Slovakia, April 24 - 27, 2002). SCCG '02. ACM, New York, NY, 177-183. DOI=http://doi.acm.org/10.1145/584458.584487

[117] Wheatley, D (1995), "Cumulative Viewshed Analysis: a GIS-based method for investigating intervisibility, and its archaeological application", in G.Lock and Z.Stancic (eds.) Archaeology and GIS: A European Perspective. pp 171-185, London: Taylor & Francis.

previously mentioned. This function is very sensitive to small changes in relative distance and in order that the results of these visibility calculations can be appreciated visually, a log scale is applied such that in the extreme case where a feature fills the observer's field of view, the maximum value is output, with each successive value thereafter representing an order of magnitude less visual intrusion. As even very small levels of visual intrusion are visible on such a scale, it also serves very well to highlight areas which are in total shadow from all visual features owing to the shape of the local landscape. Such areas of low or zero visual intrusion from modern human artefacts currently comprise a significant portion of the core areas of the Central Highlands many of which occupy the interior and valleys which are shielded by their topography. While occurring less frequently in the proximity of modified areas, pockets entirely bereft of visual intrusion can be found everywhere, owing to the high relief and general ruggedness of the terrain.

4.29 Example outputs from the voxel viewshed transform showing the visibility of each separate feature class are given in Figures 4.4. The completed absence of modern human artefacts attribute map created from the combination of these output layers is shown in Figure 4.5. Areas where no feature is visible are shown as areas of no colour on these maps.

Caveats and assumptions

4.30 For this work certain compromises and customisations are necessary to make the task manageable. These include: the cell resolution in this instance was limited to 20m for all features, re-sampling[118] was done to generate the buildings feature data in order to guarantee that smaller and larger features in the area were weighted differently by height and size so that the viewsheds produced may be viewed as a realistic representation of the visual impact of the artefacts present, the landscape was split into several overlapping tiles, such that they could be worked on in parallel by a cluster of desktop computers; and the maximum viewshed distance is 15km for all features (Bishop, 2002)[119]. In addition, Landsnet did not supply the locations and height of their power line pylons, meaning that these data had to be estimated from power line route data based on information provided by Landsnet on average distance between pylons and their average height according to relevant transmission voltage information. These assumptions were reviewed by local experts.

[118] Re-sampling of feature layers in GIS is normally carried out on a “majority class” basis wherein the value of a grid cell takes on the value of the largest feature by area that it contains. Using this rule, a 5x5m building in a 20x20m grid cell that was otherwise not classified as an artefact, say heather moor, would not be recorded on re-sampling. The “pessimistic” re-sampling used here operates on a presence/absence basis such that any grid cell containing a human artefact will be classified as such even though the actual area or footprint of the artefact may not cover most of the grid cell.

[119] https://doi.org/10.1068%2Fb12854

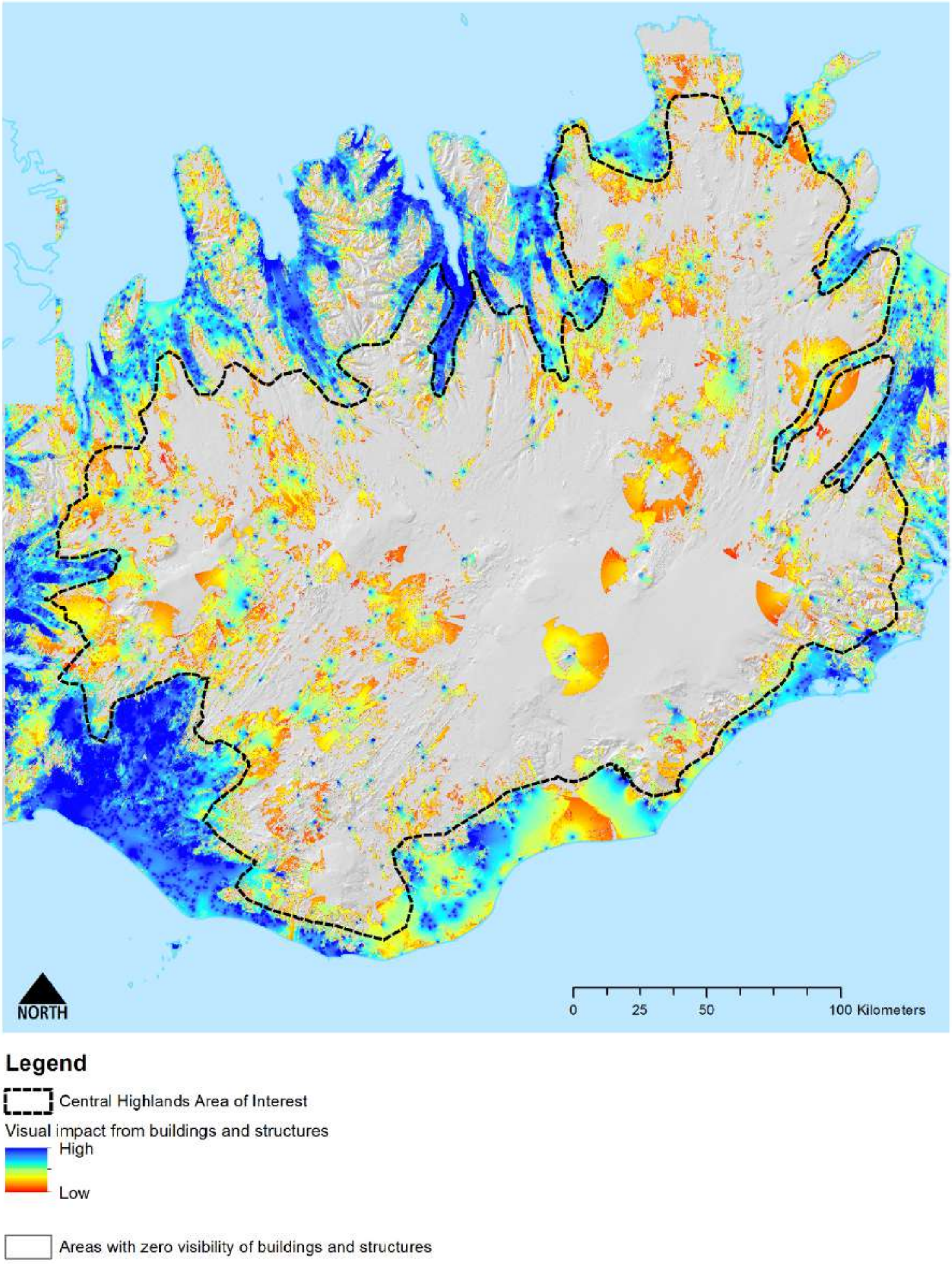


Figure 4.4a Visual impact from buildings and structures

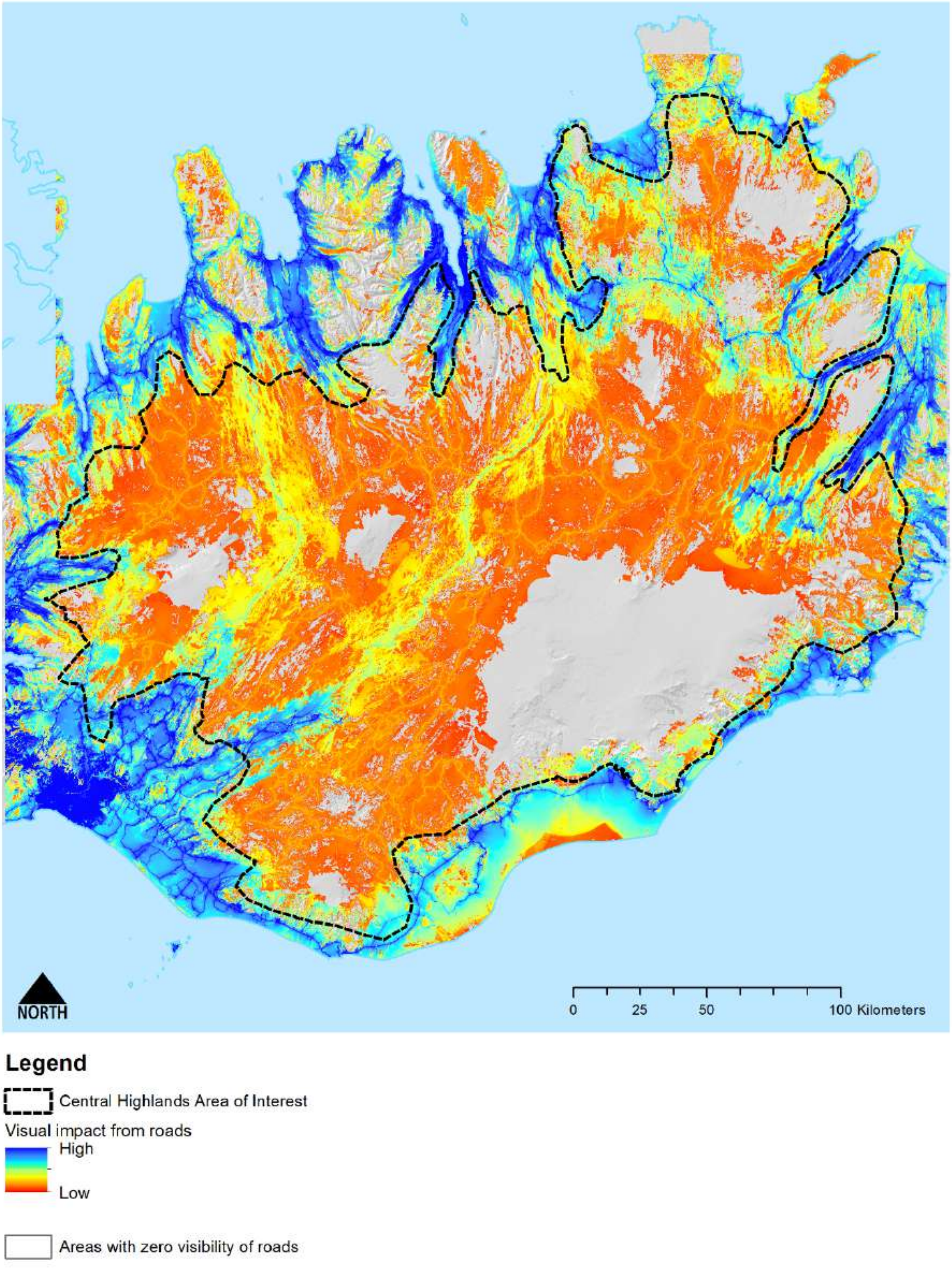


Figure 4.4b Visual impact from roads

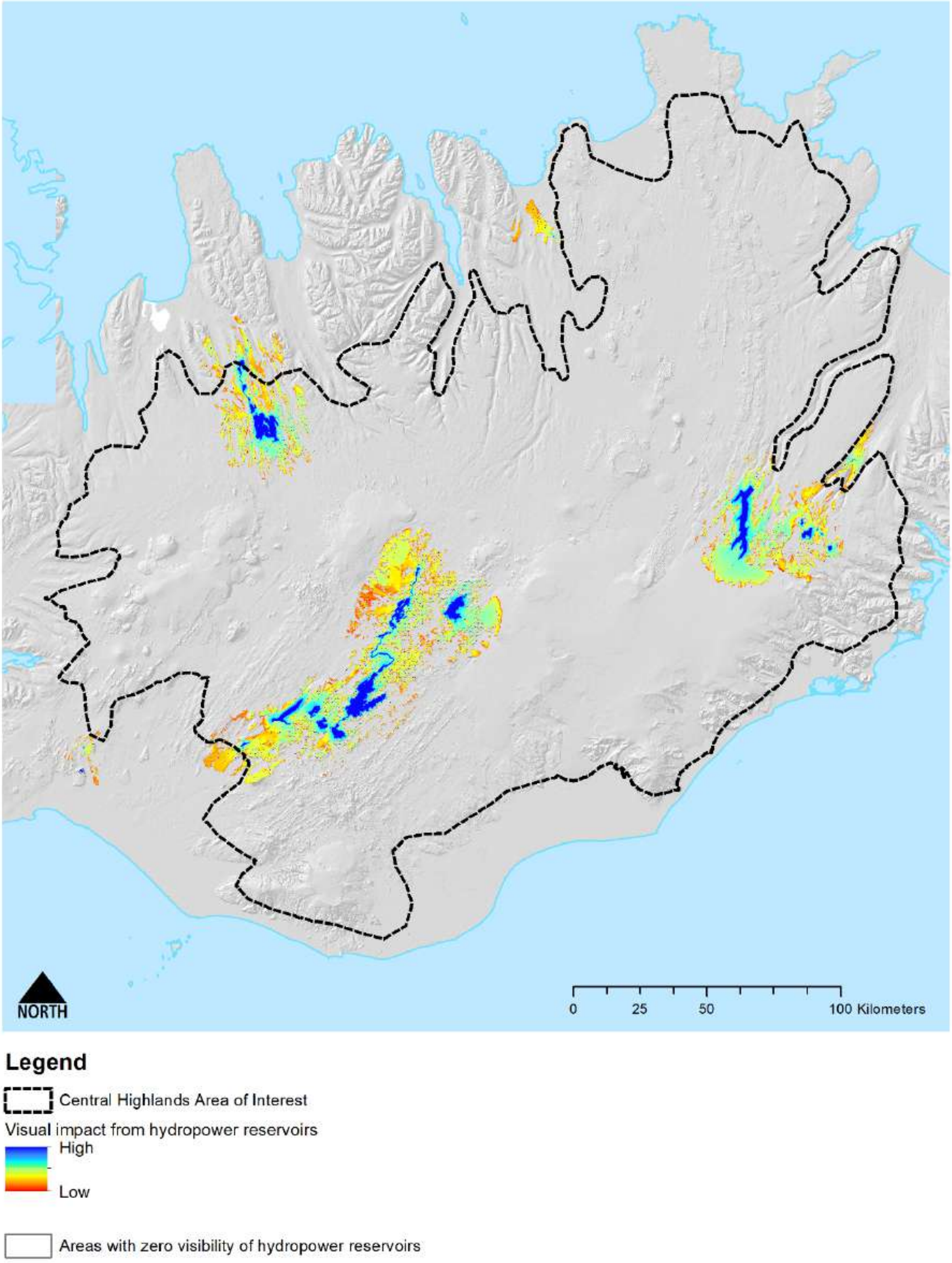


Figure 4.4c Visual impact from hydro reservoirs

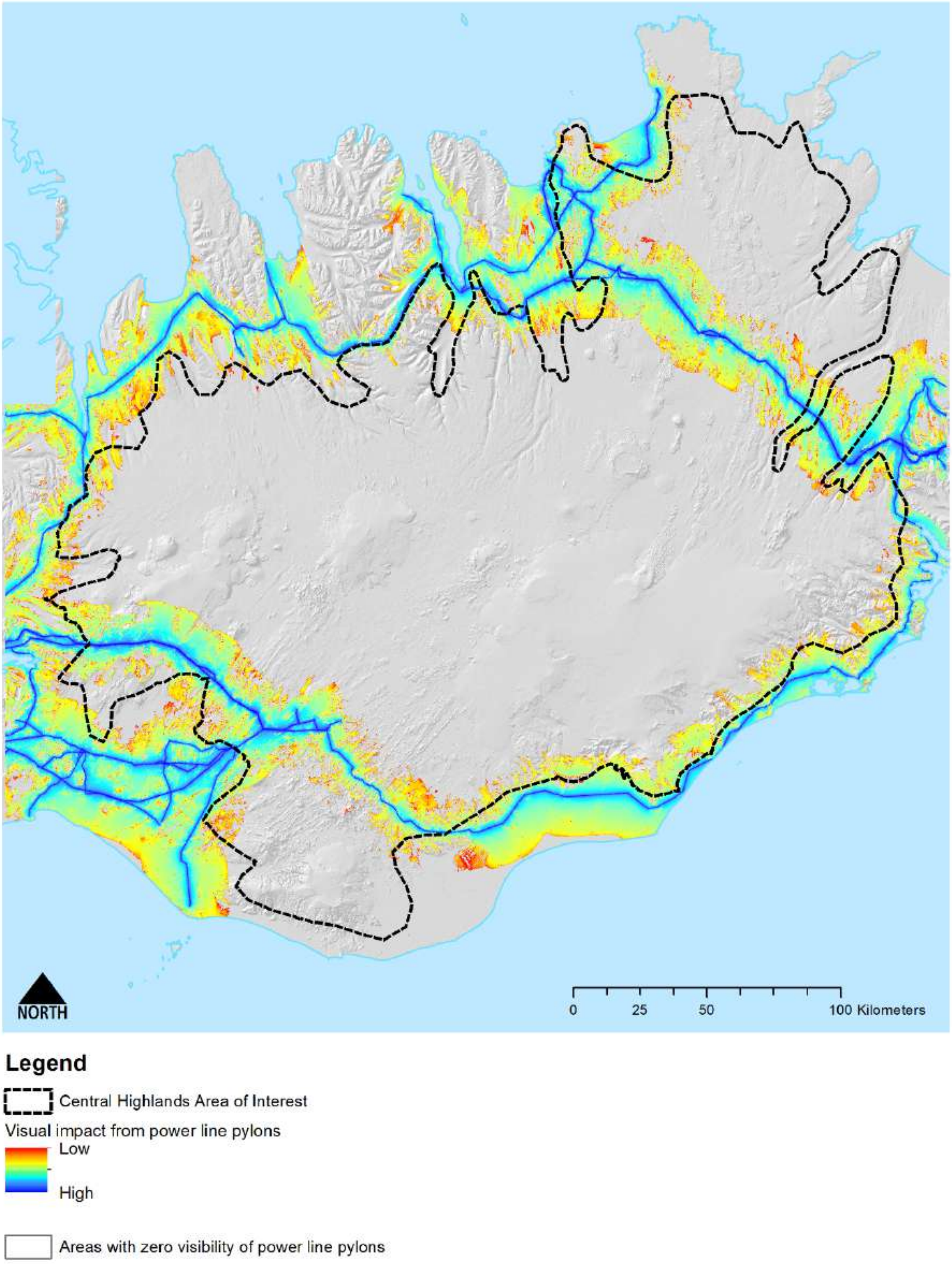


Figure 4.4d Visual impact from power line pylons

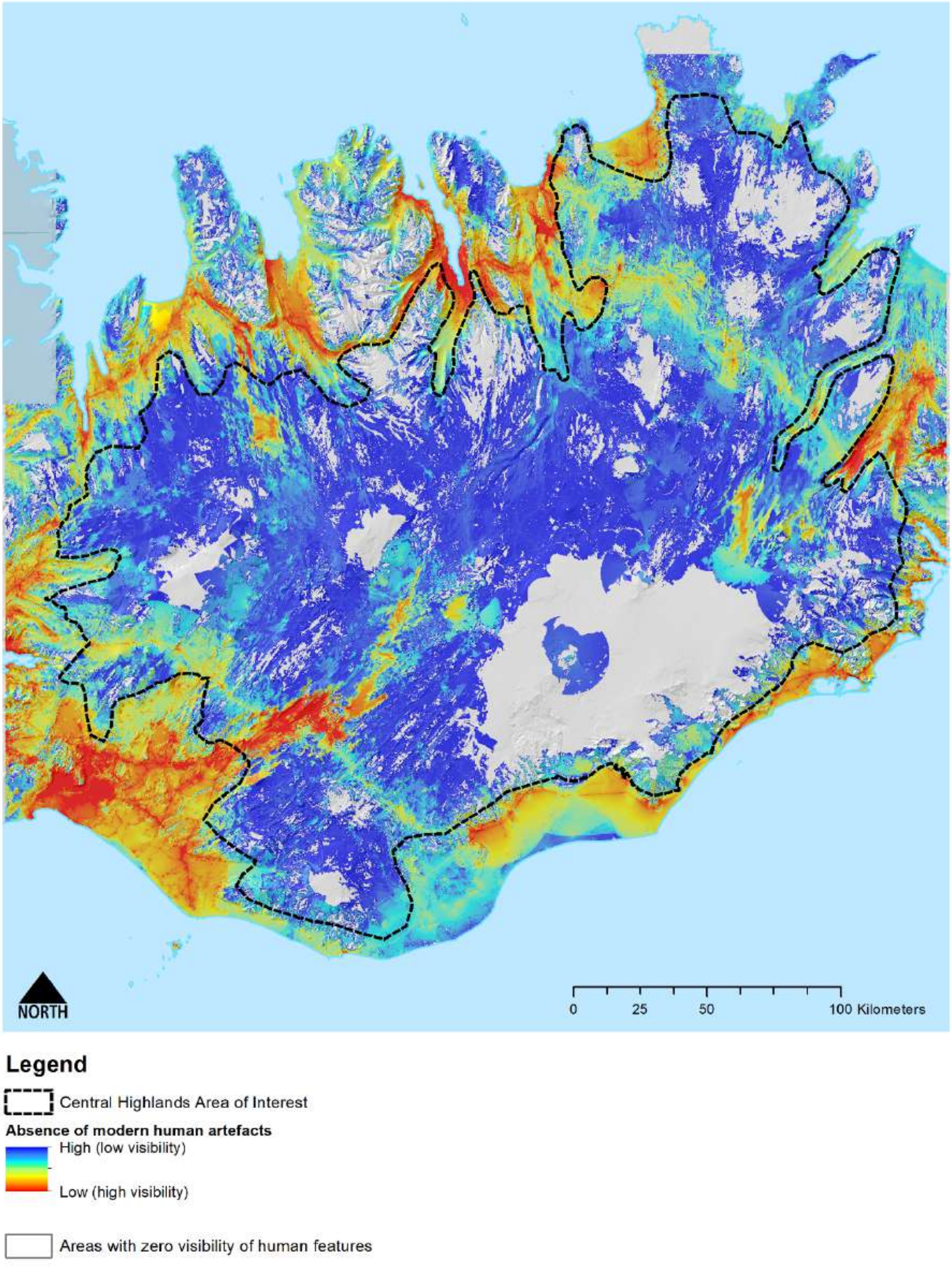


Figure 4.5 Absence of modern human artefacts

Perceived naturalness of land cover

4.31 Perceived naturalness of land cover is described here as the extent to which land management, or lack of it, creates a pattern of vegetation and land cover which appears natural to the casual observer. Perceptions of wilderness are in part related to evidence of land management activities such as fencing, improved pasture and stocking rates, as well as presence of natural or near-natural vegetation patterns. Here the AUI Farmland[120] data were used to best describe perceived naturalness in the Central Highlands.

