Wilderness Mapping in Iceland

Overview and comparative analysis of methods

Report for the Icelandic Ministry of the Environment, Energy and Climate

October 2024

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Preface

Wilderness was legally defined in Iceland in 1999. Twenty-five years later, several attempts were made to map out its extent over the country, resulting in very different maps depending on the underlying assumptions and interpretation of the law. This report provides an inventory and comparative analysis of the different methodologies used for wilderness mapping in Iceland. This was conducted at the request of the Icelandic Ministry of the Environment, Energy and Climate as a part of preparatory work on a regulation to further specify criteria for mapping *uninhabited wilderness* in Iceland, as stipulated in Article 73 of the Icelandic Nature Conservation Act 60/2013. The aim of the project is to provide an overview of the wilderness mapping methodologies that have been used, present the differences and similarities among them, and investigate the underlying assumptions and criteria used for wilderness mapping in Iceland. Furthermore, another aim of the project is to provide policymakers with a set of recommendations regarding the criteria that could be better defined to reduce the interpretative bias and increase consistency in terms of wilderness mapping in Iceland.

This was done through reviewing of wilderness mapping materials and publications produced at a regional to country-wide level in Iceland, discussing of findings during expert interviews and performing overlays and analysis of the different mapping outputs. This work relies on the author's own legal interpretation of the terminology and definitions of the Nature Conservation Act 60/2013 related to wilderness. While efforts are made to ensure that the information shared is accurate, comments, suggestions, or corrections of errors are always welcome and will be incorporated in further use of this comparative analysis. This report is for informational and advisory purposes only, based on the author's own conclusions which do not necessarily reflect the opinion of related institutions.

The author would like to thank the Icelandic Ministry of the Environment, Energy and Climate for the opportunity and trust to conduct this project and Steinar Kaldal, specialist and team leader of nature and heritage conservation; Herdís Helga Schopka, specialist; and Hafsteinn S. Hafsteinnsson, lawyer; for the cooperation. Likewise, the author would like to thank the specialists involved in the mapping projects reviewed for an excellent cooperation, openness, and very informative discussions, as well as for providing access to wilderness mapping geodata: David Christopher Ostman, Hans Hjálmar Hansen, Ingibjörg Marta Bjarnadóttir, Jón Örvar Geirsson Jónsson, Rannveig Ólafsdóttir, Ólafur Arnar Jónsson, Steve Carver and Þorvarður Árnason. This also includes the institutions, organizations and individuals involved in wilderness mapping who provided access to geodata used within the scope of this project: the Environment Agency of Iceland, Hornafjörður Research Centre, the Icelandic Institute of Natural History, the Icelandic National Planning Agency, the National Land Survey of Iceland, Micael Runnström, ÓFEIG Náttúruvernd, the University of Iceland and the Wildland Research Institute. The report also benefited from discussions with researchers affiliated to the Geography and Tourism Unit of the Institute of Life and Environmental Sciences of the University of Iceland. The author would therefore like thank them or their precious time and expertise which provided valuable guidance during the project: Ásdís Hlökk Theodórsdóttir, Edda Ruth Hlín Waage and Edita Tverijonaite.

Introduction

The Icelandic wilderness was first mapped in 1998, as a part of preliminary work for the Icelandic Act on Nature Conservation 44/1999 to legally define it under the term *untouched wilderness* (*i. ósnortið víðerni*). An official map of wilderness in Iceland was last prepared in 2009 but is now considered obsolete due to legal changes in the Icelandic Act on Nature Conservation 60/2013 under the term *uninhabited wilderness* (*i. óbyggt víðerni*) as well as in more recent amendments. However, some wilderness mapping work has been carried out by various stakeholders, either to provide an updated map of the Icelandic wilderness or to introduce alternative methods. These mapping initiatives highlight that the current definition of *uninhabited wilderness* in the nature conservation law offers various interpretations, resulting in differences in coverage and extent of *uninhabited wilderness*, depending on the underlying criteria and assumptions. Increased consistency in wilderness mapping can be expected from the application of Article 73 of the Icelandic Act on Nature Conservation 60/2013, which authorizes the minister to issue a regulation on the mapping of *uninhabited wilderness* to stipulate, among other things, the criteria and assumptions that form the basis of the mapping.

This report was prepared for the Icelandic Ministry of the Environment, Energy and Climate (IMEEC), and aims to provide an overview and comparison of the wilderness mapping methods that have been used in Iceland. This analysis will be used by policymakers to support decision-making regarding the mapping of *uninhabited wilderness* and the criteria and prerequisite that shall form its basis. Throughout this report, the basic requirement that mapping of *uninhabited wilderness* according to Article 73 of the Nature Conservation Act 60/2013 will be processed with digital geographic information systems. It was therefore emphasized that these criteria and prerequisites should be as clear and unambiguous as possible to facilitate their implementation in a digital mapping environment.

The first part of the report introduces key legal definitions linked to wilderness in Iceland, providing terminological insights on the translation of key terms and the limits inherent to their use. Further interpretation of the legal terms is given, and the main criteria are subsequently identified. The second part provides an overview of the materials falling under the scope of the project and the methods used for the comparative analysis. An inventory of these wilderness mapping methods is presented in part three, highlighting their key characteristics and introducing the two main types of wilderness mapping methods, being either based on the use of distance buffers or using topography-dependent indicators such as visibility analysis. The results of the comparative analysis are then presented in the fourth part where selected outputs are reviewed and cross-examined to highlight the similarities and divergences induced by the legal interpretation and other methodological choices, including on the wilderness extent and coverage. Inputs from case studies and public opinion research are further presented in the fifth section of the report, providing more insights into more perceptual components of wilderness mapping. The last part focuses on further discussion of the main findings and provides a set of recommendations on the potential criteria that could be better defined or considered to reduce the interpretative bias and increase consistency when mapping *uninhabited wilderness* in Iceland.

1. Wilderness in the Icelandic legislation

Wilderness is a key concept and legal object in the Icelandic nature conservation law. While discussions on the idea of wilderness are beyond the scope of this report, related references and debates have been documented from an Icelandic perspective by Sæþórsdóttir et al. (2011). This section focuses on the legal definitions of wilderness in Iceland since 1999 and their interpretation.