Data sources

4.32 Aspects of land management are identifiable from national land cover datasets like the AUI Farmland Data. These datasets are based on multispectral analyses from Satellite data. The distribution, presence and absence of features related to wilderness can often be inferred from their classes and relative positions.

4.33 Previous work by Carver (2005)[121] and Carver et al. (2008)[122] has based naturalness of land cover on a reclassification of the LCM2015[123], and the earlier products, into a smaller number of naturalness classes. The land cover classes from the AUI Farmland dataset were reviewed with local experts (e.g. mountain guides and park rangers) for ground truthing and then were applied to equivalent naturalness classes. The naturalness classes used here are shown in Table 4.1.

Table 4.1 Naturalness classifications applied to land cover features

Naturalness class	Land cover class (from AUI Farmland Database)
0	NoData
2	Cultivated Land/Shrubland
3	Grassland/Unknown (Lowland Vegetated)
4	Rich Heathland/Poor Heathland
5	Mossland/Damp Wetland/Wetland/Poorly Vegetated/Barren/Lakes/Glacier/Unknown

[120] https://www.moldin.net/nytjaland---aui-farmland-database.html
[121] Carver, S. (2005) Opportunity Mapping for New Wildwoods: a report submitted to the North Pennines AONB Partnership by the University of Leeds. University of Leeds.
[122] Wildness study in the Cairngorms National Park. Report prepared for the Cairngorms National Park Authority and SNH, September 2008. https://wildlandresearch.org/wp-content/uploads/sites/39/2018/10/Cairngorm2008.pdf
[123] Centre for Ecology and Hydrology Land Cover Map 2015 https://www.ceh.ac.uk/services/land-cover-map-2015

Methods

4.34 The AUI Farmland Database, re-projected at a nominal resolution of 20m to match other data in the overall model, is reclassified into 5 naturalness classes based on similar classifications used by SNH as shown in Table 4.1. To account for the influence that the pattern of land cover in the area immediately adjacent to the target location has upon perceived naturalness of a certain grid cell the mean naturalness class is calculated for each location within a 250m radius neighbourhood. This value is then assigned to the target cell to represent the overall naturalness score for that location. Edge effects are avoided by calculating perceived naturalness for the whole of Iceland**.** The resulting attribute map is shown in Figure 4.6.

Caveats and assumptions

4.35 The reclassification of the AUI Farmland Database into 5 naturalness classes from natural/semi-natural to improved and built on land is based on the subjective reading of the class descriptions given in the dataset documentation. There is likely to be differing levels of naturalness within the AUI Farmland Database classes due to differing levels of management (e.g. improved pastures) or topological relationships with other land classes (e.g. bare rock and barely vegetated) that are not fully accounted for within the data descriptions.

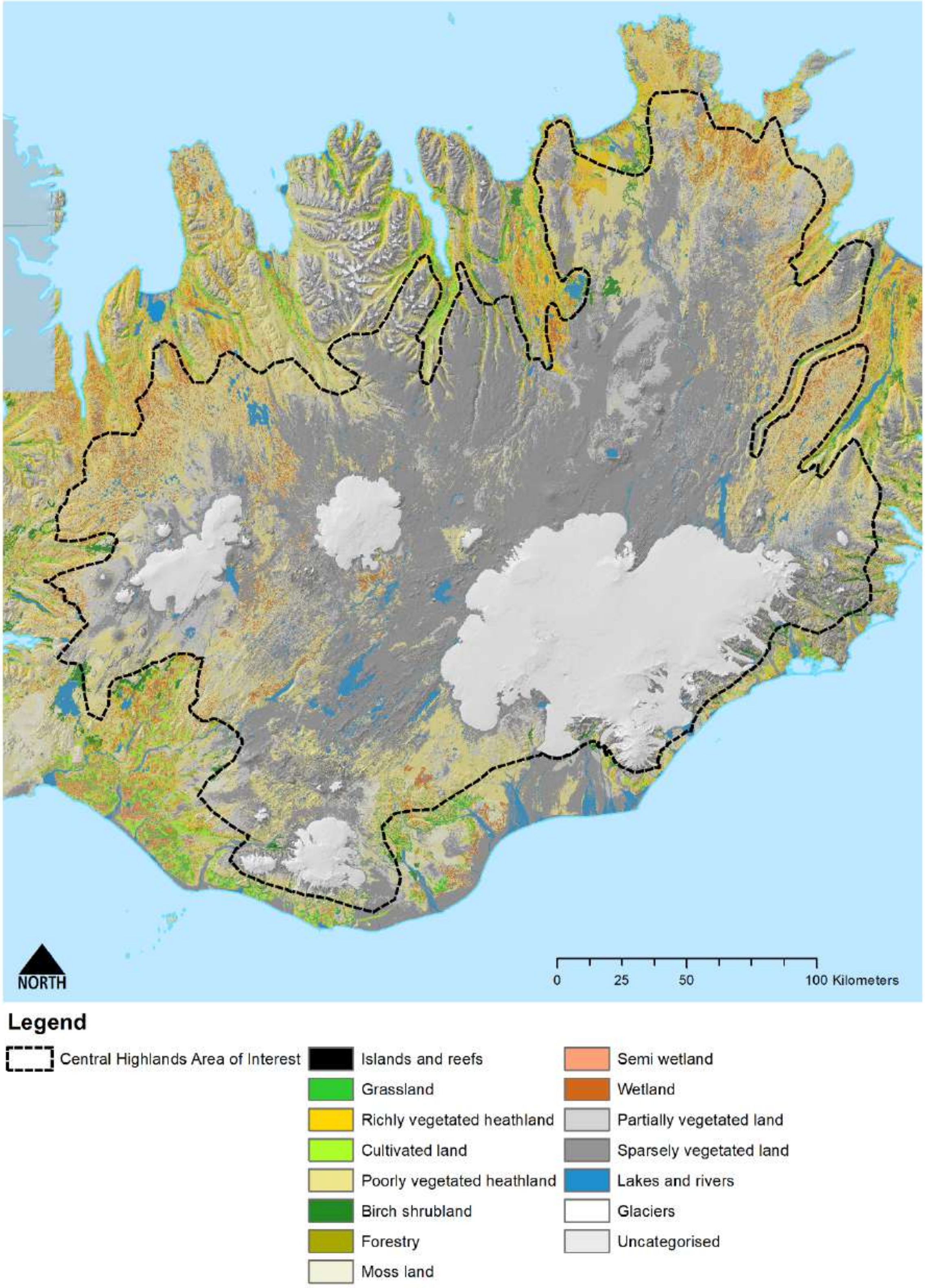


Figure 4.6 AUI Farmland database

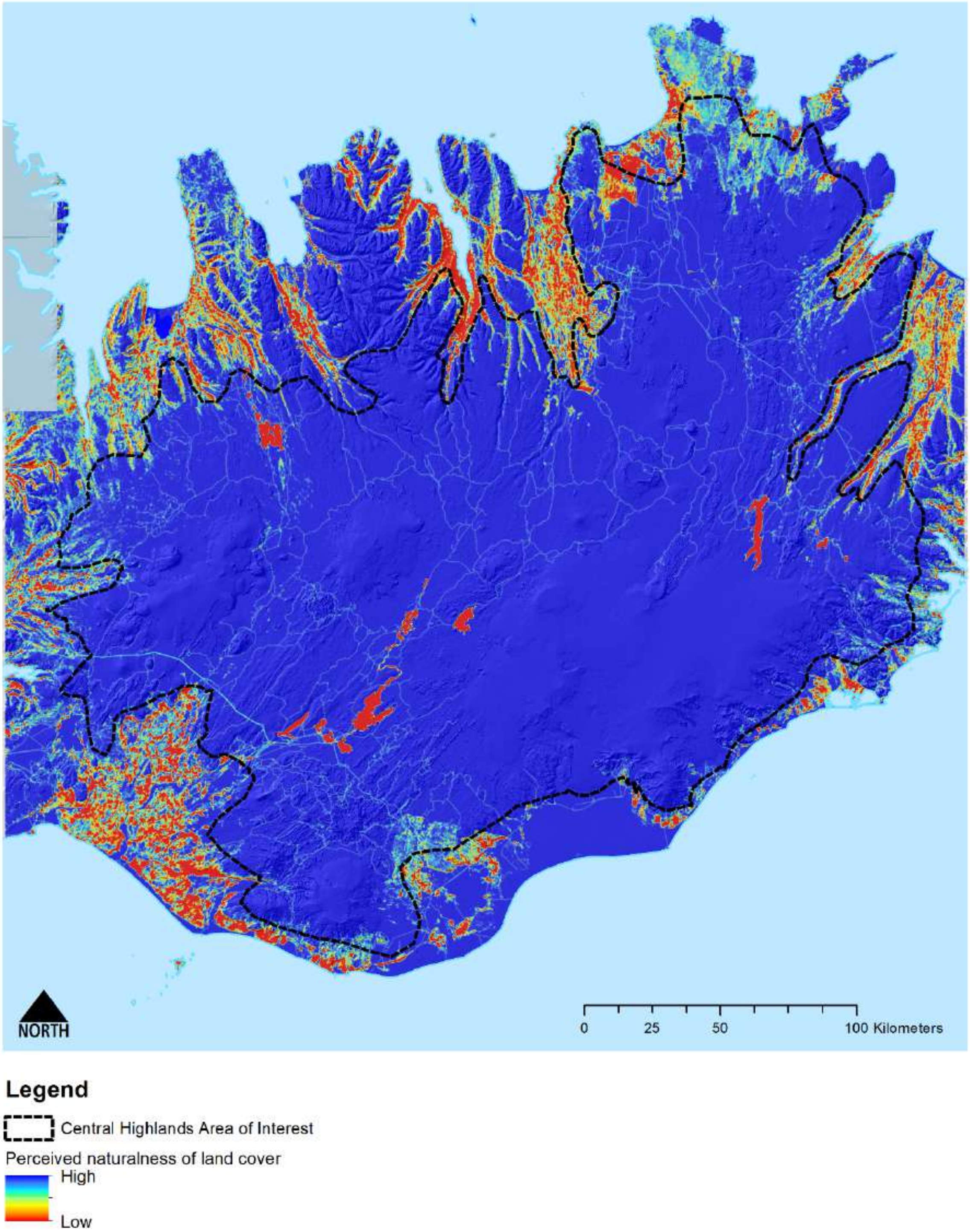


Figure 4.7 Perceived naturalness of land cover

Final WQI analysis

4.36 When completed, all measures need to be normalised onto a common scale that enables cross comparison, this is accomplished by rescaling values onto a 0-255 scale (256 values) with equal interval basis, and where low values are indicative of lower wildness.

4.37 These standardised values are then applied initially into an equally weighted multi-criteria analysis, allowing the effects of each value to be accounted for and a final value for wildness calculated. While weighting may then be altered to account for intricacies in the data and different perceptions on priorities attached to each attribute, the weights are maintained as equal in this exercise assuming each input layer to the model is of equal importance.

Part 2: Wilderness character

Openness

4.38 Developed in 2002 by Yokoyama et al[124] as a measure to display surface features on a DEM using a method independent of a light source, giving it an advantage over other methodologies such as hillshading. It accomplishes this by calculating the mean of multiple zenith or nadir angles within a defined horizontal distance from each cell of a DEM, thus representing the enclosure of each cell[125]. This allows for the enclosure of each cell to be represented graphically, thus differentiating between wide open spaces and closely enclosed valleys, assisting in the defining of the characteristics of each identified wildland area.

Data sources

4.39 The ArcticDEM is used here to represent the terrain surface of the Central Highlands for these analyses as described in para 4.6, resampled at 20m resolution.

Methods

4.40 Topographic Openness is calculated from the ArcticDEM 20m resampled DEM, using the Skyview tool within the QGIS SAGA toolbox. This generates values representing the proportion of visible sky for each cell within the dataset. The resulting openness surface is shown in Figure 4.8.

[124] Yokoyama, Ryuzo & Pike, Richard. (2002). Visualizing Topography by Openness: A New Application of Image Processing to Digital Elevation Models. Photogram Eng Remote Sens. 68(3).
[125] Daxer, Christoph. (2020). Topographic Openness Maps and Red Relief Image Maps in QGIS. 10.13140/RG.2.2.18958.31047.

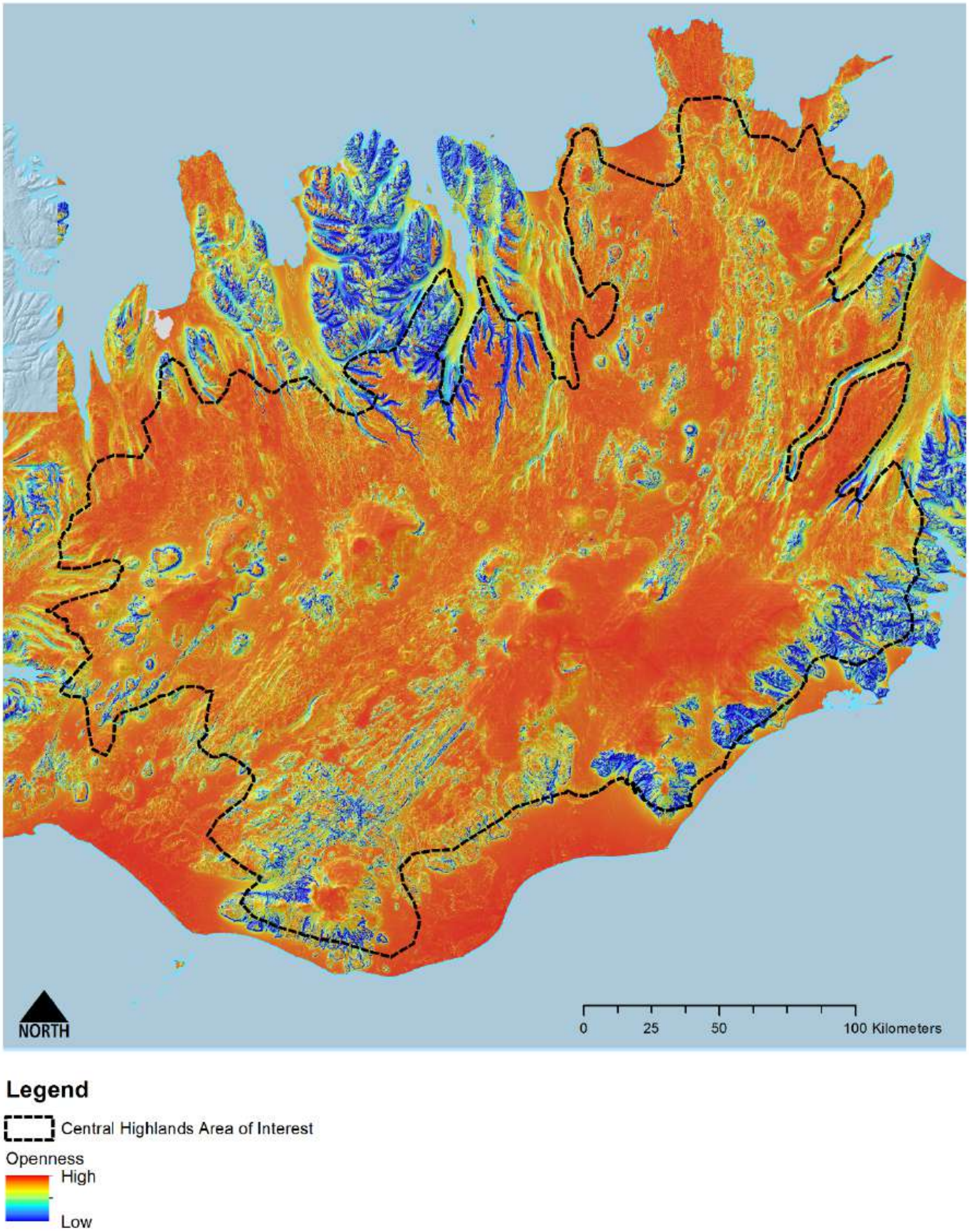


Figure 4.8 Openness

Rugged and physically challenging nature of the terrain

4.41 The nature of the terrain within the Central Highlands is varied and requires careful analysis to determine variations in its morphology (i.e. ruggedness) and challenging nature. Here, rugged and physically challenging terrain is taken to refer to the physical characteristics of the landscape including effects of steep and rough terrain that is frequently found across the Central Highlands. A digital terrain model is used to derive indices of terrain complexity that take slope (gradient), aspect and relative relief into account to create an attribute map describing the rugged and physically challenging nature of the terrain in the Central Highlands.

Data sources

4.42 The ArcticDEM is used here to represent the terrain surface of the Central Highlands for these analyses as described in para 4.6, resampled at 20m resolution.

Methods

4.43 Ruggedness is calculated from the ArcticDEM 20m resampled DEM as a simple index defined as the standard deviation (SD) of terrain curvature within a 250m radius of the target location. This is calculated. This generates values representing the amount of convex and/or concave curvature of the surface in both plan form and profile. Areas where curvature changes frequently are identified because they are deemed to represent rapidly changing terrain and hence ruggedness. This is achieved by applying a standard deviation function to the curvature surface within a 250m radius filter as shown in Figure 4.9.