1.1 - Definition in the Nature Conservation Act 44/1999

Wilderness was first introduced in the Icelandic legislation in the Nature Conservation Act 44/1999 under the term *ósnortið víðerni*, which is sometimes translated as *untouched-*, *unspoiled-*, *pristine-*, or *virgin wilderness*. However, *víðerni* does not have a clear counterpart in English, as pointed out by Árnason (2020), and was translated by Þórhallsdóttir (2002, p. 97) as *land of distant views*, while other authors used *immensity* and *vastness*. As a legal term, *untouched wilderness* is defined as follows:

An area of land at least 25 km² in size, or in which it is possible to enjoy solitude and nature without disturbance from man-made structures or the traffic of motorized vehicles on the ground, which is at least 5 km away from man-made structures or other evidence of technology, such as power lines, power stations, reservoirs and main roads, where no direct indications of human activity are visible and nature can develop without anthropogenic pressures.[1]

1.2 - Definition in the Nature Conservation Act 60/2013

In the Nature Conservation Act 60/2013, *ósnortið víðerni* was replaced by *óbyggt víðerni* in Article 5.19, translated as *uninhabited wilderness* by Jóhannsdóttir (2016). However, the term *uninhabited* only partially covers the meaning of *óbyggt*. For instance, *óbyggðir* is defined in Article 5.18 as *land area where people do not have a permanent residence and where anthropogenic structures are absent or inconspicuous* (author's own translation). In land-use plans, *uninhabited areas* (*i. óbyggð svæði*) is *where no residence or economic activities are expected, such as highlands, moors and pastures, mostly without structures other than those serving outdoor recreation, pasture use, security and telecommunications* (author's own translation of Art. 6.2.s. - Icelandic Regulations, 2016). As a legal term, *uninhabited wilderness* is defined as follows:

An area of uninhabited land that is usually at least 25 km² in size or so that one can enjoy solitude and nature without disturbance from anthropogenic structures or the traffic of motorized vehicles and usually at least 5 km away from anthropogenic structures and other evidence of technology, such as power lines, power stations, reservoirs and upbuilt roads.[2]

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[1] Source: Jóhannsdóttir (2016, p. 366). Original Icelandic wording: *Landsvæði sem er a.m.k. 25 km² að stærð eða þannig að hægt sé að njóta þar einveru og náttúrunnar án truflunar af mannvirkjum eða umferð vélknúinna farartækja á jörðu, er í a.m.k. 5 km fjarlægð frá mannvirkjum og öðrum tæknilegum ummerkjum, svo sem raflínum, orkuverum, miðlunarlónum og þjóðvegum, og þar sem ekki gætir beinna ummerkja mannsins og náttúran fær að þróast án álags af mannlegum umsvifum.*

[2] Modified from Jóhannsdóttir (2016, p. 367). Original Icelandic wording, with changes from 1999 indicated: ~~*Lands*~~*[S]væði [í óbyggðum] sem er [að jafnaði] a.m.k. 25 km² að stærð eða þannig að hægt sé að njóta þar einveru og náttúrunnar án truflunar af mannvirkjum eða umferð vélknúinna farartækja* ~~*á jörðu*~~*, [og að jafnaði]*~~*er*~~ *í a.m.k. 5 km fjarlægð frá mannvirkjum og öðrum tæknilegum ummerkjum, svo sem raflínum, orkuverum, miðlunarlónum og [uppbyggðum]* ~~*þjóð*~~*vegum*~~*, og þar sem ekki gætir beinna ummerkja mannsins og náttúran fær að þróast án álags af mannlegum umsvifum*~~. The term *mannvirkjum* was translated as *anthropogenic structures* rather than *man-made structures*. Likewise, *upbuilt roads* was used for *uppbyggðum vegum* rather than *main roads*, questioned by Jauch (2020), suggesting *built-up roads*. Other used *built roads* (Carver et al., 2023), *upbuilt roads* (Bishop et al., 2022), or *constructed roads* (Ólafsdóttir & Sæþórsdóttir, 2020c).

1.3 - Other mentions in the Nature Conservation Act 60/2013

Aside from Article 5.19, the term *uninhabited wilderness* is used in Articles 3, 46, and 73. Article 3, outlining the *conservation goals for monuments, watersheds, landscapes, and wilderness*, states that the aim shall be to *safeguard the country's uninhabited wilderness* (author's own translations). Article 46 introduces a protected area category called *óbyggð víðerni*, with the following definition:

Large areas of land where there are little or no human imprints and where nature is allowed to develop without pressure from human activities can be protected as uninhabited wilderness.[3]

Along with this definition, Article 46 also states the protection aims:

Protection shall aim at preserving the characteristics of the area, e.g. to maintain diverse and unusual landscapes, panoramas and/or protect whole large ecosystems, and ensure that present and future generations can enjoy solitude and nature there without disturbance from anthropogenic structures or traffic of motorized vehicles.[4]

Last, Article 73 states that the minister is authorized to issue a regulation on the mapping of *uninhabited wilderness* and that the regulation must, among other things, stipulate the criteria and assumptions that form the basis of the mapping. It is also stated that a map with information on *uninhabited wilderness* should be available for information to the government when planning policies on landscape protection and other land use.

1.4 - Interpretation of wilderness as a legal concept

Since its first definition in the Icelandic legislation in 1999, wilderness as a legal object evolved to become more inclusive. The term itself was changed from *untouched wilderness* to *uninhabited wilderness* to be applicable to more areas, and more flexibility was introduced with the use of the term *usually* before the minimum size and distance criteria, to enable protection of more areas (IETPC, 2013; IMENR, 2020b). Another major change is that this definition was assigned to a protected area

[3] Author's own translation. Original Icelandic wording: *Friðlýsa má sem óbyggð víðerni stór landsvæði þar sem ummerkja mannsins gætir lítið sem ekkert og náttúran fær að þróast án álags af mannlegum umsvifum.* The term *ummerkja*, translated here as *imprints* based on Jauch (2020, p. 15), can also be translated as *influences* (Jóhannsdóttir, 2016, p. 370), or as *traces* (Waage, 2013, p. 61) or *traces of [human] interferences* (Ólafsdóttir & Sæþórsdóttir, 2020c). The term *lítið sem ekkert* was here translated as *little or no*, while alternative terms include *minimal* (Jóhannsdóttir, 2016, p. 370), *scarcely noticed* (Waage, 2013, p. 61), or *barely noticeable* (Ólafsdóttir & Sæþórsdóttir, 2020c). Jóhannsdóttir (2016, p. 370) also include the term *formally* when referring to protection, Carver et al. (2023) use the expression *legally designated as wilderness protected area*, and Ólafsdóttir and Sæþórsdóttir (2020c) use *[t]he declaration of protection*.

[4] Author's own translation. Original Icelandic wording: *Friðlýsingin skal miða að því að varðveita einkenni svæðisins, t.d. að viðhalda fjölbreyttu og óvenjulegu landslagi, víðsýni og/eða vernda heildstæð stór vistkerfi, og tryggja að núlifandi og komandi kynslóðir geti notið þar einveru og náttúrunnar án truflunar af mannvirkjum eða umferð vélknúinna farartækja.* The term *varðveita* was translated as *preserving*, but other translations include *safeguarding* (Jóhannsdóttir, 2016, p. 370). The term *einkenni svæðisins* was translated as *characteristics of the area* while alternative terms include the *character of the area* (Waage, 2013, p. 61). The term *víðsýni* was translated as *panoramas*. Alternatives include *wide views* (Waage, 2013, p. 61), or *openness* (Carver et al., 2023). The term *vernda heildstæð* was translated as *protect whole*, while *conserve complete* was also used (Jóhannsdóttir, 2016, p. 370) as well as *holistic* (Waage, 2013, p. 61). The term *af mannvirkjum* was translated as *from anthropogenic structures*, though *caused by human constructs* was also used (Waage, 2013, p. 61). Last, *vélknúinna* was translated as *motorized*, but other translations use the term *motor* (Jóhannsdóttir, 2016, p. 370; Waage, 2013, p. 61) or *mechanized* (Ólafsdóttir & Sæþórsdóttir, 2020c).

category in Article 46, comparable to the International Union for the Conservation of Nature (IUCN) category 1b (Icelandic Minister for the Environment and Natural Resources [IMENR], 2012). However, most of the definition was moved to Article 5.19, with additional requirements and protection goals remaining in Article 46 (Icelandic Environment and Transport Parliamentary Committee [IETPC], 2013). It seems clear that *uninhabited wilderness* refers to two distinct, yet closely related, planning concepts and management tools in the respective articles.

In this report, it is assumed that *uninhabited wilderness* as defined under Article 5.19 constitutes the basis for mapping as presented in Article 73.[5] Meeting the requirements of Article 5.19 being a prerequisite for protection under Article 46,[6] such a map would lay groundwork for protected area establishment. Yet, further requirements related to Article 46 would be needed to identify within *uninhabited wilderness* areas (i.e. per Article 5.19), those that can be considered for legal protection as such,[7] in line with the explanatory notes of Article 73 (IMENR, 2020a). However, mapping *uninhabited wilderness* fulfills a broader role than preparing potential legal designation under article 46, through its incorporation in land-use planning and landscape protection. Mapping should therefore not be limited to areas compatible with the requirements of Article 46. Based on the assumption that mapping of *uninhabited wilderness* should be primarily based on Article 5.19, the following interpretation of the components of the legal definition is suggested in Table 1.

Table 1: Suggested interpretation (and translation) of the components of the legal definition by the author

Component	Translation	Interpretation
Svæði í óbyggðum	*Area of uninhabited land*	Uninhabited requirement (Article 5.18 criteria): Area of land, without permanent settlements, where anthropogenic structures are absent or inconspicuous.
sem er að jafnaði a.m.k. 25 km² að stærð eða þannig	*that is usually at least 25 km² in size or so*	Flexible size requirement of 25 km² to emphasize that it mainly applies to large areas while also allowing smaller areas to qualify if the following conditions are met:
að hægt sé að njóta þar einveru og náttúrunnar	*that one can enjoy solitude and nature*	Recreational opportunity requirement for: Being alone or with few by choice Strong presence natural features and processes
án truflunar af mannvirkjum eða umferð vélknúinna farartækja	*without disturbance from anthropogenic structures or the traffic of motorized vehicles*	Requirement of minimal negative interference from: Construction works made by humans (e.g. buildings, bridges, pylons, antennas, potentially including roads, dams or flood barriers) and the flow of engine-powered transportation means
og að jafnaði í a.m.k. 5 km fjarlægð frá	*and usually at least 5 km away from*	Flexible distance requirement of 5 km, allowing for exceptions
mannvirkjum	*anthropogenic structures*	Constructions, such as buildings, bridges, pylons, antennas, potentially roads and dams or flood barrier.
og öðrum tæknilegum ummerkjum svo sem	*and other evidence of technology such as*	Other noticeable imprints, traces, or signs of technology (i.e. machinery and equipment developed from the application of scientific knowledge), including:
raflínum	*power lines*	Cables used for the transmission of electrical power from a power station to a user
orkuverum	*power stations*	Station that generates electricity by converting the energy of

[5] Confirmed by specialists at the IMEEC (personal communication, June 7th, 2024): *kortlagning óbyggðra víðerna ætti að vera í samræmi við það hvernig óbyggð víðerni eru skilgreind og sú skilgreining kemur fram í 19. tölul. 5. gr.*

[6] Confirmed by specialists at the IMEEC (personal communication, June 7th, 2024): *Ef friðlýsa á svæði samkvæmt þeim friðlýsingarflokki þá þurfa viðkomandi svæði samt sem áður að uppfylla skilgreiningu 19. tölul. 5. gr. laganna.*

[7] Confirmed by specialists at the IMEEC (personal communication, June 7th, 2024): *[…] Þannig getur kortlagningin horft til 46. gr. laganna hvað varðar möguleg svæði sem hægt væri að friðlýsa sem óbyggð víðerni en svæðin þurfa alltaf að uppfylla skilgreiningu 19. tölul. 5. gr.*

		water, steam, coal, oil or gas.
miðlunarlónum	*reservoirs*	Large natural or artificial lake used to collect water for transmission to a power plant.
og uppbyggðum vegum	*and upbuilt roads*	Roads that are built from several layers.[8]

Overall, *untouched wilderness* relies on three main criteria: uninhabited settings (land area without permanent settlements, where structures are absent or inconspicuous), usually large size (usually over 25 km²), and usually away (usually by more than 5 km) from structures and other evidence of technology (including but not limited to power lines, power stations, reservoirs, and upbuilt roads). Smaller areas are accepted if solitude and nature can be enjoyed without disturbances from structures and traffic of motorized vehicles.

Defining a protected *uninhabited wilderness* area according to Article 46 would however require additional criteria, such as those stated in the article: *Large areas of land where there are little or no human imprints and where nature is allowed to develop without pressure from human activities can be protected as uninhabited wilderness*. These remind of the characteristics that IUCN 1b areas should generally fulfill (Dudley, 2008, pp. 14-15), although the IUCN criteria put a stronger emphasis on biological objectives (Table 2). The high degree of intactness mentioned by the IUCN seems stricter than the mention in Article 46 that nature is allowed to develop without pressure.

Table 2: Comparison of Article 46 definition elements and the corresponding descriptive characteristics of IUCN 1b areas

Article 46	Corresponding IUCN 1b descriptive characteristic
Large areas of land	*Be of sufficient size to protect biodiversity; to maintain ecological processes and ecosystem services; to maintain ecological refugia; to buffer against the impacts of climate change; and to maintain evolutionary processes.*
Where there are little or no human imprints	*Be free of modern infrastructure, development and industrial extractive activity, e.g. roads, power lines, cellphone towers, other permanent structures, hydropower development, intensive livestock grazing, low-flying aircraft etc., preferably with highly restricted or no motorized access.*
Where nature is allowed to develop	*Be characterized by a high degree of intactness: containing a large percentage of the original extent of the ecosystem, complete or near-complete native faunal and floral assemblages, retaining intact predator-prey systems, and including large mammals.*
Without pressure from human activities	*Be free of inappropriate or excessive human use or presence which will decrease wilderness values and ultimately prevent an area from meeting the biological and cultural criteria listed above.*