Caveats and assumptions

4.44 It is understood that there are many ways of looking at and measuring ruggedness or roughness of a terrain surface. Other methods considered included fractal complexity[126], combinations of slope and aspect and statistical indices derived from these. As with the perceived naturalness map, a radius of 250m is used to estimate ruggedness within a fixed neighbourhood around the target location. This is used to spatially limit the ruggedness index to the immediate vicinity of the observer.

4.45 Ruggedness is inversely correlated with openness though not universally so. In the Central Highlands open areas tend to be the wide gently rolling/flat gravel plains, mountain plateaus and ice caps which correspondingly exhibit low levels of ruggedness and high openness with vast and far horizons. Rugged areas are the deeply incised valleys and fells together with the edges of the ice caps where heavily crevassed icefalls can be observed. In these areas landscapes tend to exhibit more enclosed characteristics with limited visible extents and near horizons. Local areas of high ruggedness can be found in otherwise open landscapes where local variations in topography such as incised river gorges have an effect.

[126] Fractal complexity refers to the degree to which an object can be divided into separate objects each of which is similar to the original. For example, a tree can be split into a series of branches each of which may resemble the original tree. These branches can then be divided themselves into twigs, each of which again may resemble the original tree and its branches.

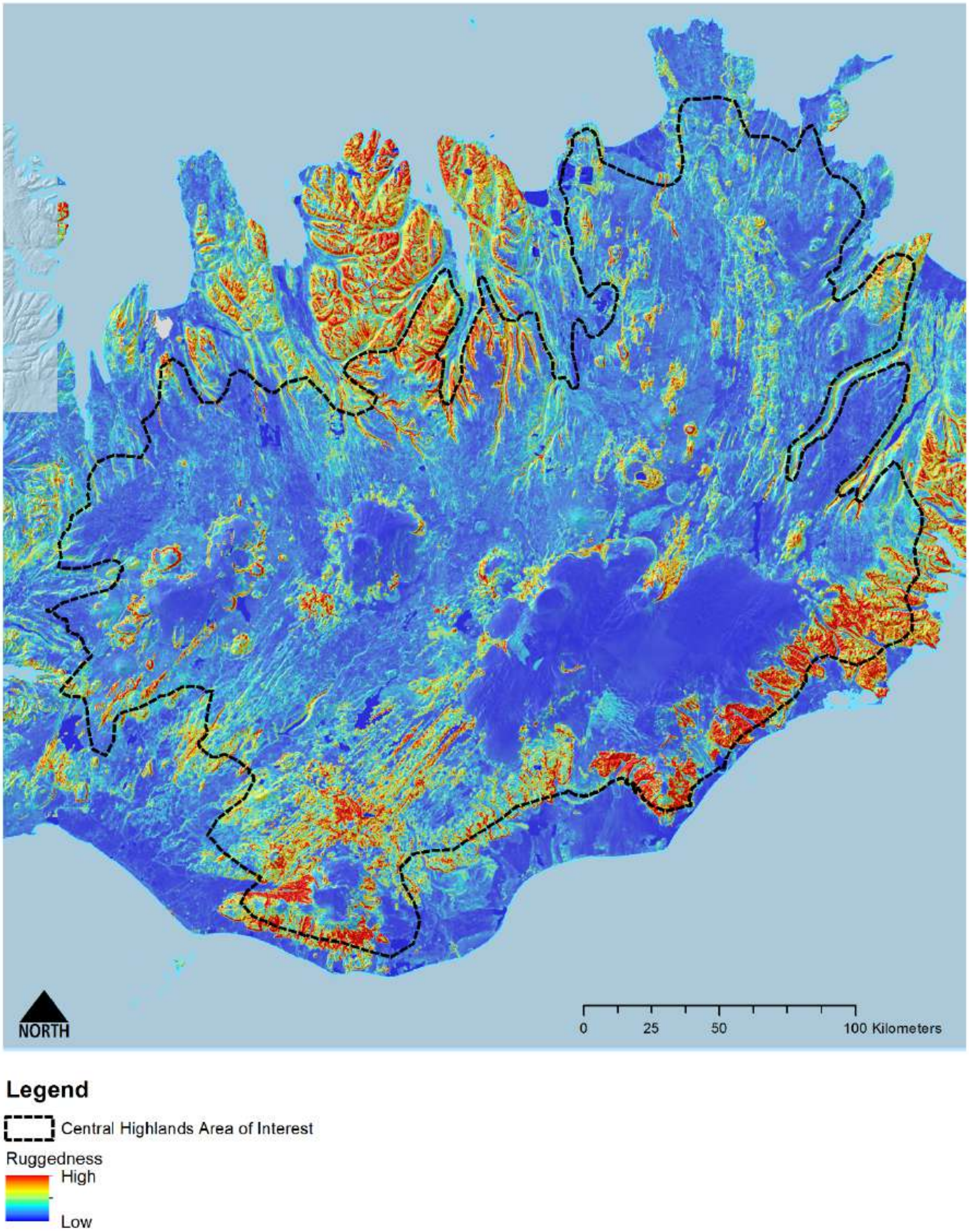


Figure 4.9 Rugged and physically challenging nature of the terrain

Accessibility

4.46 While there is a relatively well-developed network of gravel roads across parts of the Central Highlands, with corresponding effects on remoteness from mechanised access as detailed in paragraphs 4.5-4.15, much of Iceland's interior has a remote feel due in part to the time it takes to get there from the main centres of population. This is an essential aspect of the Central Highlands' wilderness character. This is modelled here using a population-weighted accessibility surface taking the road network, road type and average speed of driving into account.

Data Sources

4.47 Road data and type (with estimated typical driving speeds) is derived from the LMÍ (Landmælingar Íslands) roads data, while population data for Iceland is derived from the LandScan Global 2019 dataset[127].

Methods

4.48 A population weighted accessibility surface is derived from the above datasets using a combination of the CostDistance tool in ArcGIS and a simple weighted linear summation model. Centres of population are extracted from the LandScan data using increasing population density thresholds (n=10) to identify a range of population centres from farmsteads and villages to major towns and the city of Reykjavik. These are used as journey source (origins) for the CostDistance calculations. The road network is assigned average estimated driving speeds according to road types from the LMÍ road database and used with background offroad walking speed of 5 km/hr as a friction or cost surface with the CostDistance tool to calculate isochrone surfaces. This provides a 'time taken to travel' surface for each of the population density thresholds. The ten travel time surfaces are then combined in a linear weighted summation model using the relative population thresholds as weights. The resulting accessibility surface is shown in Figure 4.10.

Caveats and assumptions

4.49 Typical driving speeds are estimated from road type and local knowledge. These are conservative estimates but will vary, especially on the rough gravel roads typical in the remotest areas of the Central Highlands.

4.50 Only ten population thresholds are used to define the journey source/origin locations. More thresholds could be used, but ten is deemed sufficient for the range of typical population centres found in Iceland.

4.51 Travel times offroad are assumed to be uniform at 5 km/hr walking speed. The remoteness model described in paragraphs 4.5-4.15 provides more detail on actual walking times and patterns for offroad areas.

[127] https://landscan.ornl.gov/

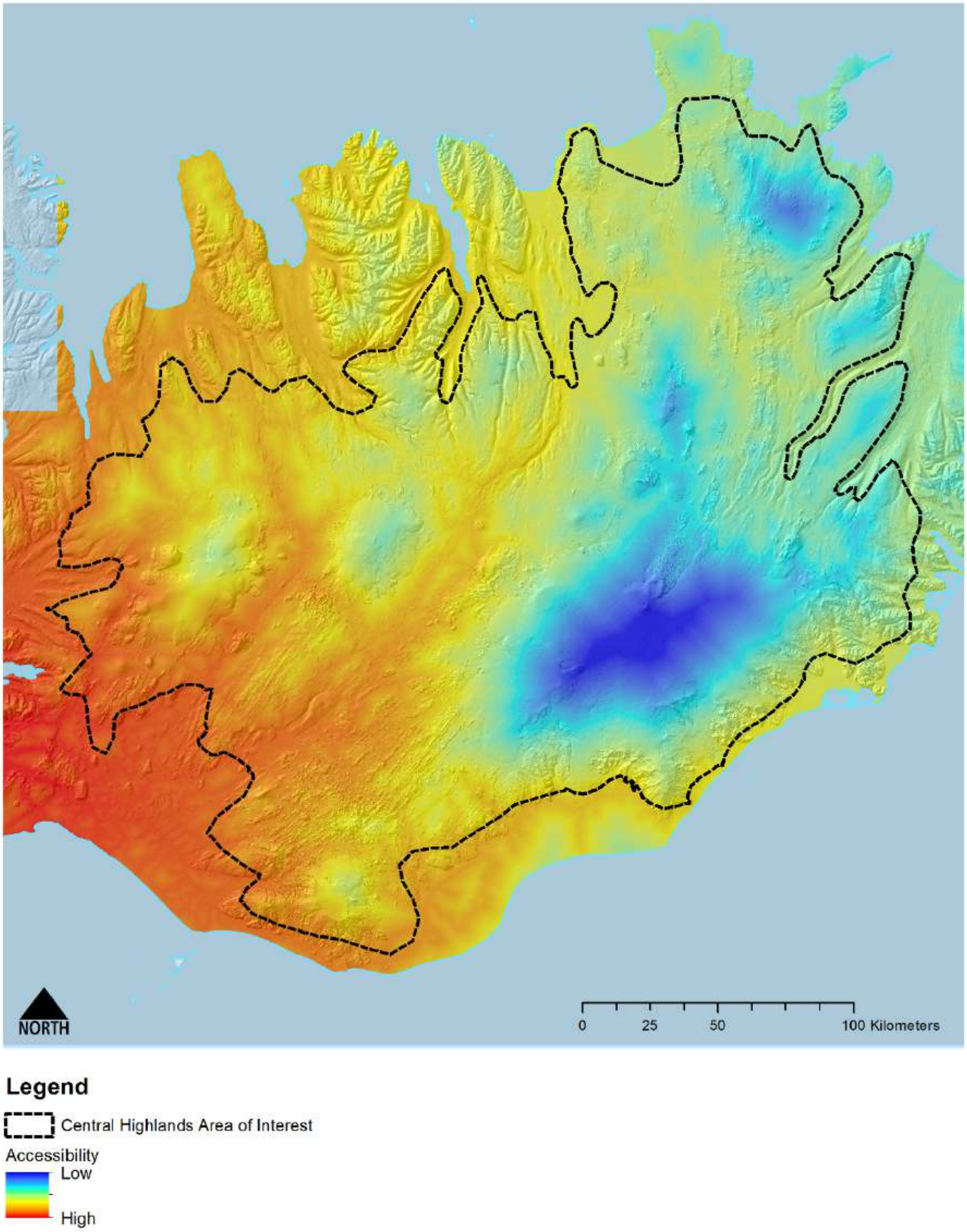


Figure 4.10 Accessibility from populated areas

Mobile phone coverage

4.52 Mobile phone coverage is remarkably good across much of Iceland including the Central Highlands. This is an important additional factor influencing sense of remoteness and affecting wilderness character due to the prevalence of mobile communications in modern society. The ability to make an emergency call to summon help should it be needed (e.g. in case of personal injury, vehicle breakdown, navigational error, etc.) along with access to digital maps and GPS location has a significant impact on wilderness character, self-reliance, solitude and risk.

4.53 Mobile phone reception is determined by rough line of sight between the user and the nearest cell mast. Line of sight is controlled by intervening topography and because the topography across much of the Central Highlands is very open (see para 4.38-4.40) and there are several cell masts in the Highlands area, mobile phone coverage is correspondingly good and extensive.

Data sources

4.54 There are two principal mobile phone providers that provide coverage across the Central Highlands. These are Vodafone[128] and Síminn[129].

Methods

4.55 Coverage maps where captured and georeferenced from the company web sites. These show 4G, 3G and GSM coverage areas.

4.56 Georeferenced mobile coverage maps are reclassified to show where there is no coverage from either service provider, and the areas are then mapped. The areas with no mobile phone coverage are shown in Figure 4.11.

Caveats and assumptions

4.57 These data are not available as raw data and had to be captured from web imagery. The resulting maps are therefore a generalisation and at low resolution, so cannot be relied upon at local scales. They do, however, serve to illustrate the general pattern of areas where there is no mobile phone coverage which enhances the need for self-reliance and increases the feeling of remoteness and isolation.

[128] https://vodafone.is/english/mobile-coverage/
[129] https://www.siminn.is/en/network

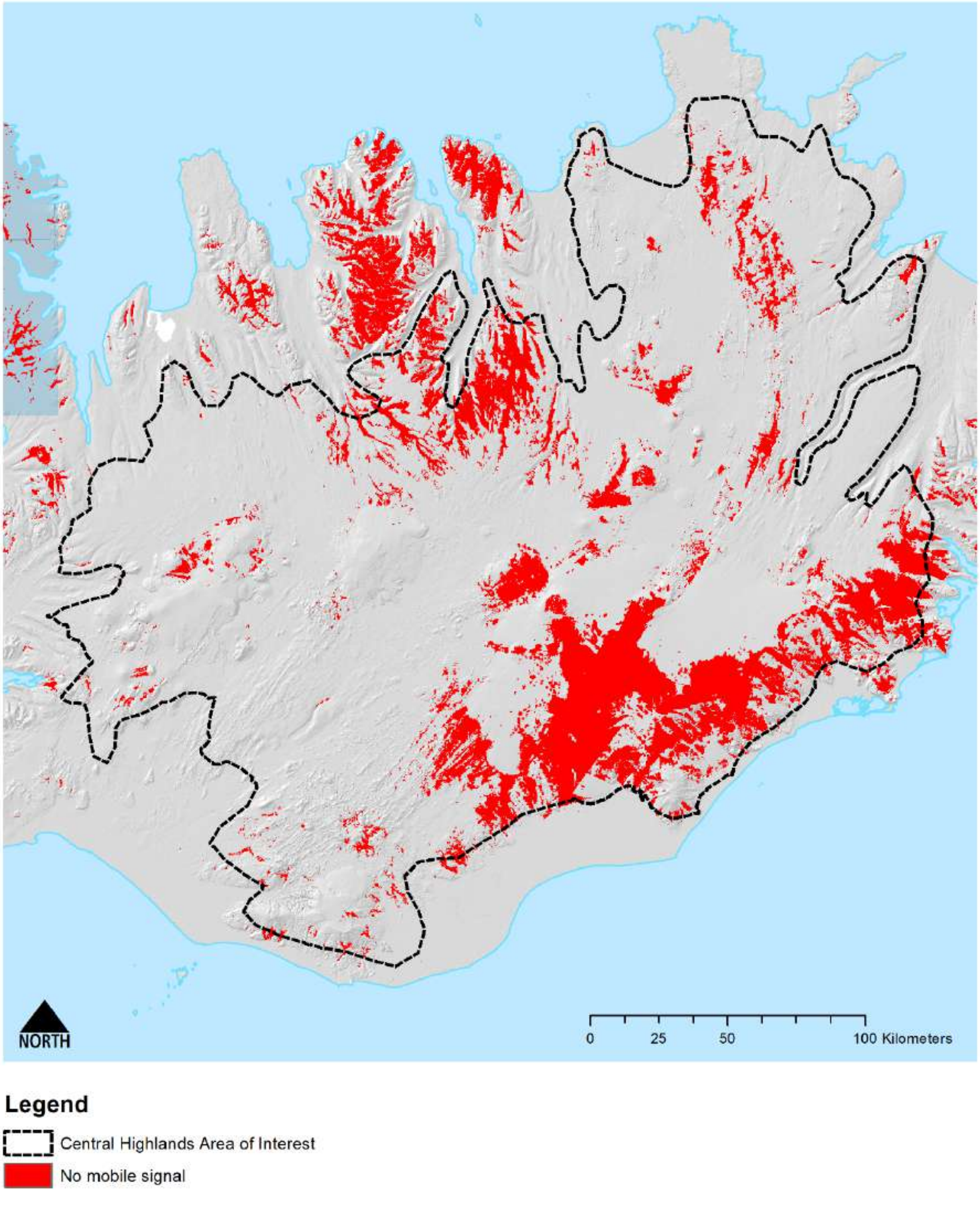


Figure 4.11 Areas without mobile phone coverage (based on Vodafone and Síminn networks)

Livestock grazing

4.58 Livestock grazing is carried out over the summer in parts of the Central Highlands. This includes both sheep and horses, the latter being used principally for recreation. Associated with this grazing activity is fencing, 4x4 tracks and shepherds' huts.

4.59 As a human economic land use, grazing of animals and associated infrastructure has an influence on wilderness character in the areas where it takes place.

Data sources

4.60 There is at present no detailed map data on livestock densities though the associated vehicle tracks and buildings are known, and part of the wilderness quality analysis described here.

4.61 The best data available shows approximate boundaries of livestock grazing areas. This is shown in Figure 4.12[130].

Caveats and assumptions

4.62 There is no data on livestock densities and therefore no reliable information on where sheep and horses are most likely to be observed.

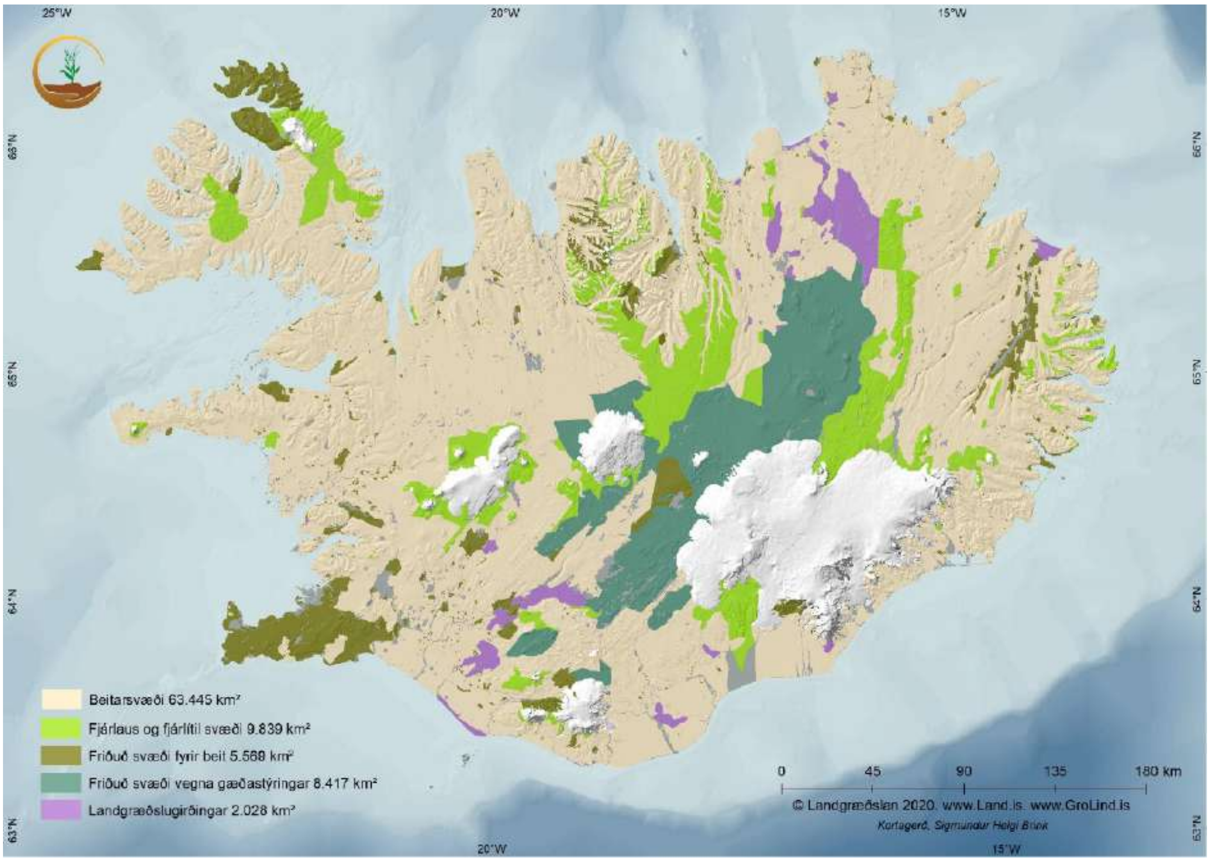


Figure 4.12 Livestock grazing units

130 https://grolind.is/wp-content/uploads/2020/06/Kortlagning-beitilanda-2020.pdf

Landscape character

4.63 Landscape character has been mapped across Iceland and the 27 different landscape type units across 7 categories described in a recent report prepared by EFLA and Land Use Consultants, Scotland[131]. The boundaries of these landscape units and the information contained in the report are used here to supplement the information wilderness character. The landscape character areas are shown in Figure 4.13.