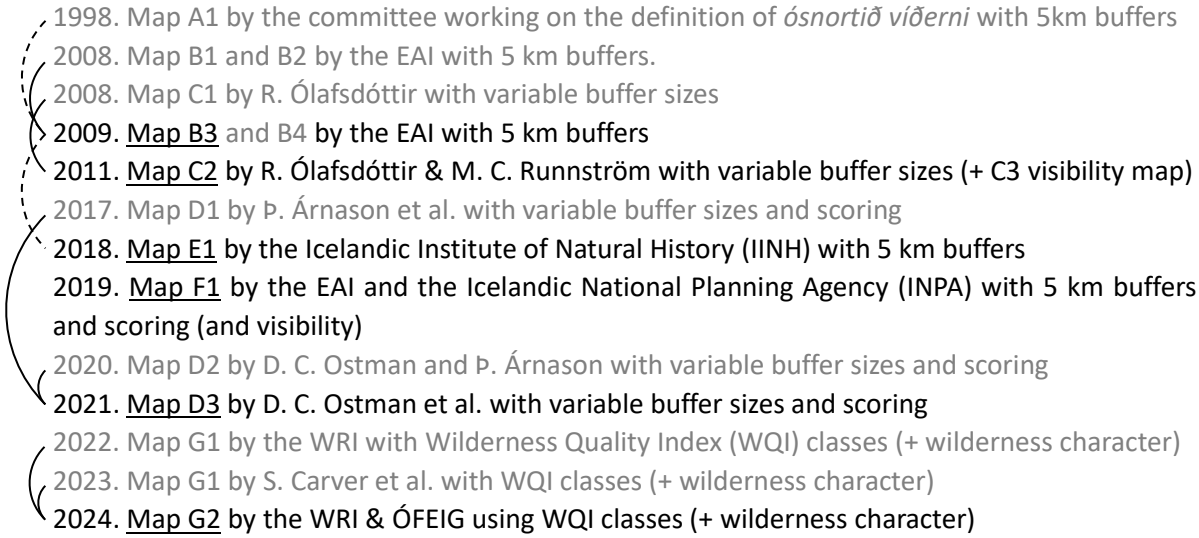
The opportunities for solitude, which are stated among the protection goals rather than with the strict requirements of Article 46, are also among the key characteristics of IUCN 1b areas: *[o]ffer outstanding opportunities for solitude, enjoyed once the area has been reached, by simple, quiet and non-intrusive means of travel (i.e., non-motorized or highly regulated motorized access where strictly necessary and consistent with the biological objectives listed above)*. The IUCN management of motorized access seems primarily focused on biological goals, while Article 46 seems more generic: *[to] ensure that present and future generations can enjoy solitude and nature there without disturbance from anthropogenic structures or traffic of motorized vehicles*. Despite more flexibility in Article 46 than the IUCN 1b characteristics, it remains much stricter than Article 5.19, which has become more inclusive over time (e.g. use of *uninhabited* instead of *untouched*, and of *usually* for the size and distance thresholds), to be applicable to more areas.

[8] Definition of *uppbyggður (vegur)* by the Modern Icelandic Dictionary. Original wording: *byggður upp af mörgum lögum*. Retrieved June 20th, 2024, from: https://islenskordabok.arnastofnun.is/ord/62294. See section 6.2 for further discussion on the definition of this term.

2. Materials and methods

2.1 - Wilderness maps in Iceland

A selection of regional to country-wide maps of *untouched/uninhabited wilderness* produced in Iceland was listed for comparative analysis. Other mapping approaches or versions of existing maps were later identified and incorporated into the study to provide a more comprehensive inventory of the methods used for wilderness mapping in Iceland. Publications and other materials produced by the same specialist teams usually focused on a similar mapping methodology adjusted over time and are therefore considered as a single method in the analysis, while referring to former versions as needed. This is particularly true for early maps made by the EAI, work by researchers from the Hornafjörður Research Center of the University of Iceland (Árnason et al., 2017; Ostman & Árnason, 2020; Ostman et al., 2021), as well as for work led by Rannveig Ólafsdóttir at the University of Iceland (Ólafsdóttir, 2008; Ólafsdóttir & Runnström, 2011b), and work led by Steve Carver at the Wildland Research Institute (WRI) at the University of Leeds (Carver et al., 2023; WRI, 2022; WRI & ÓFEIG, 2024). Due to a lack of information or limited data access, some mapping outputs could not be as thoroughly investigated as others. The inventory of regional to country-wide wilderness maps produced in Iceland is listed below and linked by team (the dashed link indicates a very similar method). To simplify references to each map, a code was assigned to each map, composed of a letter related to the mapping team and a number for the version of the map. The most relevant and updated versions included in the comparative approach were underlined.



A review of these methods was carried out with a focus on the criteria and assumptions inherent to each approach and key points were extracted. Complementary information was obtained from the experts involved in these projects to discuss the findings from the reviewing phase. The emphasis was placed on understanding the methodological choices and discussing the issues or challenges encountered throughout the mapping process. This was done through 11 online meetings and phone calls lasting between 30 min and 2 hours, using a semi-structured approach to provide space for an open discussion. Insights from the expert interviews further completed the review of each method. Geodata was analyzed using ArcGis Pro 3.2.0 to calculate surface areas and overlay the boundaries from each approach. As most maps use buffer-based methods, comparisons could easily be performed. Data from Carver et al. (2023) and the WRI (2022; WRI & ÓFEIG, 2024) however consisted of high-resolution Wilderness Quality Index (WQI) values classified in five categories. Some of the WQI classes were extracted and overlaid with other maps for comparisons. The data was also used to visualize the distribution of WQI classes within and beyond wilderness areas according to other methods.

2.2 - Case studies and perception studies

Additional publications were also included to expand the discussion section of the report, using case studies related to practical use of wilderness mapping, as well as perception studies to better address the more subjective components of the legal definition.

The case-studies included are not intended to provide an exhaustive summary of the range of management implications of wilderness mapping in Iceland, but rather to expand on wilderness impact assessment and measurements using different methods. The selected case studies were as follows:

2019. Report by WRI: *Hvalá Power Plant Proposal - Review of Impacts on Wilderness*
2020. Report by D. C. Ostman and Þ. Árnason: *Landscape impact of wind farms - development of a methodology for analysis and assessment*
2021. Report by WRI: *Vonarskarð 4x4 Hypothetical Access Route - Review of Impacts on Wilderness*
2024. Report by A. D. Sæþórsdóttir et al.: *Impact of Skrokkaldavirkjun on the landscape, wilderness and protected areas*

The perception studies included relate to travel experiences and public perceptions of wilderness and provide valuable insights regarding the type of disturbance induced by different structures and other features. This is particularly relevant in relation to some of the criteria used for wilderness mapping. These include four reports and four research articles:

2016. Report by the Social Science Research Institute of the University of Iceland (SSRIUI): *"This Is an Indescribable Connection, This Feeling of Being Alone with Nature" - Qualitative Study of the Experience of the Wilderness and Attitudes towards Demarcation and Management among Different Outdoor Recreational Groups in the Central Highland*
2016. Report by R. Ólafsdóttir et al.: *Attitudes and experiences of Icelanders in the wilderness, uninhabited areas and Central Highland of Iceland*
2017. Report by A. D. Sæþórsdóttir et al.: *Impact of Blönduvirkjun on the experience of visitors*
2017. Research article by Þ. Stefánsson et al.: *When tourists meet transmission lines: The effects of electric transmission lines on tourism in Iceland*
2018. Research article by A. D. Sæþórsdóttir and C. M. Hall: *Floating Away: The Impact of Hydroelectric Power Stations on Tourists' Experience in Iceland*
2020. Report by the SSRIUI: *Infrastructure development in the wilderness of Iceland. Public assessment of the curtailment effects of structures*
2020. Research article by R. Ólafsdóttir and A. D. Sæþórsdóttir: *Public Perception of Wilderness in Iceland*
2022. Research article by A. D. Sæþórsdóttir et al.: *The practicality of purism scales when planning tourism in wilderness*

3. Inventory of wilderness mapping methods in Iceland

Wilderness mapping methods used in Iceland can be grouped into two main categories. The first and most common category is based on the use of distance thresholds, usually drawn by making buffers around incompatible features (e.g. structures, roads). The second main category uses more complex outputs integrating digital elevation models (topography) in multi-criteria indicators.

3.1 - Inventory of buffer-based mapping methods

3.1.1 - Early buffer-based mapping of untouched wilderness (1997-1998)

Mapping methods based on distance-buffers have been used in early work related to the preparation of the first legal definition of *untouched wilderness* (*i. ósnortið víðerni*) by a working group around 1997-1998 (Icelandic Parliament, 1997). The following criteria were used for Map A1 (Figure 1):

- Distance of 5 km from anthropogenic structures and other evidence of technology, such as:
  - Power lines
  - Power plants
  - Reservoirs
  - Main roads (*i. þjóðvegum*) cf. Road Act 1994/45 (Icelandic Parliament, 1994).
- Surface area of at least 25 km²

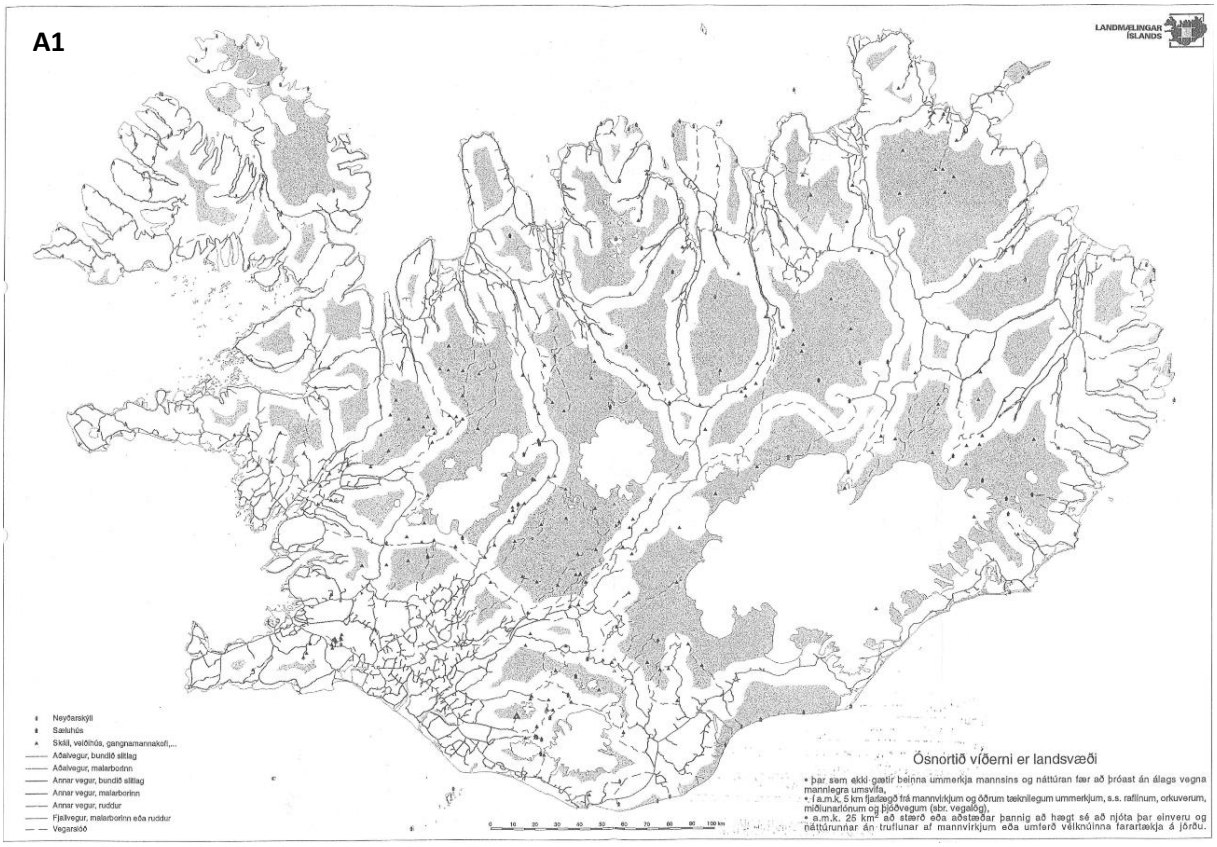


Figure 1: Map of untouched wilderness A1, by the committee working on the definition in 1998. Source: Árnason et al. (2017)

Some jeep tracks and buildings, such as mountain huts, can still be found in the *untouched wilderness*, while other buildings received a 5 km buffer. Anthropogenic structures (*i. mannvirki*) in the area should according to the committee be made in such a way that it is possible to remove them and erase their traces (Icelandic Ministry for the Environment [IME], 1998), therefore introducing an impermanency or reversibility criteria. Further information and interpretation about this early work and a version of this map can be found in Árnason et al. (2017, pp. 5-6).

3.1.2 - Official map of untouched wilderness (~2008, 2009)

Following a similar approach with a standard 5 km buffer size, the EAI prepared the country's first official map of *untouched wilderness*. Two editions of the map are referred to in a methodological note obtained from the EAI (Bjarnadóttir, personal communication, May 29th, 2024), and two earlier versions were found from other publications (Ólafsdóttir, 2008; Ólafsdóttir & Runnström, 2011a). Although the criteria and data used for the older maps (B1 & B2, see Figure 2 and Figure 3) are unclear, the two official editions (B3 & B4, see Figure 4 and Figure 5) were based on conclusions from the 1998 work group (IME, 1998), using data from the National Land Survey of Iceland (NLSI):

- Distance of 5 km from:
  - Buildings, except:
    - *Isolated houses* (*i. fristundahús*)
    - Ruins (1st edition only, i.e. B3)
  - Main roads (*i. þjóðvegur*) according to the road act
  - Power lines above ground
  - Artificial lakes (reservoirs)
- Surface area of at least 25 km²

Coverage extent (n.d., i.e. Map B1 & Map B2): unknown (no GIS data access).

Coverage extent (2009 1st edition, i.e. Map B3): 37.962 km², or about 37% of the country as a whole.

Coverage extent (2009 2nd edition, i.e. Map B4): 33.825 km², or about 33% of the country as a whole.

Note that all the maps produced by EAI also include in darker colors protected areas (as well as areas protected under special law for B3 and B4).

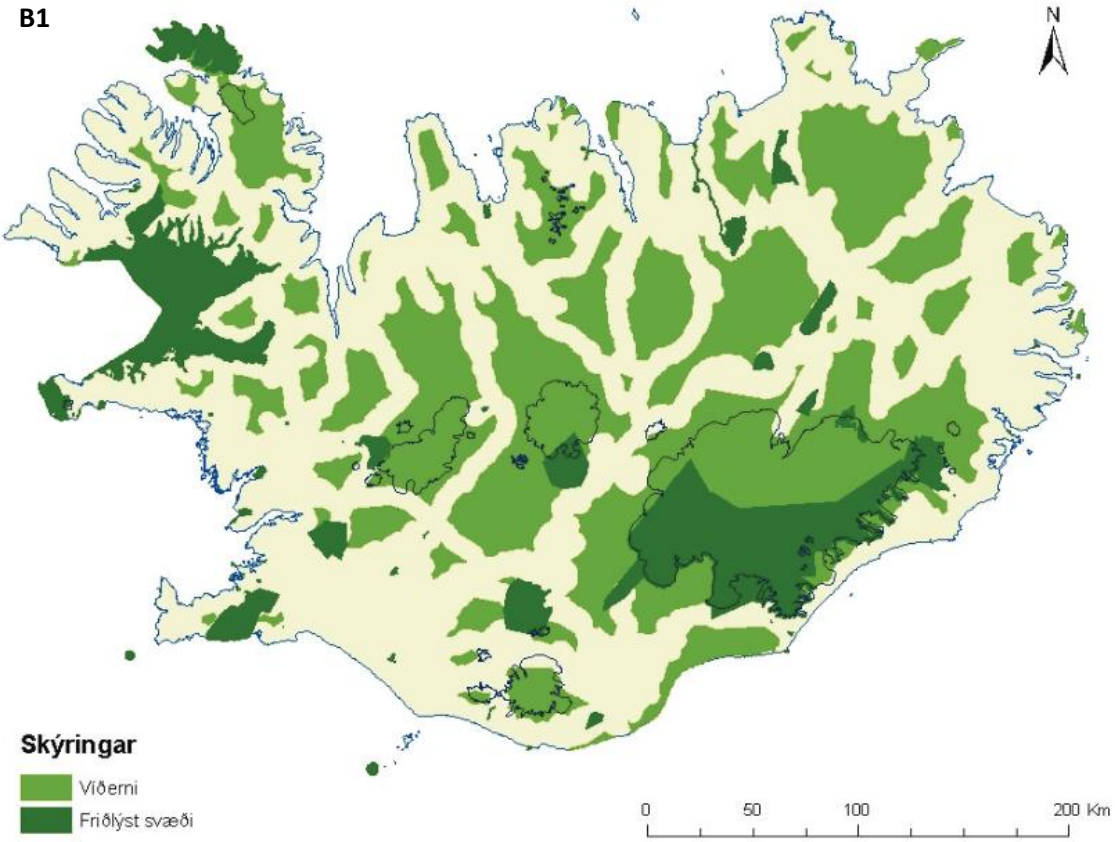


Figure 2: Map of untouched wilderness B1 - EAI, n.d. Source: Ólafsdóttir (2008)

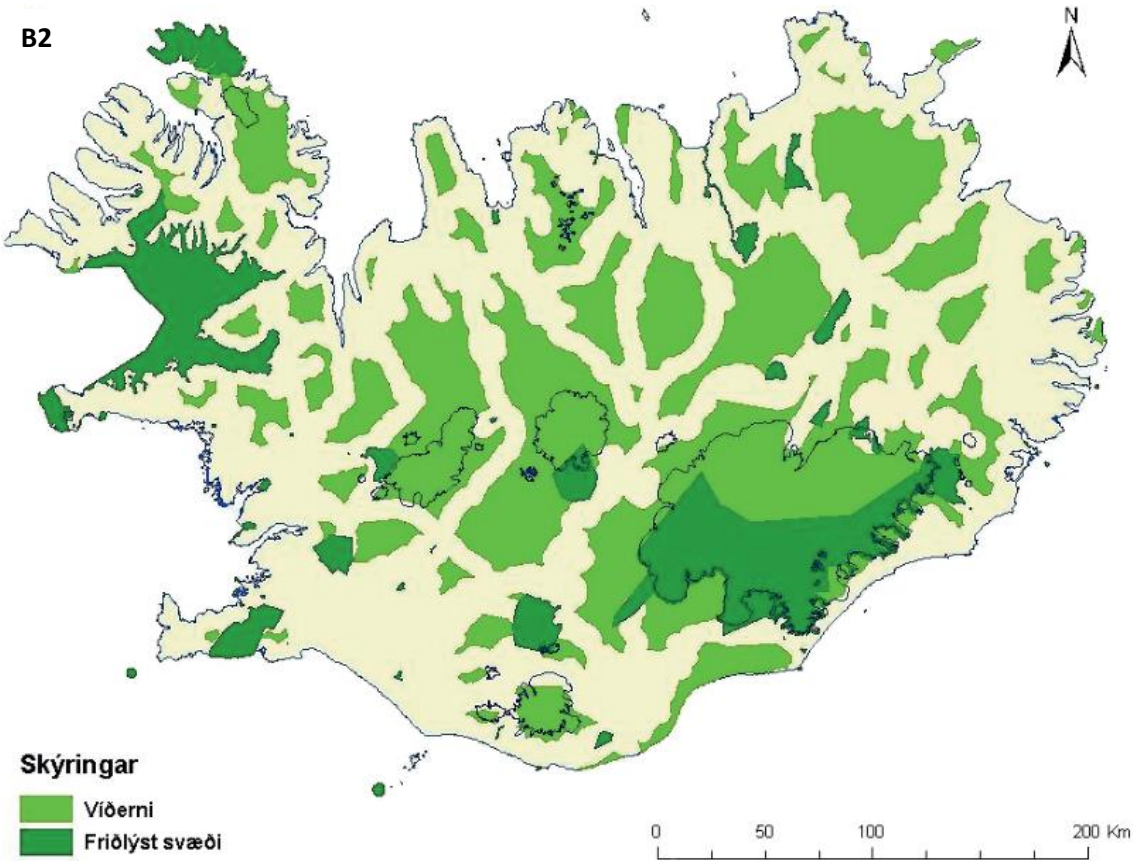


Figure 3: Map of the untouched wilderness B2 - EAI, n.d. Source: Ólafsdóttir and Runnström (2011a)