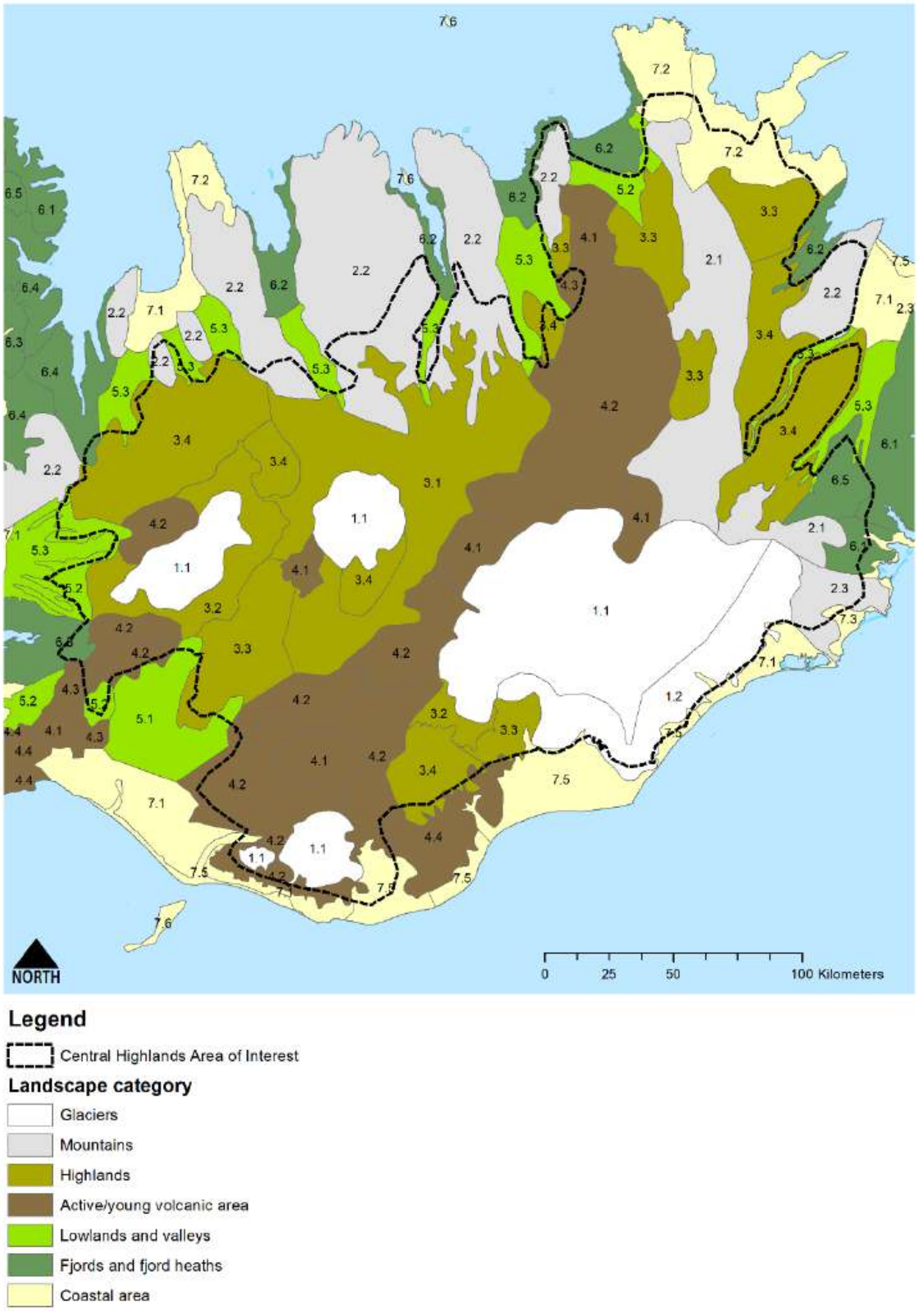


Figure 4.13 Landscape categories

[131] https://www.skipulag.is/media/landsskipulagsstefna-vidbaetur/Skyrslan_Lokaeintak-2-.pdf

5. Results: wilderness quality mapping of the Central Highlands

5.1 Section 4 has described the selection and creation of attributes of wilderness quality and character across the Central Highlands of Iceland and adjoining areas. This section describes the process of using these attributes in mapping the wilderness quality index (WQI) as a continuum across the Central Highlands and defining the areas and boundaries of core wilderness areas meeting the criteria defined by the IUCN and Wild Europe Working Definition, taking into account the national legal definition of wilderness and mapping provisions.

Wilderness quality

5.2 Wilderness quality is defined here based on three wilderness attributes: remoteness from mechanised access, absence of modern human artefacts, and perceived naturalness of land cover. These three wilderness attributes are combined through a Multi-Criteria Evaluation (MCE) analysis to create a Wilderness Quality Index (WQI). This is displayed in Figure 5.1 and shows the spatial patterns in the variation wilderness quality across the area of interest. The model uses a simple weighted linear summation model wherein each of the three attributes are standardised on a common scale, equally weighted, and summed to provide a standardised index.

5.3 Further maps are created showing the detail for the central highlands, when split into Core, Buffer and Transition zones based on a Jenks "Natural Breaks" Classification model as used by SNH in their 2014 Phase 2 map of Wild Land Areas in Scotland. The method examines the distribution of the WQI values across the mapped area and divides these into a specified number of classes such that the difference from the mean within each class is minimised. The classification used here follows the SNH 2014 methodology and uses 5 classes (Figure 5.2) with class 5 being 'Interior Core', class 4 as 'Core', class 3 as 'Buffer', class 2 as 'Transition' and class 1 being 'Not Wild'.

5.4 A further map (Figure 5.3) depicts how the Wild Europe Working Definition is used to identify 'Core' and 'Core plus Contiguous Buffer' areas larger than 3,000 ha (30 km^2) and >10,000 ha (100 km^2) respectively. In Figure 5.3 Jenks class 3 areas not contiguous with 'Core' areas > 3000 ha (together with any class 4 areas < 3,000 ha) are classified as 'Buffer' and all class 2 as 'Transition' zone. All class 1 areas are classified as 'Not wild'. It is possible to use 2,500 ha to more closely match the 25 km^2 criteria used in the Nature Conservation Act No 60/2013 but few significant changes in the core areas defined are noted, demonstrating the areas defined here are robust and not overly sensitive to the specific area threshold used. This is partly due to their large size and partly due to the role of gravel roads and power lines acting as corridors between and dividing adjacent wilderness areas.

5.5 Figure 5.4 shows the resulting Category Ib "Wilderness" areas as defined through the mapping carried out in Figures 5.1-5.3. The remaining buffer and transitional zones larger than 25 km^2 with the area of interest that are not part of the wilderness areas could feasibly be designated Cat II "Natural Park". The core Cat Ib Wilderness areas are numbered 1 through 17 and geographical names assigned. The Cat II areas are unnumbered but surround much of the Cat Ib core wilderness, effectively creating an outer buffer zone.

5.6 While the boundaries shown in Figure 5.4 are precise and accurate, they are based on statistical reclassification of a combination of the three measured wilderness attributes as illustrated in Figures 5.1 and 5.2 and the application of area thresholds in Figure 5.3. This can result in complex boundaries and some inclusions of isolated patches of buffer inside wilderness areas. These are due to localised patches of enhanced visual impact (e.g. as seen from vantage points on peaks or ridges) or modified land cover. These are left "as seen" for the purposes of this report but would be removed or used to modify external boundaries in the next stage in work to formalised wilderness area designation in Iceland. This would involve working with planners and local experts to draw formal boundaries using these maps as a guide. Small inclusions can then be verified and removed if necessary.

Wilderness character

5.7 The wilderness areas shown in Figure 5.4 are further classified according to a range of variables describing their geographical nature and wilderness character. Table 5.1 summarises each of the 17 wilderness areas by their geographical characteristics. Each wilderness area is described based on information regarding wilderness character as described in section 4. This includes area, elevation range, openness, ruggedness, accessibility, mobile phone coverage, livestock grazing and landscape character classes. The character of each wilderness area is described in further detail in Appendix 1.

Table 5.1 Wilderness Character

No.	Name	Area (km²)	Altitude (m)	Openness (mean%)	Ruggedness[1] (mean)	Accessibility[2] (mean)
1	Keflavík og Látraströnd	124	17-1168	88	1.54	22180
2	Heljardalsfjöll	2,083	30-983	97	0.40	30213
3	Náttfaravíkur og Kinnarfjöll	237	9-1214	91	1.11	20507
4	Tröllaskagi	1,478	34-1440	89	1.33	18167
5	Smjörfjöll	870	109-1255	96	0.53	29108
6	Dimmifjallgarður	511	351-1037	96	0.52	25968
7	Nýjabæjarfjall	1,198	189-1541	93	0.93	19060
8	Bleiksmýrardalur	1,402	130-1254	96	0.62	20225
9	Ódáðahraun	1,379	382-1678	98	0.44	29226
10	Fljótsdalsheiði	413	297-710	99	0.25	29548
11	Askja í Dyngjufjöllum	380	523-1517	96	0.60	29530
12	Ríki Vatnajökuls	12,315	4-2108	97	0.53	30002
13	Hofsjökull og Þjórsárver	1,907	554-1789	98	0.35	18796
14	Langjökull	2,095	294-1670	97	0.45	14472
15	Trölladyngja	546	750-1465	98	0.38	25674
16	Fjallabak	408	67-1383	93	1.26	14115
17	Mýrdalsjökull og Eyjafjallajökull	1,124	56-1637	95	0.87	13426

[1]Ruggedness is a unitless number calculated as standard deviation of slope curvatures (rate of change of slope) within a 250m radius. Higher numbers indicate greater ruggedness.

[2]Accessibility is a unitless number calculated as a population/distance weighted surface taking typical road class driving speeds into account. Lower numbers indicate an area closer to more populated areas such as Reyjavik and Akureyri (with shorter driving times), and higher numbers further away (with longer driving times).

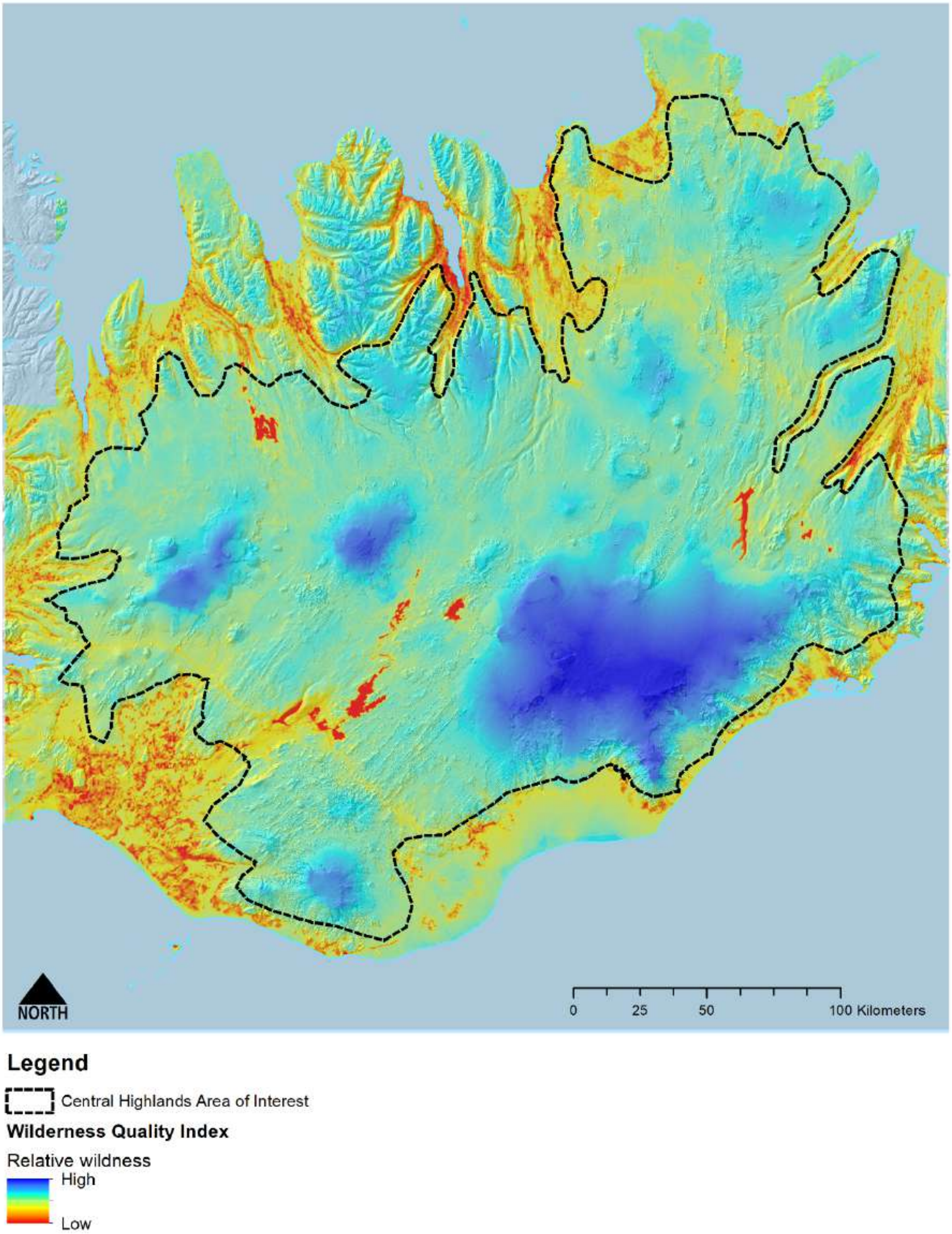


Figure 5.1 Wilderness Quality Index

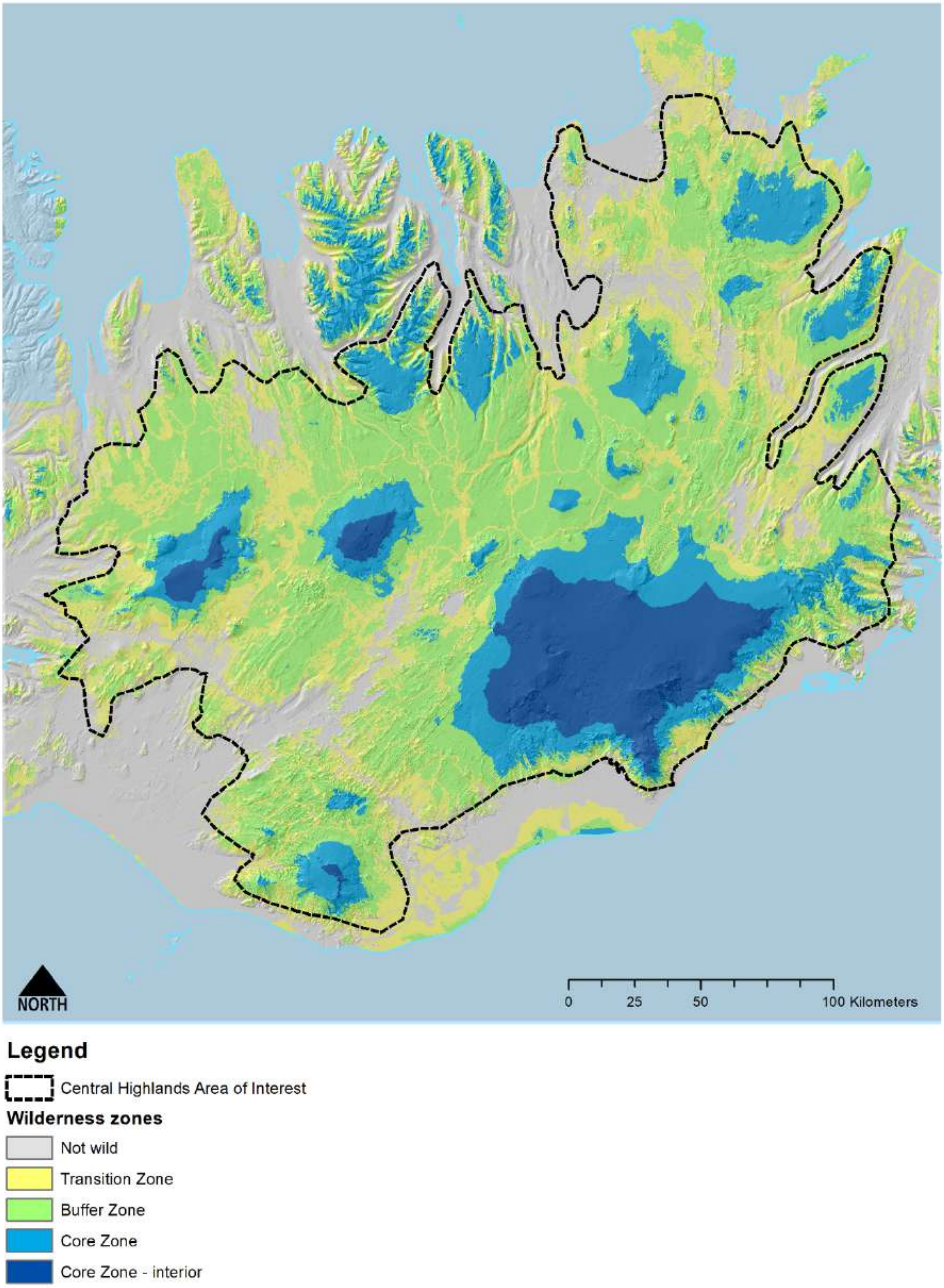


Figure 5.2 Wilderness Quality Jenks

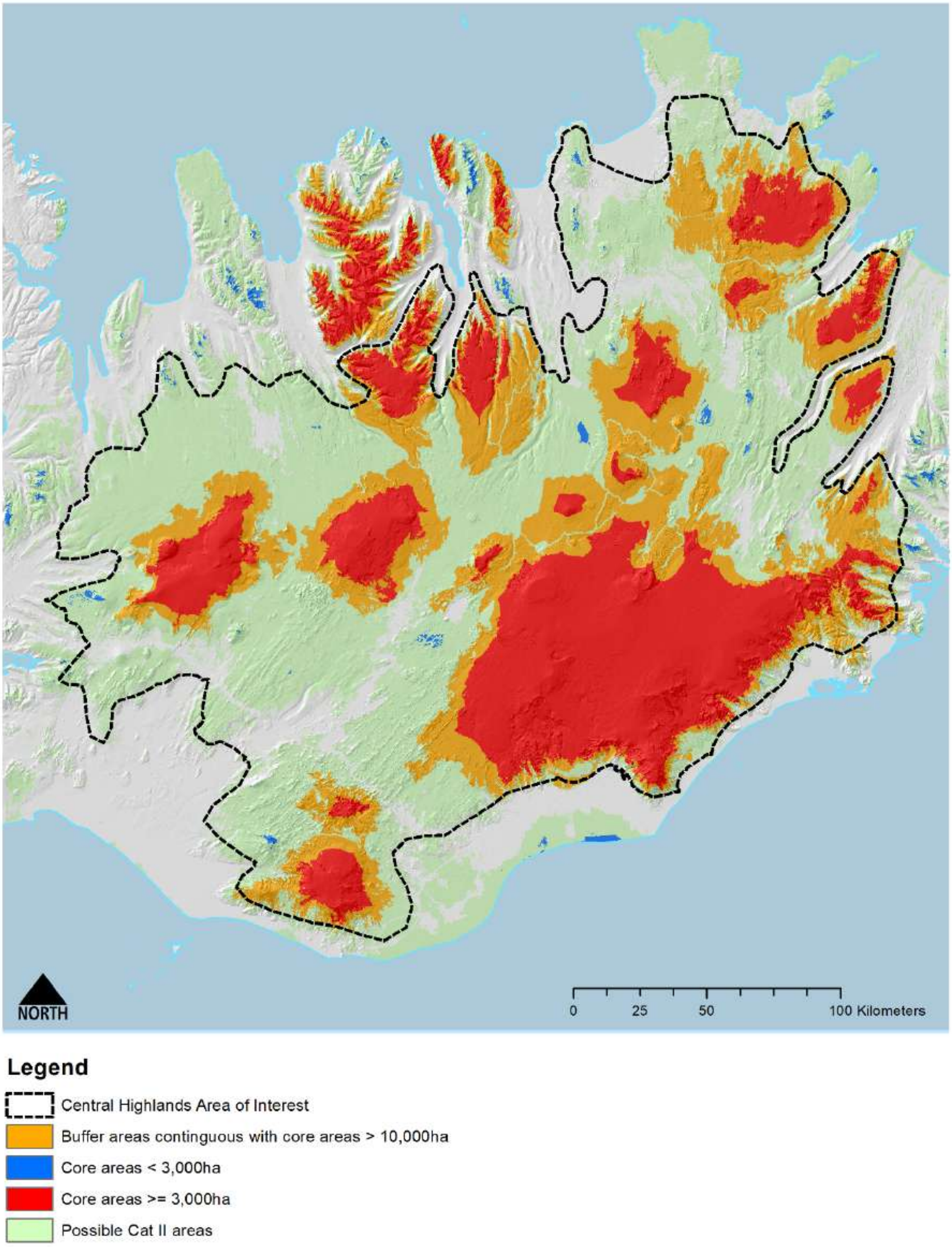
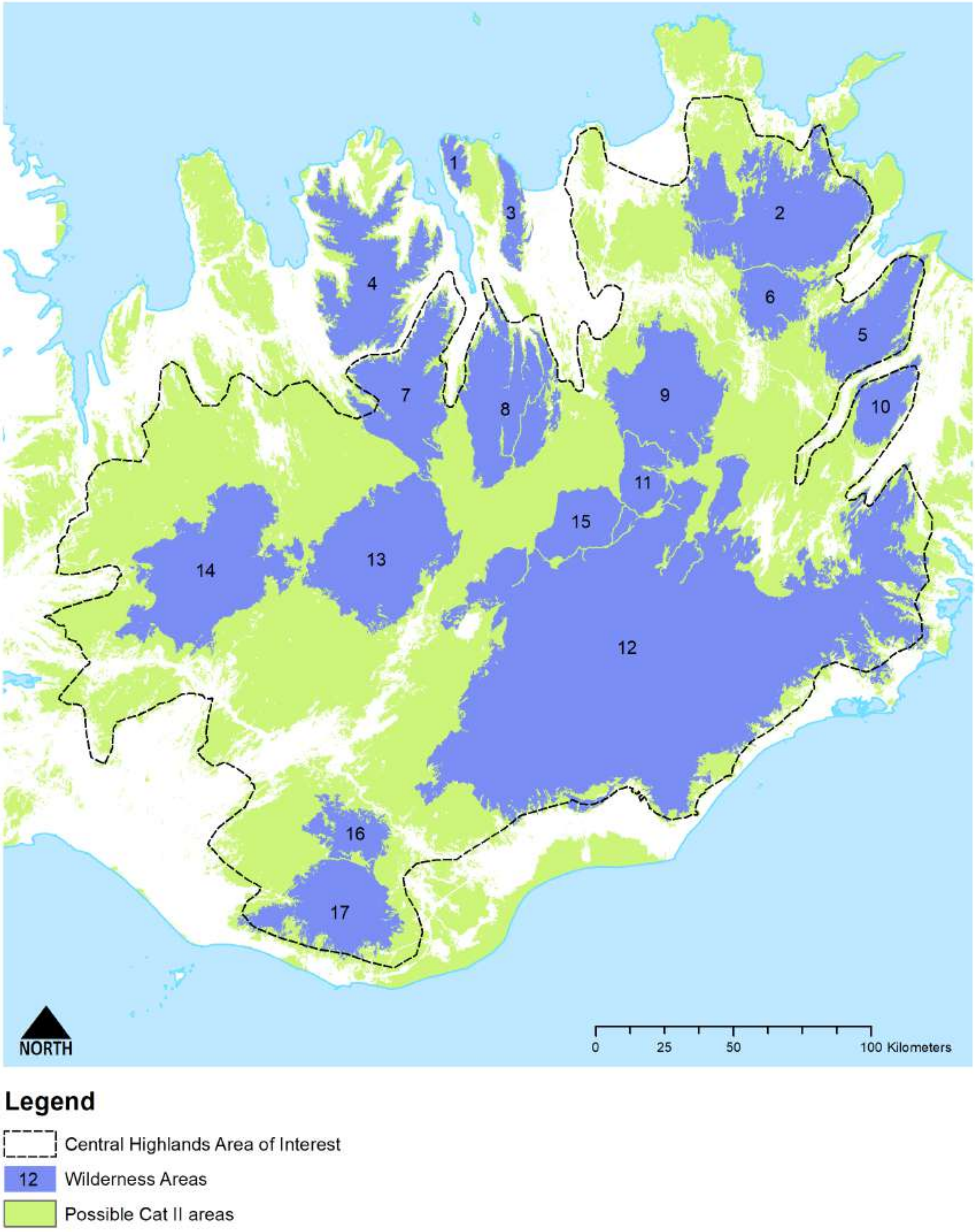


Figure 5.3 Wilderness Areas above size constraints



1. **Keflavík og Látraströnd**
2. **Heljardalsfjöll**
3. **Náttfaravíkur og Kinnarfjöll**
4. **Tröllaskagi**
5. **Smjörfjöll**
6. **Dimmifjallgarður**
7. **Nýjabæjarfjall**
8. **Bleiksmýrardalur**
9. **Ódáðahraun**
10. **Fljótsdalsheiði**
11. **Askja í Dyngjufjöllum**
12. **Ríki Vatnajökuls**
13. **Hofsjökull og Þjórsárver**
14. **Langjökull**
15. **Trölladyngja**
16. **Fjallabak**
17. **Mýrdalsjökull og Eyjafjallajökull**

Figure 5.4 Wilderness areas in the Central Highlands

6. Comparison with alternative wilderness mapping techniques

6.1. The work described here follows commonly applied international standards in mapping wilderness quality as employed elsewhere in Europe, North America, China, Australia, etc. It builds on previous experience in applying these models to Iceland by the report authors in the Drangar Peninsula[132] and Vonarskarð[133]. The work applies lessons learnt from previous mapping exercises in Iceland.

6.2. Most international wilderness quality mapping combines continuous models of wilderness attributes that are selected and mapped at a resolution appropriate for the scale and geographical context of the area/country of interest. For example, the EU's Wilderness Index is derived by combining data on distance from road and rail, distance from settlement, and naturalness of vegetation in comparison to the potential natural vegetation (PNV) in the absence of human land use[134]. The Scottish Wild Land Areas mapping uses four attributes: perceived naturalness of land cover, absence of modern human artefacts, remoteness from mechanised access, and rugged and challenging nature of the terrain[135]. The Chinese mapping uses biophysical naturalness of land use, population density, remoteness from settlement, remoteness from roads/railways, settlement density and roads/railways density[136]. Each map and respective scale of mapping utilises attributes that are both appropriate for the landscape, the size of the mapped area and the local culture/society present.

6.3. It is useful to compare the suggested wilderness areas in Figure 5.4 with previous wilderness maps drawn for Iceland. These include the EU Wilderness Index (2013)[137], the map by Ólafsdóttir and Runnström (2011)[138], and the recent map by Árnason and Ostman (2021)[139]. Figures 6.1-6.3 show these maps superimposed over the wilderness areas from Figure 5.4.

6.4. A simple visual comparison of the suggested wilderness areas developed here and shown in Figure 5.4 and overlaid on previous mapping is Figures 6.1-6.3 demonstrates a reasonable degree of similarity. This is only to be expected since despite differences in criteria, data and approach, all these maps are dealing with the same landscape and the same underlying characteristics of wilderness, namely remoteness and naturalness.

[132] https://4a039f3a-67a6-4339-a434-5330cd524327.filesusr.com/ugd/d3e1ab_1e309cd094954522ab605283ec353293.pdf
[133] https://wildlandresearch.org/wp-content/uploads/sites/39/2021/09/Vonarskard-Report-v1.7.pdf
[134] Wilderness Register and Indicator for Europe (2013) https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf
[135] https://www.nature.scot/guidance-mapping-scotlands-wildness-and-wild-land-non-technical-description-methodology
[136] Cao, Y., Yang, R., Long, Y. and Carver, S., 2018. A preliminary study on mapping wilderness in mainland China. International Journal of Wilderness, 24(2). https://ijw.org/2018-mapping-wilderness-in-mainland-china/
[137] Wilderness Register and Indicator for Europe (2013) https://ec.europa.eu/environment/nature/natura2000/wilderness/pdf/Wilderness_register_indicator.pdf
[138] Ólafsdóttir, R. and Runnström, M.C., 2011. How wild is Iceland? Wilderness quality with respect to nature-based tourism. Tourism Geographies, 13(2), pp.280-298. https://doi.org/10.1080/14616688.2010.531043
[139] https://www.ramma.is/media/rannsoknir/OstmanEtal2021_WildernessIceland.pdf

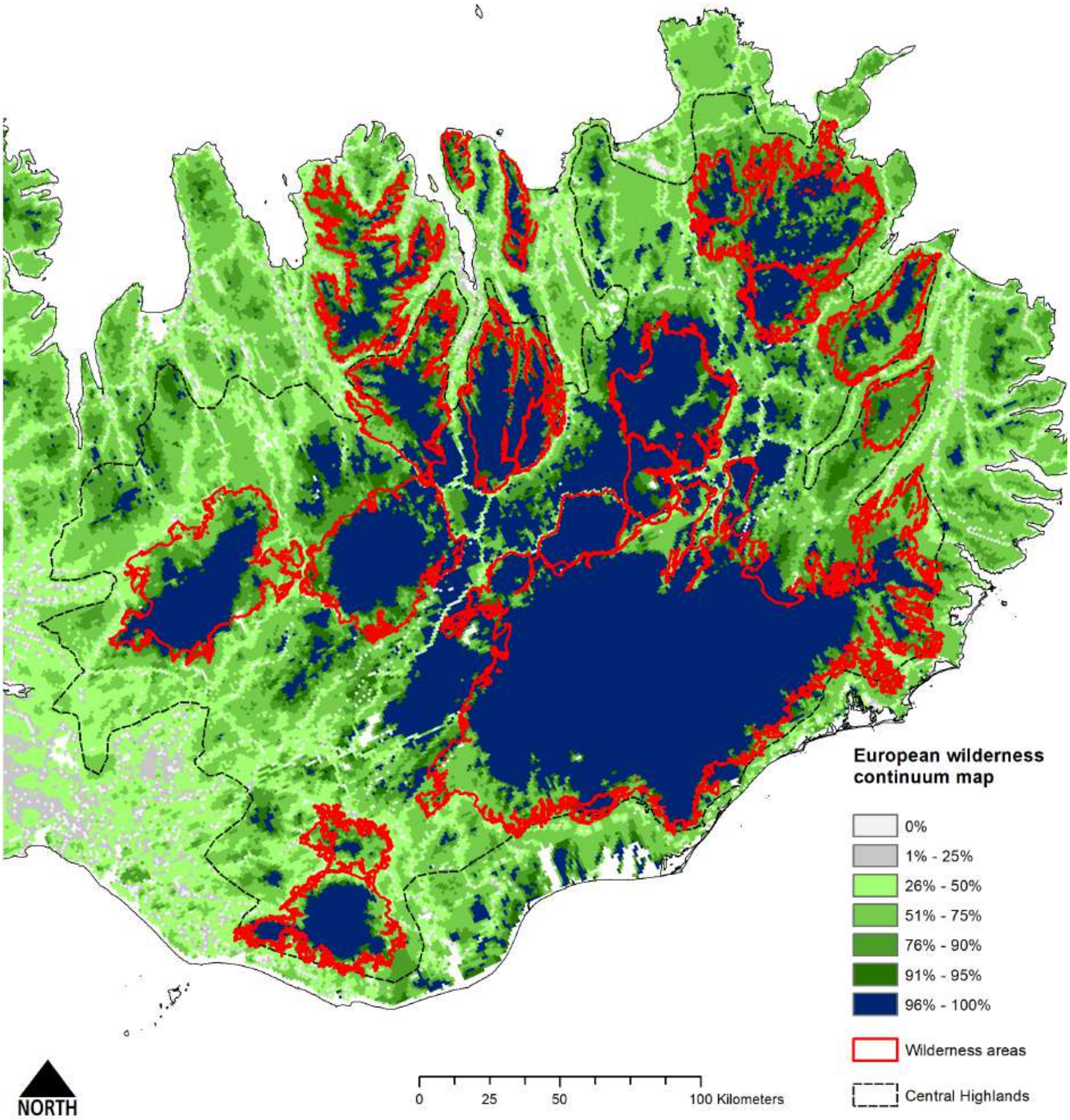


Figure 6.1 Comparison with Kuiters et al. (2013) EU Wilderness Index

6.5. The greatest degree of similarity is shown in Figure 6.1 when comparing the current areas with those mapped at a European scale by Kuiters et al. (2013). This is perhaps unsurprising due the use of similar methods (multi-criteria evaluation) and an emphasis on continuous data, naturalness and remoteness. However, there are marked differences in the detail shown since the mapping described in this report has been performed at a much finer resolution (20m) compared to the Kuiters et al map (1km) enabling much more realistic models and data to be brought to bear that better reflects the actual landscape and patterns of wilderness present.

6.6. The comparisons made against the mapping by Ólafsdóttir and Runnström (2011) in Figure 6.2 and by Árnason and Ostman (2021) in Figure 6.3 demonstrate the greatest deviation. Both maps show significantly more wilderness areas being present despite a good spatial match with those areas where the separate maps agree. This is due to the more simplistic nature of the mapping criteria used by Ólafsdóttir and Runnström (2011) and by Árnason and Ostman (2021).

6.7. The Ólafsdóttir and Runnström (2011) map is a straightforward spatial mapping of the criteria described in the previous Nature Conservation Act No 44/1999 which maps those areas more than 5km from a road or building as simple buffers and then selects those that are more than 25km^2 in size. Here, all buildings and roads are used regardless of road grade or building size, with the result that a shepherd's hut has the same effect as a geothermal power station on the wilderness buffers. Scale of development and the influence or impact that this has on the landscape is not considered. The work by Ólafsdóttir and Runnström (2011) does expand the mapping further by including a binary viewshed analysis to show the zones of theoretical visibility (ZTVs) of human features, but this is not included in the final wilderness map.

6.8. The Árnason and Ostman (2021) map employs the same criteria for roads but only for paved roads and thus excludes the impact of gravel roads on remoteness across large areas of the Central Highlands (whereas a previous mapping of 2017 by same authors applied 5km buffer to all roads in the national register of the Road Authority[140]). It applies simple buffers of 3km vs. 5km for power lines depending on the voltage level. There is an attempt to take relative impact into account by varying the buffer distances applied based on a scoring system calculated from the use and number of buildings/structures present, their surface area, visibility and connection to the road network. Paved roads are buffered at a uniform 5km. The resulting wilderness areas are much more extensive than those presented by Ólafsdóttir and Runnström (2011) or in the work presented here and conform more to the suggested Cat II areas. This is due to the exclusion of gravel roads from consideration and the use of simple buffering, albeit modified with a scoring system.

6.9. The work and the maps presented in this report differ from the previous work in that rather than using simple distance/area proxies, the attributes mapped here represent the actual measurement of human impacts from land use, settlement and infrastructure development on wilderness landscapes. This is achieved using high resolution spatial data and modelling tools that are able to provide true and accurate representations of the spatial patterns in human impacts and their effect on wilderness quality and character. The wilderness areas presented in Figures 5.2-5.4 are the most detailed and accurate models of wilderness areas in the Central Highlands to date and successfully identify and delimit the boundaries of wilderness areas meeting IUCN Cat Ib and Wild Europe Working Definition criteria.

[140] https://www.skipulag.is/media/pdf-skjol/Kortlagning_Viderna_Web2.pdf

6.10. The boundaries of the 17 core wilderness areas shown in Figure 5.4 are necessarily quite complex at this stage. This is because they are defined using combinations of accurately measured wilderness attributes and statistical classification of the resulting surface in Figure 5.2. While boundaries are combined in Figures 5.3 and 5.4 to meet Wild Europe Working Definition, it is envisaged that a further stage of refinement in collaboration with planners and government will be required to refine and simplify these for practical use.