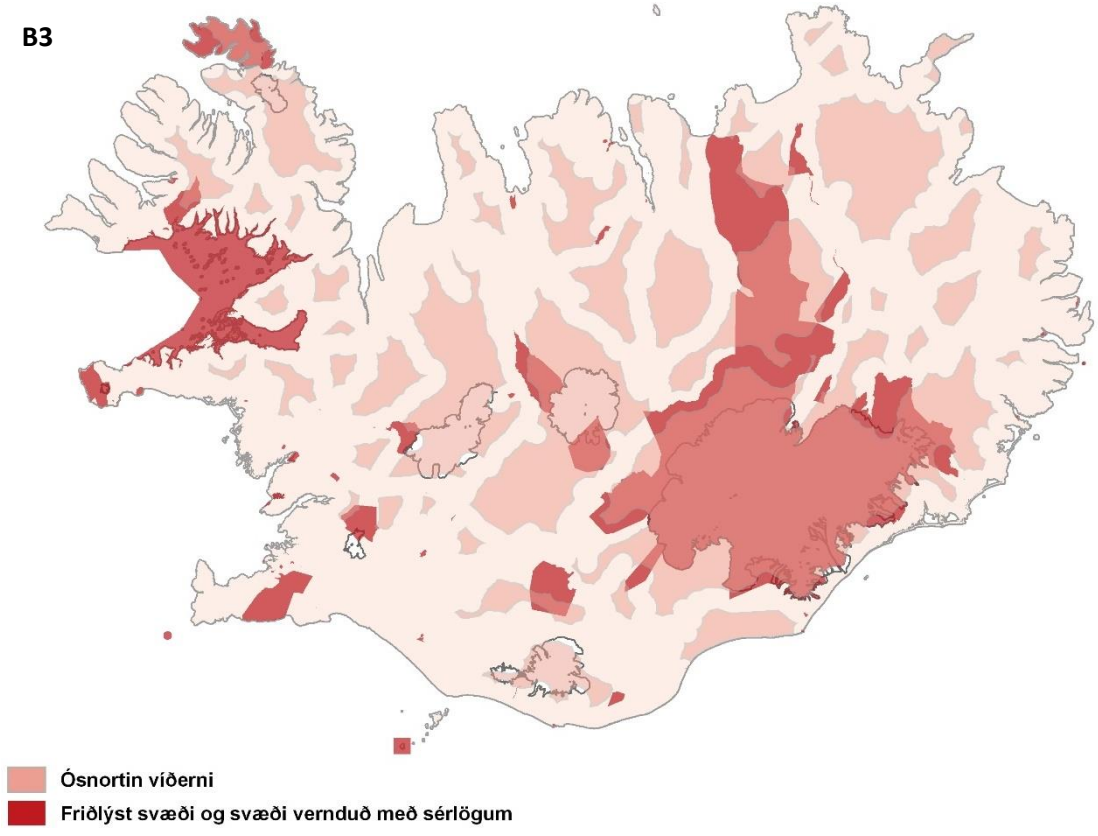


Figure 4: Map of untouched wilderness B3 - EAI, 2009. Source: Árnason et al. (2017)

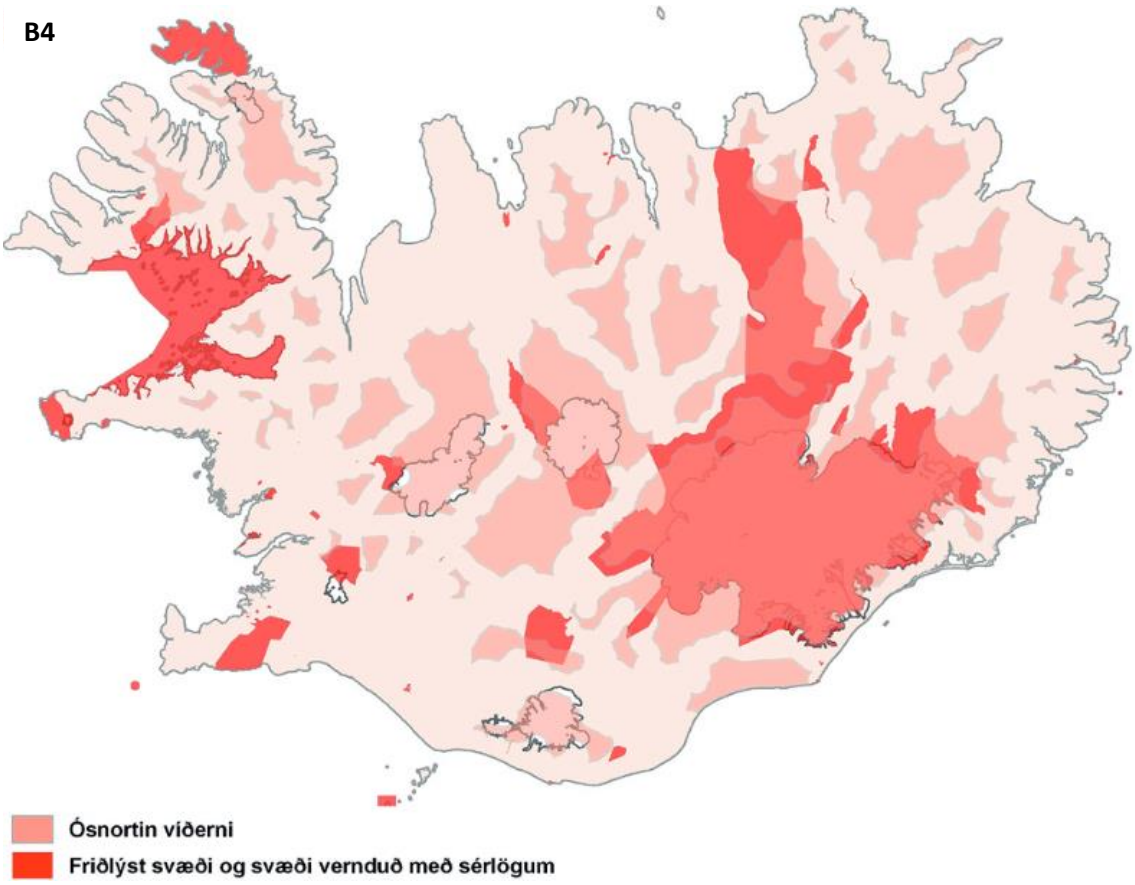


Figure 5: Map of untouched wilderness B4 - EAI, 2009. Source: Ólafsdóttir and Runnström (2011a)

These four versions are difficult to interpret due to the lack of information. The first map (B1) includes as wilderness the area around Hálslón reservoir, which was filled in 2006-2007, and might therefore be based on data older than the IS50V 2.1 database released in April 2008. This was most likely updated for the second map (B2). In the 2009 editions of the map (B3 & B4), the reservoirs of Hágöngulón and Kelduárlón area are not accounted for despite having a buffer in the earlier version (i.e. B1 & B2). Additional mountain roads also received a buffer, such as Hlöðuvallavegur, which reduced the extent of *untouched wilderness*. On the other hand, some other tracks or structures were also removed (e.g. Askja-Gæsavatnaleið area), resulting in wilderness "gains" in the latest versions, which might be related to changes of classification in the database. According to the documentation available for these two maps, most of the changes between the first (B3) and second (B4) official editions are related to whether buffers were computed around ruins (B4) or not (B3), for example in Hornstrandir or Lónsöræfi areas, which contributes to the larger extent of *untouched wilderness* in the first edition (B3) compared with the second (B4).