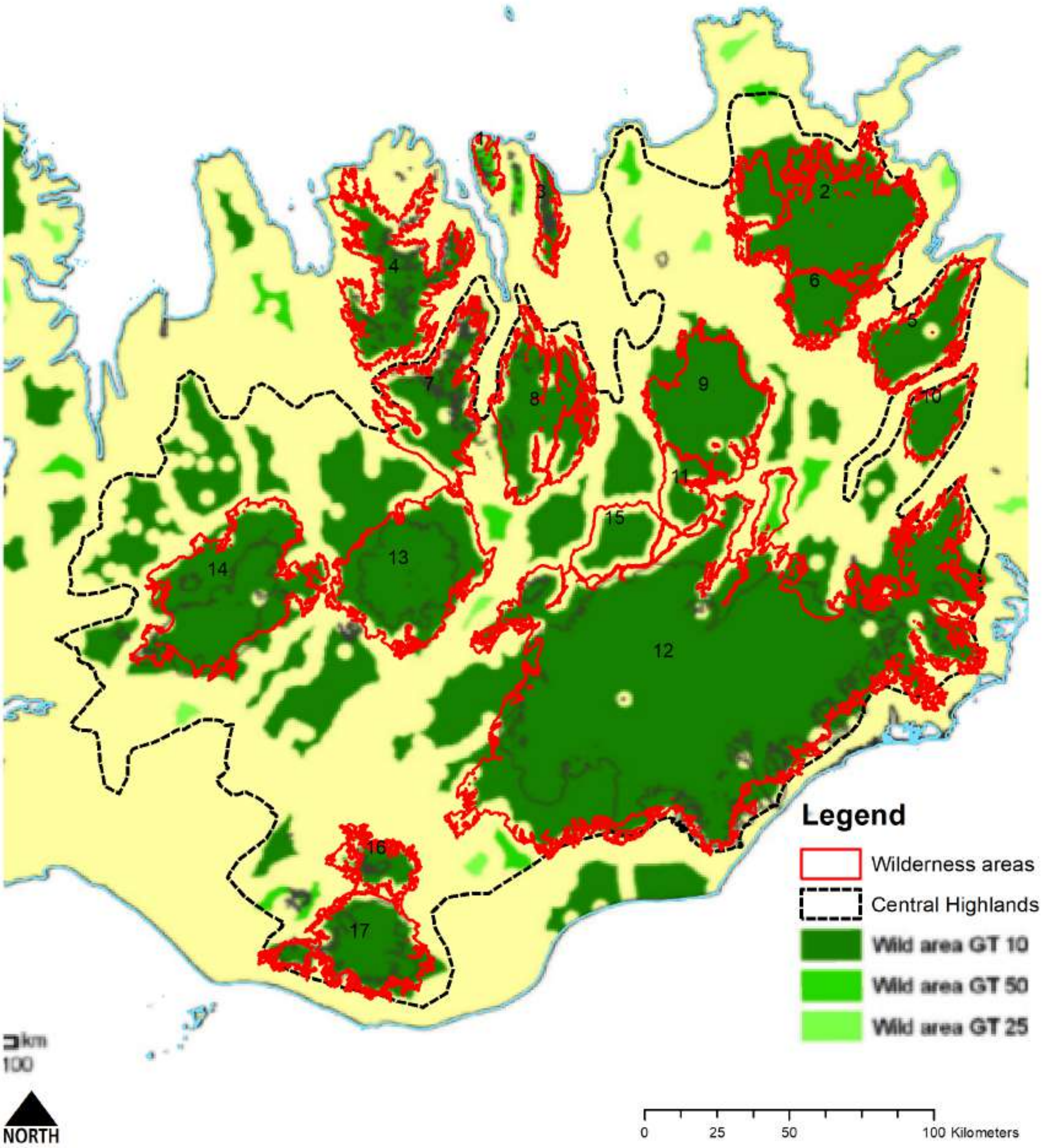


Figure 6.2 Comparison with Ólafsdóttir and Runnström (2011) wilderness areas

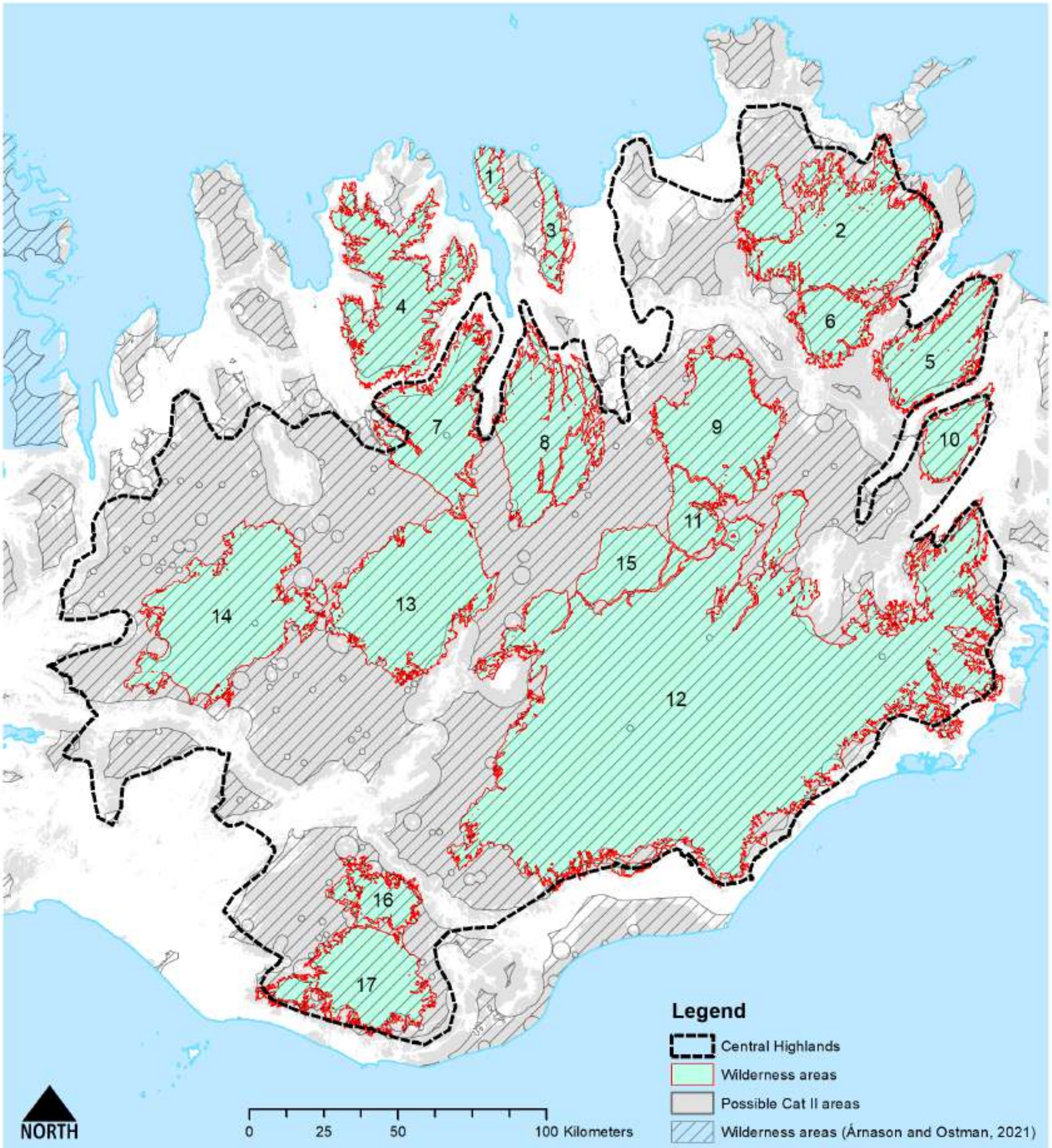


Figure 6.3 Comparison with Árnason and Ostman (2021) wilderness areas

7. Conclusions

7.1 This report, and the maps contained within it, represent the most detailed and accurate mapping of wilderness quality and wilderness character for the Central Highlands of Iceland that has been done to date. The data sources and methods used, together with the wider approach focusing on combined models of wilderness quality attributes and character descriptions, have enabled 17 separate and distinct core wilderness areas to be defined along with surrounding buffer and transition zones (Figure 5.4).

7.2 The mapping takes visual impact from human artefacts (buildings, structures, roads, and energy infrastructure), remoteness from mechanised access (roads usable by the public) and naturalness of the land cover into account when modelling wilderness quality as continuous mapped spatial attributes. These three attributes are combined using multi-criteria evaluation techniques and statistical models to define wilderness core, buffer and transition zones following the wilderness criteria and guidance defined in the Wild Europe Working Definition.

7.3 Additional mapped information is used to describe the wilderness character of each of the 17 core wilderness areas. This includes spatial data on variations in topographic openness, ruggedness, accessibility to centres of population, mobile phone coverage, livestock grazing and landscape character assessments. These data are used to provide detailed descriptions for each of the core wilderness areas (Appendix 1).

7.4 Figure 7.1 shows the 17 core wilderness areas overlaid on an aerial image of Iceland. It should be clear that core areas 12, 13, 14 and 17 are dominated and characterised by their respective ice caps. Other core areas tend to be either mountainous areas, open volcanic lava fields, barren gravel plains or combinations thereof. Each wilderness area has, however, its own unique character depending on its constituent components, topography and overall geographical context.

7.5 The exact boundaries of the core areas and buffer/transition zones are derived from detailed spatial data and models that measure the impact of human artefacts, remoteness and naturalness rather than relying on simple proxies such as distance buffers. As a result, these tend to be complex and generate complicated boundaries. It is suggested here that these will need to be simplified for planning and policy use.

7.6 Winter driving offroad over snow and ice remains an issue that requires further attention. While much of the mapping and analysis carried out here relates to summer conditions and rules (e.g. limiting vehicles to those roads usable by the public) the map in Figure 4.2c demonstrates the potential effect of winter offroad driving in much reducing remoteness. This is an issue highlighted in recent reports by Roger Crofts and is potentially one that could limit opportunities for the Icelandic government to designate large areas of the Central Highlands under IUCN Categories[141]. This requires careful engagement with the 4x4 community to explore options for limiting offroad winter driving to certain areas outside of mapped wilderness cores. This point is clarified in Article 46(2) of the Nature

[141] http://www.rogercrofts.net/files/iceland/Heart%20Iceland%20NP%20recommendations.pdf

Conservation Act No 60/2013 which states: "*The protection should aim to safeguard the characteristics of the areas e.g. to maintain diverse and unusual landscapes, panoramas and/or conserve complete large ecosystems, and ensure that present and future generations can enjoy therein solitude and nature without disturbance from man-made infrastructures or traffic from motor vehicles*."

7.7 It is also noted that the areas mapped are under threat from renewed interest in energy resource exploitation including new hydro and geothermal schemes as well as wind energy.

7.8 The advantages of the mapping approach described here are that it is: (a) based on internationally recognised methods and approaches, (b) based on best available data sources, (c) based on measurement rather than proxies, (d) performed at a high resolution and accuracy, and (e) is robust and repeatable. It is tailored to both the IUCN and Wild Europe definitions as well as the more subjective aspects of the definition in the Nature Conservation Act No 60/2103.

7.9 The repeatability of the models and approach used here is the key to the future planning and policy use of these wilderness boundaries and maps. These provide government, planners and policy makers with baseline information reflecting the status of wilderness areas in Iceland's Central Highlands under current levels of use and development. Existing impacts from human infrastructure, vehicular access, remoteness and land cover are taken into account and measured in a robust manner, such that new development proposals can be assessed.

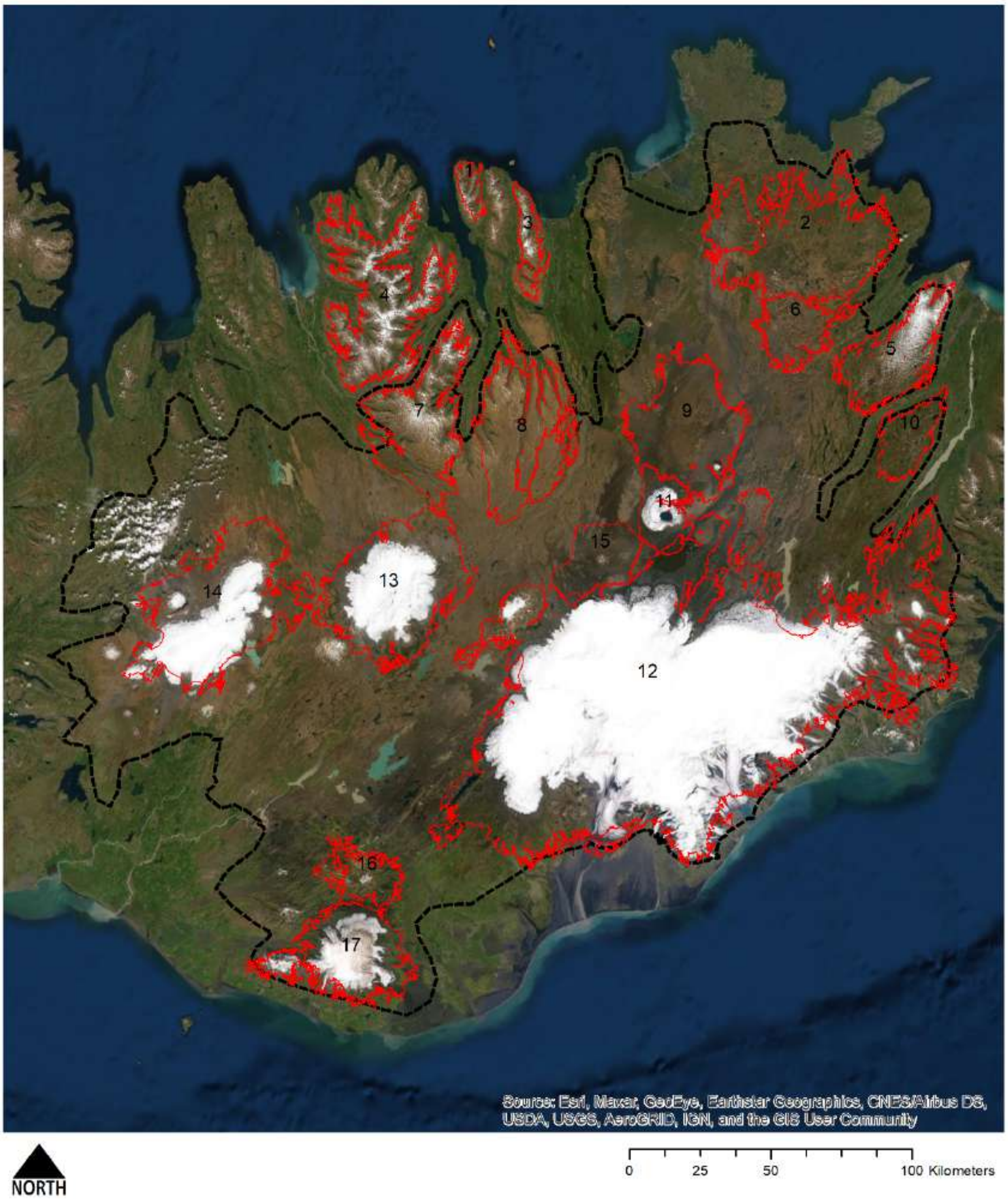


Figure 7.1 Geographical context of wilderness areas

Appendices

Appendix 1. Core Area Descriptions

Appendix 1 provides core area wilderness character descriptions for each of the 17 wilderness core areas based on characteristics of openness, ruggedness, accessibility from centres of population, mobile phone coverage, livestock grazing and landscape character assessments.

A1.1 Keflavík og Látraströnd

General setting and description

While this area sits outside of the Central Highlands area of interest, it does come out in the mapping process and so is included here for completeness. This is a relatively small area of wild coastal mountains along the northwest edge of a peninsula often referred to as Gjögraskagi or Flateyjarskagi forming the eastern shore of Eyjafjörður and bounded on the east by the fjord of Hvalvatnsfjörður and valley of Leirdalsheiði.

Topography

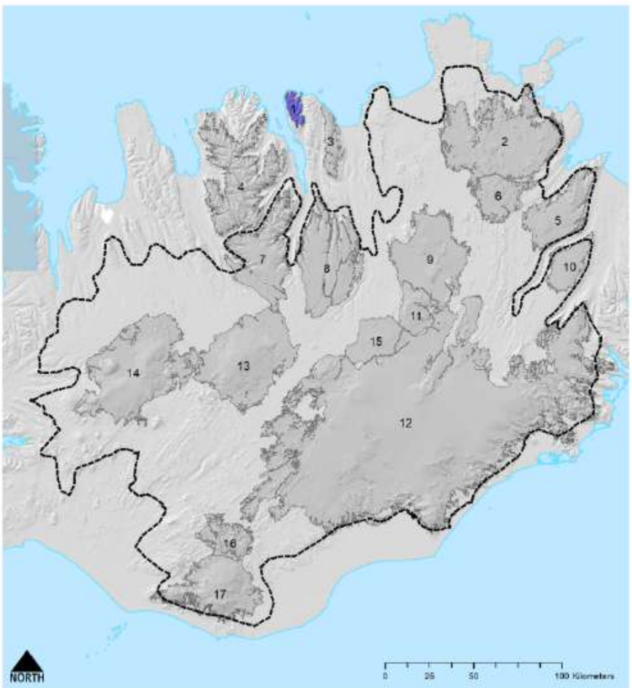
Topographically the area is formed of high mountains with steep slopes down to sea or valley. Geomorphology is formed of ancient lava beds, deeply dissected by past glaciation. A few small, cirque and mountain glaciers are found in the area.

Landscape assessment

The landscape is rugged, rough and largely unvegetated on the upper slopes with any vegetation restricted to lower altitudes. The views are largely enclosed with high degrees of topographic shielding except on the summits and ridges and the west-facing slopes along Eyjafjörður where there are expansive views across the fjord and over to the Tröllaskagi peninsula.

Land use

There are remains of old farms along the edge of Eyjafjörður linked by a rough track from Grenivík, as well as in Keflavík and Þorgeirsfjörður to the east. There is limited livestock grazing in the area. The area is relatively accessible by road from the town of Akureyri but the eastern edge is only accessible by a 4x4 vehicle. Mobile phone coverage is limited to the coast slopes and higher summits.



A1.2 Heljardalsfjöll

General setting and description

This is a large area of core wilderness in the far northeastern corner of the Central Highlands area of interest. At the centre of this area is a relatively low and undulated range of mountains (799m) – from which it derives its name – surrounded by a wide hinterland of low, undulating hills, plains and valleys interspersed with rivers, wetlands and small lakes.

Topography

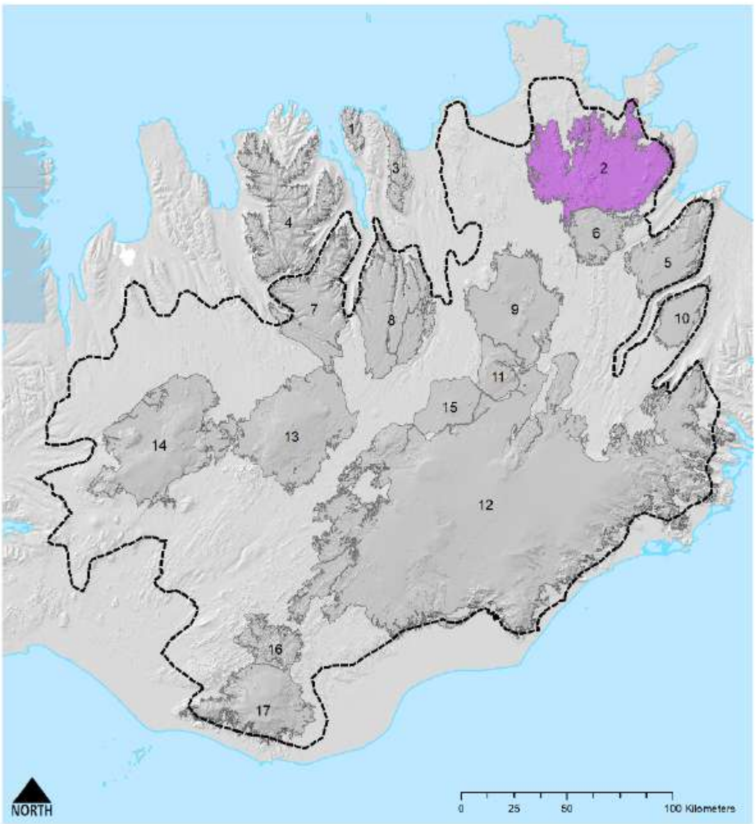
The topography is largely very open with a few areas of enclosed topography associated with incised mountain valleys. There are few rugged areas on the northeast of the Heljardalsfjöll mountains and outlying hills.

Landscape assessment

The landscape is dominated by high, though relatively rounded mountains of the Heljardalsfjöll and surrounding high plains. There are some areas of low moors where the core area approaches the coast near the Langanes peninsula.

Land use

There is livestock grazing high up in the area . Mobile phone coverage is largely present but with some areas of no signal in the deeper valleys. The area is very remote from most of Iceland's larger centres of population.



A1.3 Náttfaravíkur og Kinnarfjöll

General setting and description

This area sits outside of the Central Highlands area of interest, it does come out in the mapping process and so is included here for completeness. This is a relatively small area of wild coastal mountains similar to area 1 along the northeast edge of the peninsula often referred to as Gjögraskagi or Flateyjarskagiforming the western shore of Skjálfandi and bounded on the west by the Flateyjardalur valley and Flateyjardalsheiði.

Topography

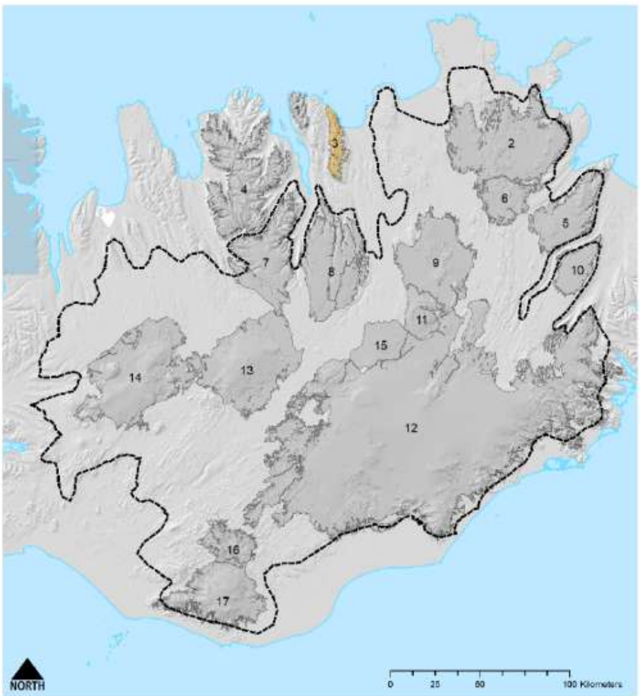
Topographically the area is formed of high mountains with steep slopes down to sea or valley. Geomorphology is formed of ancient lava beds, deeply dissected by past glaciation. Several small cirque and valley glaciers are found in the area, of which Grímlandsjökull glacier is the largest one.

Landscape assessment

The landscape is rugged, rough and largely unvegetated on the upper slopes where the peaks hold the snow with any vegetation restricted to lower altitudes. The views are largely enclosed with high degrees of topographic shielding except on the summits and ridges and the east-facing slopes along Skjálfandi where there are expansive views across the bay and over to Tjörnes peninsula and across the Skjálfandafljót and Laxá river valleys.

Land use

There are the remains of old farms along the edge of Skjálfandi bay. There is probably littlelivestock grazing in the area apart from perhaps the lowest-lying valleys closest to Flateyjardalur and Kaldakinn valley. The area is relatively accessible by road from the town of Akureyri. Mobile phone coverage is largely good with some areas of no reception in the deeper valleys.



A1.4 Tröllaskagi

General setting and description

This area sits outside of the Central Highlands area of interest, but it does come out in the mapping process and so is included here for completeness. This is a large area of wild coastal mountains forming the Tröllaskagi peninsula bounded by Eyjafjörður in the east and Skagafjörður in the west, and that stretches inland toward the Central Highlands bounded to the south by Öxnadalur.

Topography

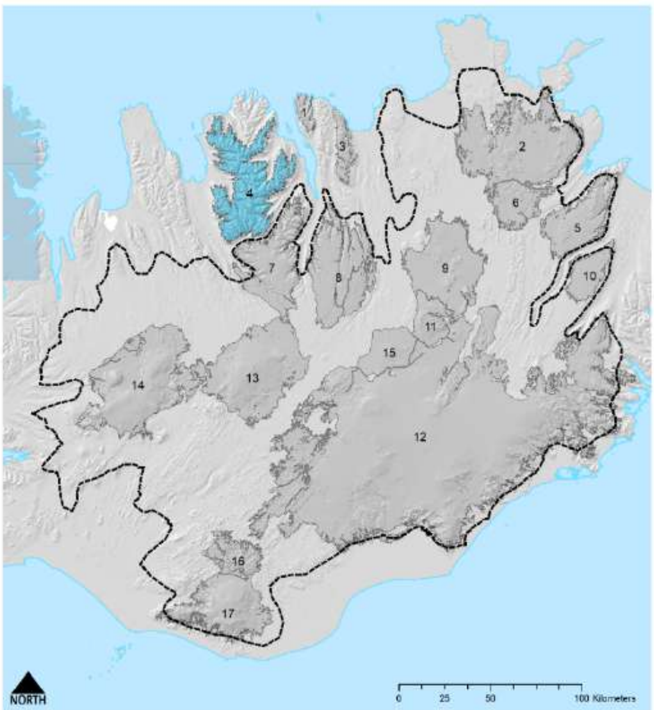
Topographically the area is formed of high mountains with steep slopes down to sea or valley. Geomorphology is formed of ancient lava beds, deeply dissected by past glaciation. The Tröllaskagi area is known for its numerous cirque and mountain glaciers of which this part includes more than 80 named glaciers. the area is penetrated from east and west by several large, uninhabited valleys.

Landscape assessment

The landscape is rugged, rough and largely unvegetated on the upper slopes where the peaks hold the snow and ice with any vegetation restricted to lower altitudes. The views are largely enclosed with high degrees of topographic shielding except on the summits and ridges and down/up valley views.

Land use

There are the remains of old farms along some of the larger though now uninhabited valleys. There is some livestock grazing in the area associated with the larger inhabited valleys. The area is relatively accessible by road from the town of Akureyri. Mobile phone coverage is largely absent with many areas of no reception in the deeper valleys. What reception there is, is limited to outer facing slopes and high peaks and ridges.



A1.5 Smjörfjöll

General setting and description

Smjörfjöll is a relatively large area located in the northeast corner of the Central Highlands. In the northeast of the area is a range of flat-topped mountains (Max 1255m) with scattered lakes and steep sides. This is bounded to the southwest by a wide low, plateau of undulating hills, plains and valleys interspersed with rivers and small lakes and the broad flat-topped Sandfell.

Topography

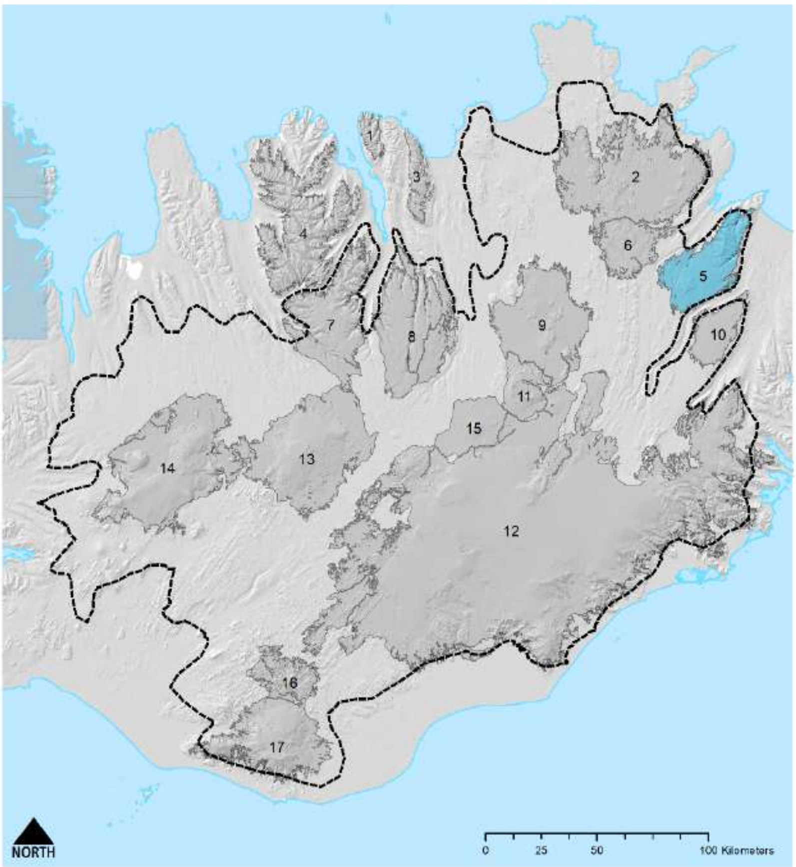
The topography is largely very open with a few areas of enclosed topography associated with incised mountain valleys. There are few rugged areas on the northeast of the Smjörfjöll mountains and Böðvarsdalur. There's a small number of cirque glaciers in the highest passes.

Landscape assessment

The landscape is dominated by high, flat-topped mountains of the Smjörfjöll and its curtilage of flatter and lower plateau plains to the south. The area is densely pattern by small lakes occupying hollows in the glacially smoothed terrain.

Land use

There is some livestock grazing but the highest part of the Smjörfjöll area has little vegetation. Mobile phone coverage is very good but with some areas of no signal in the deeper valleys. The area is very remote from most of Iceland's larger centres of population.



A1.6 Dimmifjallgarður

General setting and description

Dimmifjallgarður is effectively a southern extension to the larger Heljardalsfjöll mountains area located in the northeast corner of the Central Highlands but is separated from this by a road corridor. In the northeast of the area is the southern end of the Heljardalsfjöll mountains and this is bounded to the south by high moors and Highway 1.

Topography

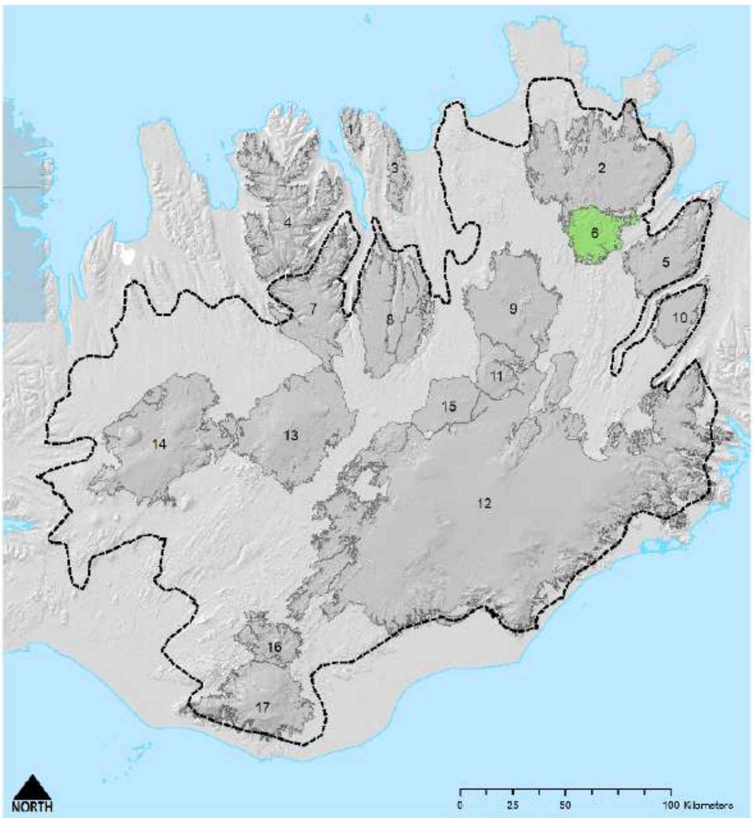
The topography is largely very open with a few minor areas of enclosed topography associated with incised mountain valleys. There are few rugged areas on the southern peaks of the Heljardalsfjöll mountains.

Landscape assessment

The landscape is dominated by mountains of Heljardalsfjöll mountains overlooking the lower moors and rolling plains to the south. The area is intersected by dry valleys.

Land use

There is some livestock grazing but much of the land has little vegetation. Mobile phone coverage is good but with some areas of no signal in the deeper valleys. The area is remote from most of Iceland's larger centres of population.



A1.7 Nýjabæjarfjall

General setting and description

Nýjabæjarfjall is a continuation of the Tröllaskagi area located south of Highway 1 and Öxnadalsheiði/Norðurárdalur and reaches south down towards the Hofsjökull glacier.

Topography

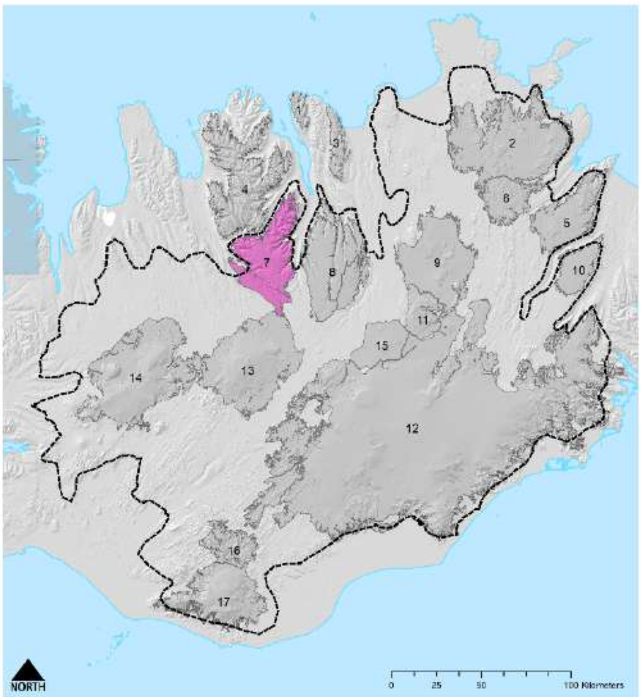
The topography of Nýjabæjarfjall is dominated by flat-topped mountains with incised mountain valleys and the high gravel plains of Hofsafrétt and Nýjabæjarafrétt to the south. Austari-Jökulsá river cuts through from the northwest of Skagafjörður south towards Hofsjökull.

Landscape assessment

The landscape is dominated by mountains of Seldalsfjall and Nýjabæjarfjall in the north and the wide open Hofsafrétt and Nýjabæjarafrétt in the south. These two distinct areas are demarked by the upper reaches of the Austurdalur and Vesturdalur. The area offers wide open views.

Land use

There is some livestock grazing but most of the land generally has little vegetation. Mobile phone coverage is generally good but with some areas of no signal in the deeper valleys. The area is fairly remote but accessible from Highway 1.



A1.8 Bleiksmýrardalur

General setting and description

Bleiksmýrardalur is an area of high plateau located south of Akurayri and Highway 1. It may be regarded as a northerly extension of the Sprengisandur.

Topography

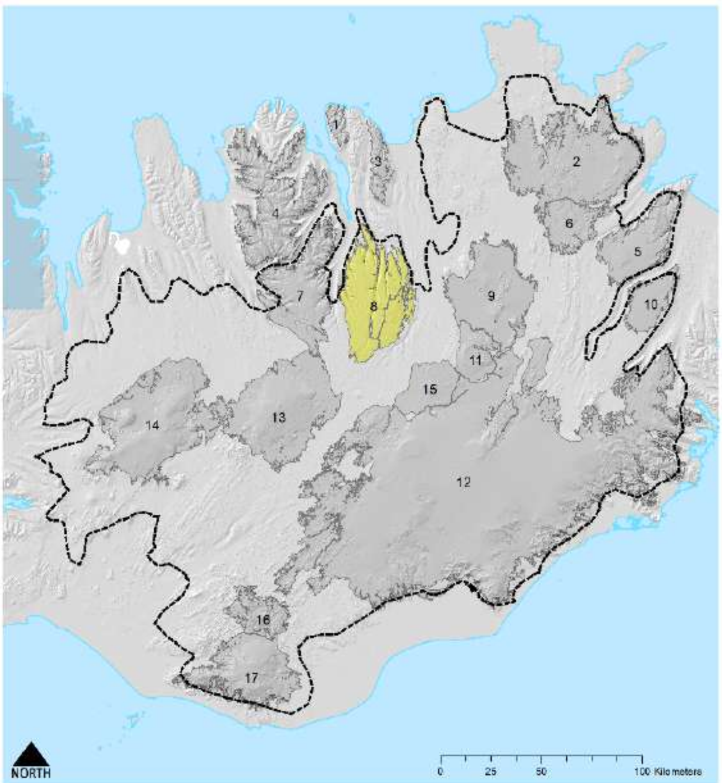
The topography of Bleiksmýrardalur is dominated by flat-topped mountains with deeply incised north-south mountain valleys and the high gravel plains of Nýjabæjarafrétt to the south. The plateau is divided east from west by the long Bleiksmýrardalur.

Landscape assessment

The landscape is dominated by wide open plateau mountains of Bleiksmýrardalur, the valley itself and the Nýjabæjarafrétt in the south. The area offers wide open views of the central highland glaciers to the south.

Land use

There is some livestock grazing in the valleys but most of the land generally has little vegetation on the plateau. Mobile phone coverage is generally absent on the plateau and in the deeper valleys. The area is remote but accessible in the north from Highway 1.



A1.9 Ódáðahraun

General setting and description

Ódáðahraun is an area of young volcanic mountains and lava flows north of the Vatnajökull and immediately south of Highway 1. The area is bounded on the east by the Jökulsá á Fjöllum river and on the west by Heilagsdalur Valley, the Kraká and Suðurá rivers. The area, along with areas 11 and 15, is separated from the Vatnajökulssvæðið only by road gravel road corridors.

Topography

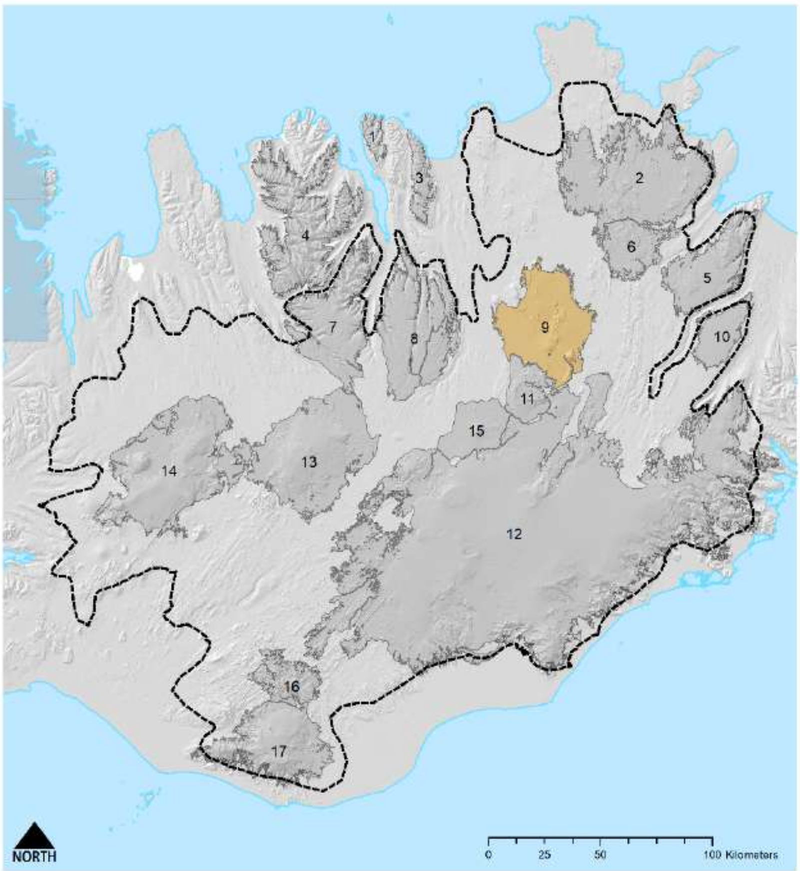
The topography of Ódáðahraun is dominated by flat, rugged lava fields, volcanic craters and other volcanic landforms. Significant volcanoes include Kollóttadyngja, Kerlingardyngja and Ketildynga.

Landscape assessment

The landscape is open with long view distances depending on local terrain. Because of the permeable basalt lavas there are few rivers and no significant lakes of any size. Along the margins of the lavas there are large springs with crystal clear water.

Land use

The area is mostly protected from grazing (see Fig. 4.12) and most of the land generally has very little vegetation on the lava flows. Mobile phone coverage is generally good. The area is remote but accessible in the north from Highway 1.



A1.10 Fljótsdalsheiði

General setting and description

Fljótsdalsheiði is a modest area with high moors consisting of rounded hills and plateau located in the east of the Central Highlands. This is bounded to the southeast by the Lagarfljót and in the northwest by Jökuldalur.

Topography

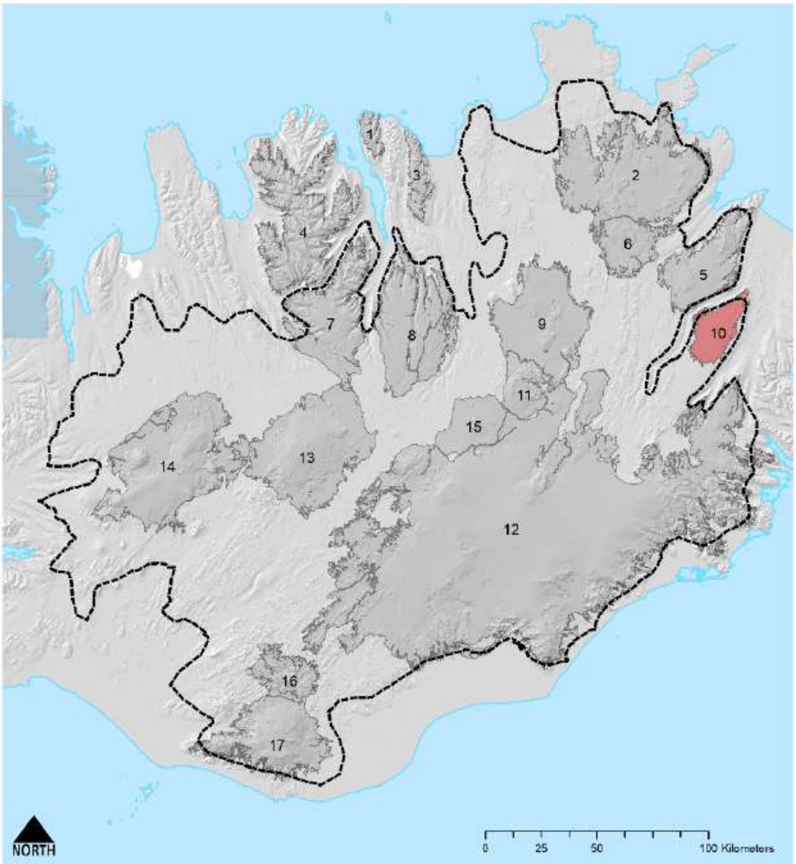
The topography is very open with hardly any areas of enclosed topography.

Landscape assessment

The landscape is dominated by high moors. The area is characterised by small, rounded hillocks and undulating terrain containing many small lakes and ponds.

Land use

There is livestock grazing and reindeer hunting in the area. Vegetation is dominated by moorland plants. Mobile phone coverage is excellent throughout. The area is very remote from most of Iceland's larger centres of population.



A1.11 Askja

General setting and description

Askja is the iconic laked-filled volcanic caldera at the heart of the Central Highlands immediately north of the Vantajökull. Beyond the caldera it is an area of young lava flows that surround the caldera's flanks and Dyngjufjöll mountains. The area, along with areas 9 and 15, is separated from the Vatnajökulssvæðið only by gravel road corridors.

Topography

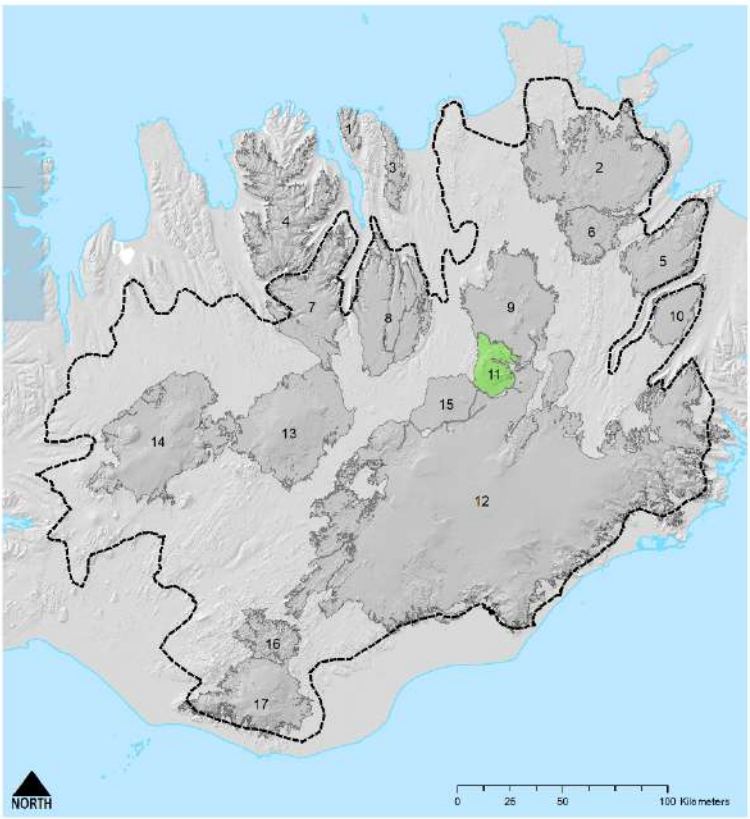
The topography of Askja is dominated by the caldera mountains, it's lake and geothermal activity.

Landscape assessment

The landscape is open with long view distances but heavily dependent on location relative to the caldera.

Land use

There is no livestock grazing and most of the land generally has no vegetation on the lava flows. The main land use is recreation, and the caldera is a popular tourist destination. Mobile phone coverage is generally good except inside the rim of the caledera where signal is absent. The area is remote but accessible from gravel roads.



A1.12 Vatnajökulssvæðið

General setting and description

The Vatnajökull and its surrounding landscape is perhaps the most iconic of all Icelandic wilderness landscapes. The area is large and is the largest ice cap in Iceland.

Topography

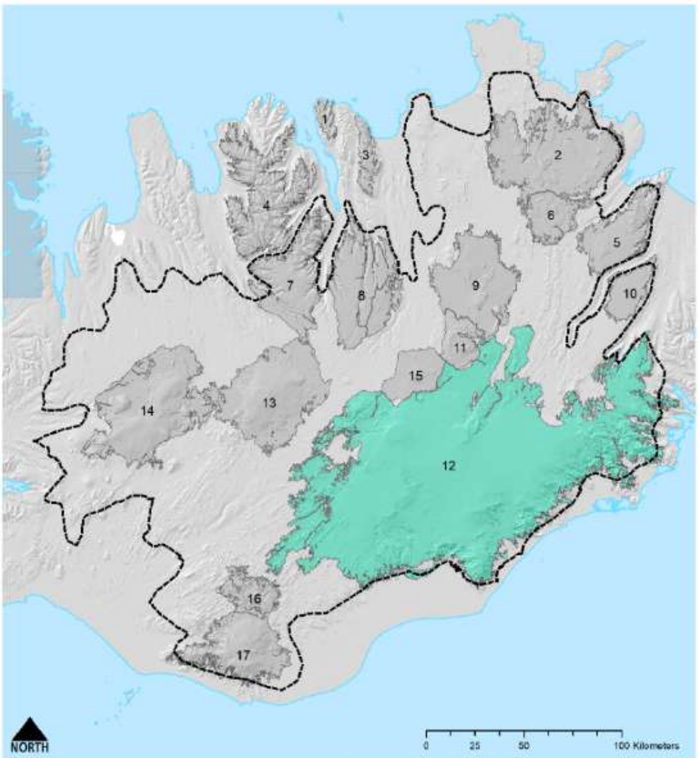
The topography of Vatnajökulssvæðið is dominated by the vast ice cap, sub-glacial volcanoes (Grímsvötn, Bárðarbunga, Tungnafellsjökull, Kverkfjöll and Öræfajökull), glaciers flow from around its edges and rugged mountain ridges. The Vatnajökulssvæðið also includes an area of coastal mountains and uninhabited valleys in the east.

Landscape assessment

The landscape is varied with large expansive open areas on the ice cap and to the north, and complex, enclosed and rugged areas around the edges of the glacier to the south and east. Here, the ice flows have carved deep valleys with further open areas across the expansive lakes and rivers along its southern coastal margin.

Land use

Most of the landscape is snow and ice covered and there is no livestock grazing to the west and north of the glacier but sheep graze in the southeast valleys where there is also reindeer hunting. . The main land use is recreation and tourism. Mobile phone coverage is generally poor with many areas without signal. Much of the area is extremely remote.



A1.13 Hofsjökull og Þjórsárver

General setting and description

Hofsjökull og Þjórsárver combines a large area of ice cap and an internationally significant protected wetland area that is important for breeding birds including pink footed geese.

Topography

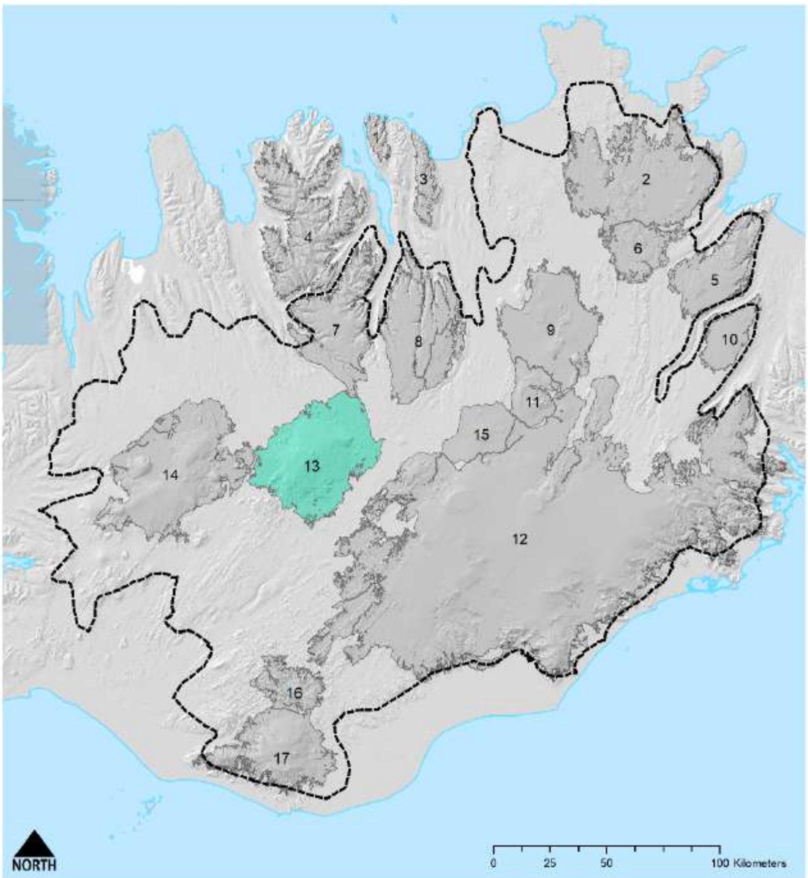
Hofsjökull og Þjórsárver comprises the large ice cap (Hofsjökull) in the north and the curtain of wetland to the south bounded by the Þjórsá river.

Landscape assessment

The landscape is varied with large expansive open areas on the ice cap and with few enclosed and rugged areas around the edges with further open areas across the expansive wetland areas and gravel plains.

Land use

There is some livestock grazing inthe northern margins of the area. Mobile phone coverage is excellent with very few minor areas of no signal. Much of the area is very remote.



A1.14 Langjökull

General setting and description

Langjökull is a large area of one main ice cap and three smaller ice caps together with hills, lava flows, rivers and lakes. It is one of the most accessible part of the Central Highlands wilderness areas.

Topography

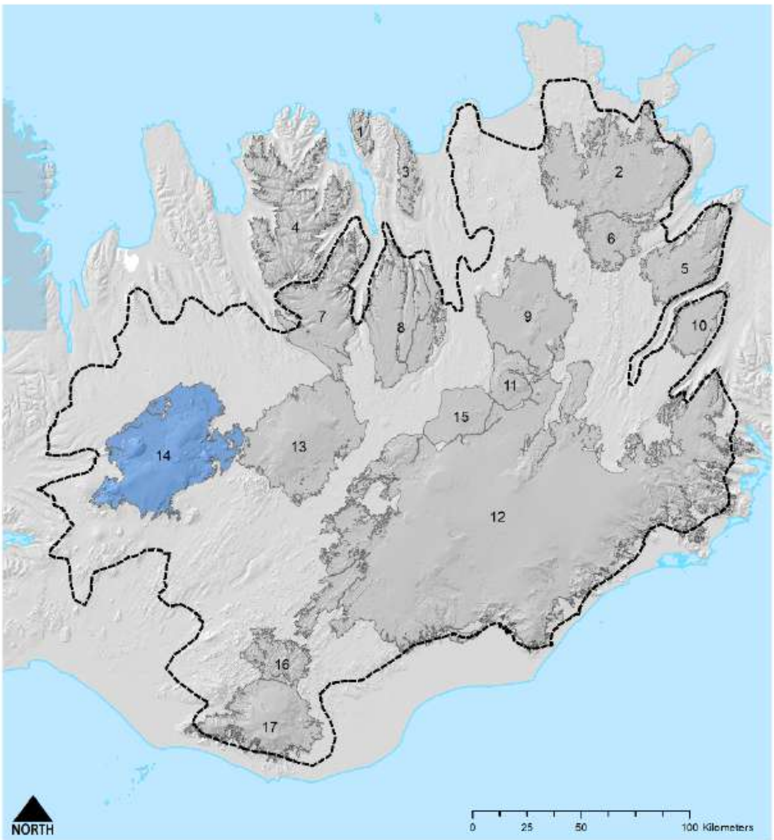
Langjökull comprises the large ice cap and its three smaller outlying ice caps of Eiríksjökull, Þórisjökull and Hrútfellsjökull (also called Regnbúðajökull).

Landscape assessment

The landscape is varied with large expansive open areas on the ice cap and with enclosed and rugged areas around the edges with further open areas across the surrounding lave fields and gravel plains.

Land use

There are livestock grazing areas on the ice-free lands around the ice cap, especially to the north. There are semi-permanent ice roads across the ice cap used for glacier tours. Mobile phone coverage is good with just a few minor areas of no signal in and around hills and valleys. The area is the least remote of all the Central Highland wilderness areas, being as it is, relatively close to Reykjavik.



A1.15 Trölladyngja

General setting and description

Trölladyngja is a modest wilderness area adjacent to and immediately north of the Vatnajökull centred roughly around the Trölladyngja volcano. The area, along with areas 11 and 9, is separated from the Vatnajökulssvæðið only by gravel road corridors.

Topography

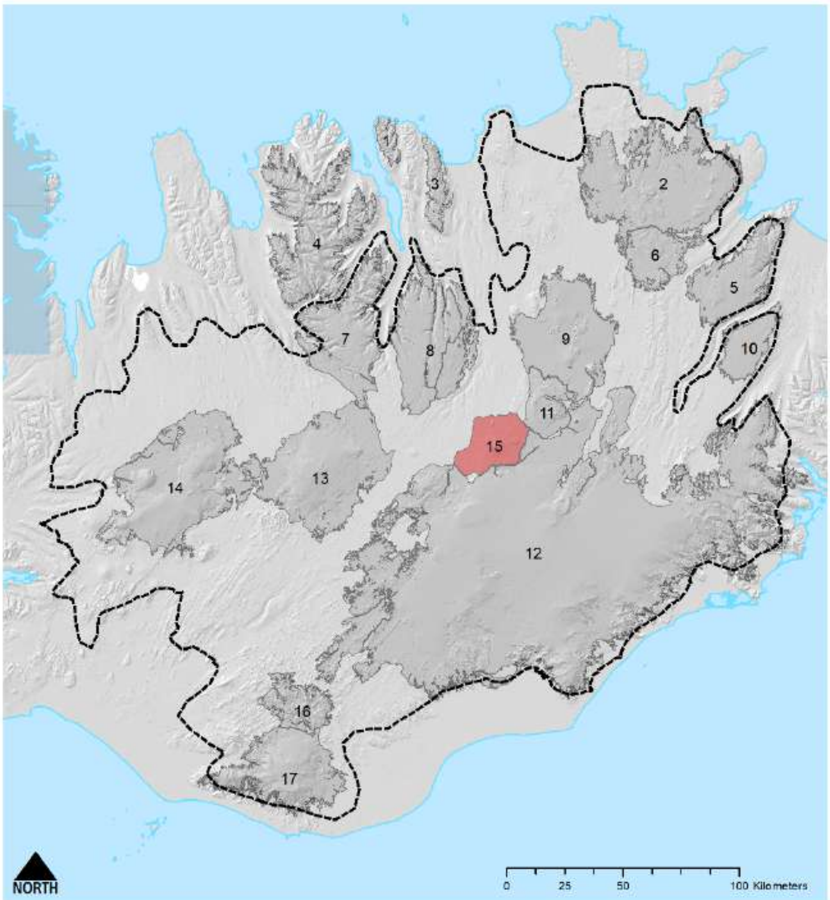
Trölladyngja comprises the volcano, one of the largest shield volcanoes of Iceland, and surrounding lava flows.

Landscape assessment

While the surface is rugged lava flows the landscape is open and relatively flat.

Land use

There is no livestock grazing in the area and very limited vegetation on the lava flows. Mobile phone coverage is mixed and depends on location. The area is very remote and accessible only by long drive along rough gravel roads.



A1.16 Fjallabak

General setting and description

Fjallabak is a modest sized wilderness area adjacent to and immediately north of the Mýrdalsjökull and Eyjafjallajökull ice caps.

Topography

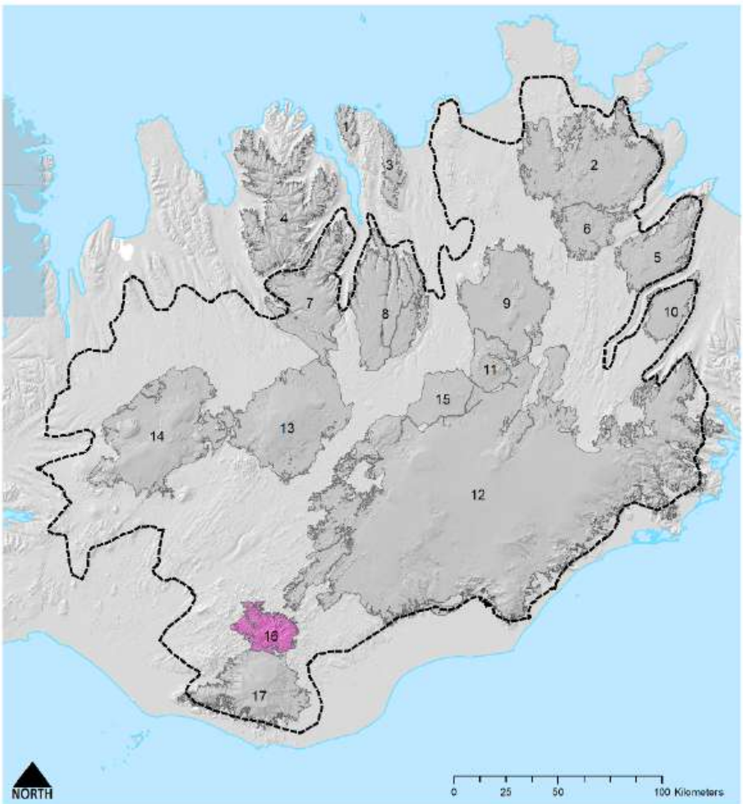
The area consists of a range of colourful eroded hills of a large central volcano, interspersed with rivers, lakes, and hot springs. The area contains two small ice caps/glaciers, Kaldaklofsjökull and Torfajökull.

Landscape assessment

The landscape is rugged giving rise to few open views and enclosed feel. Open views are limited to hill tops and summits and glaciers. The colourful geology and geothermal activity adds interest.

Land use

There is little livestock grazing in the area and very limited vegetation on the eroded hills and lava flows. Mobile phone coverage is mixed and depends on location with no signal in many of the deeper valleys. The area is relatively accessible from Reykjavik with the colourful rocks and hot springs making it a popular tourist destination for hiking and sight-seeing.



A1.17 Mýrdalsjökull og Eyjafjallajökull (Suðurjöklar)

General setting and description

Mýrdalsjökull og Eyjafjallajökull are two ice caps which together form a large wilderness area in the most southerly part of the Central Highlands.Together with Tindfjallajökull they are sometimes coined "Suðurjöklar" (South Glaciers). The area of Þórsmörk is north and west of the area where the Markafljót flows west from the glaciers.

Topography

The area consists of two ice caps, the large Mýrdalsjökull to the east and the smaller Eyjafjallajökull to the west, both of which sit above active volcanos. The area around the ice caps is deeply dissected hills, ridges and valleys. Large glacially fed rivers, Markaflót and Krossá flow west

Landscape assessment

The landscape is dominated the ice caps, the views from which are open and expansive. This contrasts with the deep valleys which are enclosed and rugged.

Land use

There is some livestock grazing in the valleys where vegetation is present. Mobile phone coverage is extensive but there may be areas with no signal in some of the deeper valleys. The area is relatively accessible from Reykjavik with easy access from Highway 1 along the south coast.