Among these four maps, the first version of the 2009 map (i.e. B3, Figure 4) will be considered as the official one since it is the one used by the INPA in the Icelandic National Planning Strategy (INPS) 2015-2026 (INPA, 2016). This version of the map is therefore used for the comparative analysis.

3.1.3 - Buffer-size variations based on classifications (2008, 2011)

Variations in buffer sizes were introduced by Ólafsdóttir (2008) to account for the differences of impact across features within a single category. Based on the criteria derived from wilderness literature, review on methodological research in wilderness mapping and best practices at that time,[9] the following buffer sizes were used to produce Map C1 (Figure 6):

- Distance from mechanized access:
  - 5 km from major roads (*i. stofnvegir*)
  - 3 km from connecting roads (*i. tengivegir*)
  - 2 km from county roads (*i. landsvegir*)
- Distance from permanent settlement:
  - 5 km from urban nuclei (*i. byggðakjarni*)
  - 5 km from industrial and service facilities (incl. hotels and guesthouses)
  - 3 km from farms and single houses
- Apparent naturalness:
  - 5 km from largest high-voltage power lines
  - 5 km from energy, telecommunication, and utility structures
  - 2 km from mountain huts (isolated houses)
  - 0,5 km from ruins

Coverage extent (Map C1): ~43.000 km², or ~42% of the country as a whole (no 25km² threshold)

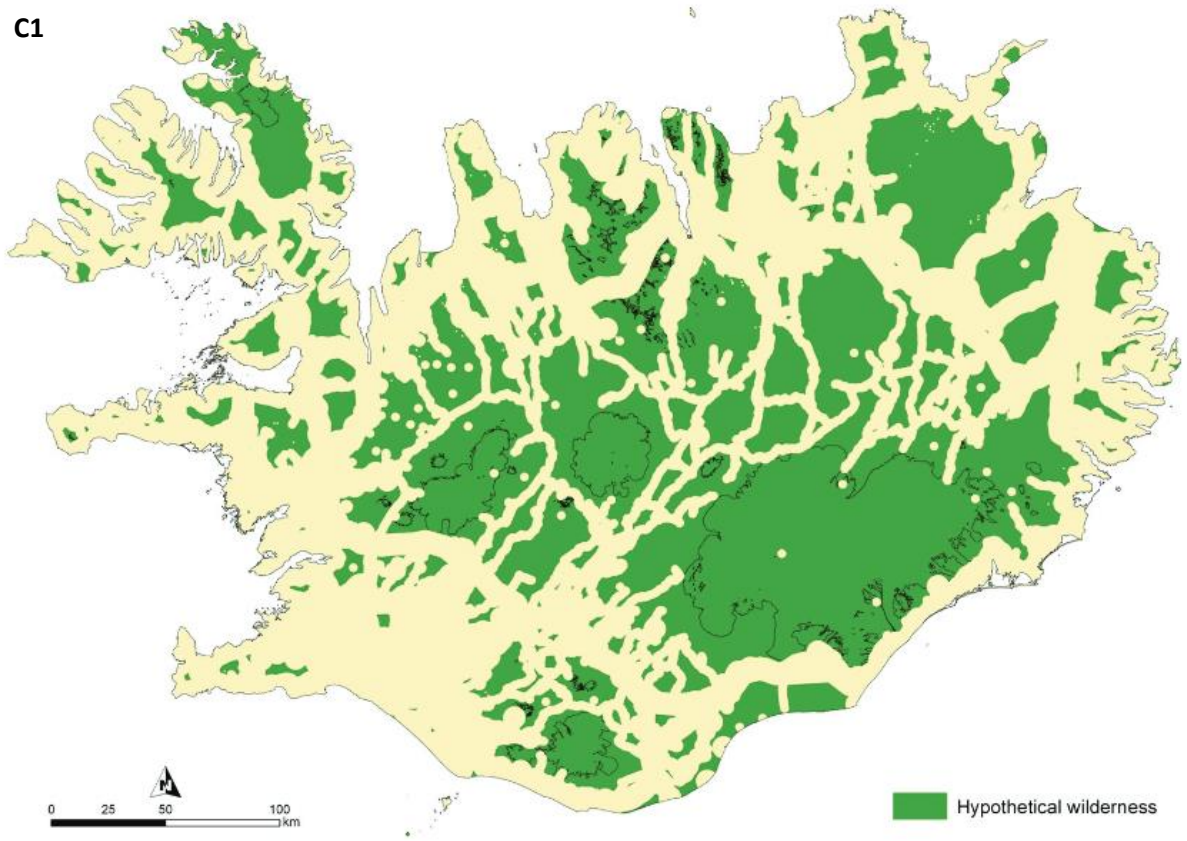


Figure 6: Map of untouched wilderness C1, using variable buffer sizes (2008). Source: Ólafsdóttir (2008)

[9] Emphasis added by R. Ólafsdóttir on the methodological difference and academic approach compared to earlier maps.

Few years later, Ólafsdóttir and Runnström (2011a, 2011b) made some adjustments to the features used and buffer sizes for each criterion, producing Map C2 (Figure 7):

- Remoteness from mechanized access:
  - 5 km from major roads
  - 5 km from collector/country roads
  - 3 km from highland roads
- Remoteness from permanent settlement
  - 25 km from urban nuclei with >100,000 inhabitants
  - 5 km from urban nuclei with <100,000 inhabitants
  - 5 km from industrial and service facilities
  - 5 km from farms and single houses
- Apparent naturalness
  - 5 km from power lines
  - 5 km from power and telecommunication constructions, water and drainage system facilities
  - 3 km from mountain huts

Coverage, without surface area threshold: 34.695 km², or about 34% of the country as a whole.

Coverage with a 25 km² surface area threshold (Map C2): 34.161 km², or about 33% of the country as a whole.

The reasoning to assign a 3 km buffer to highland roads was to account for lower traffic intensity, lower visibility from a distance, and for the absence of traffic signals and signs. However, reservoirs did not receive any buffer. It was concluded that buffer approaches are easily applicable but require extensive data and classification.

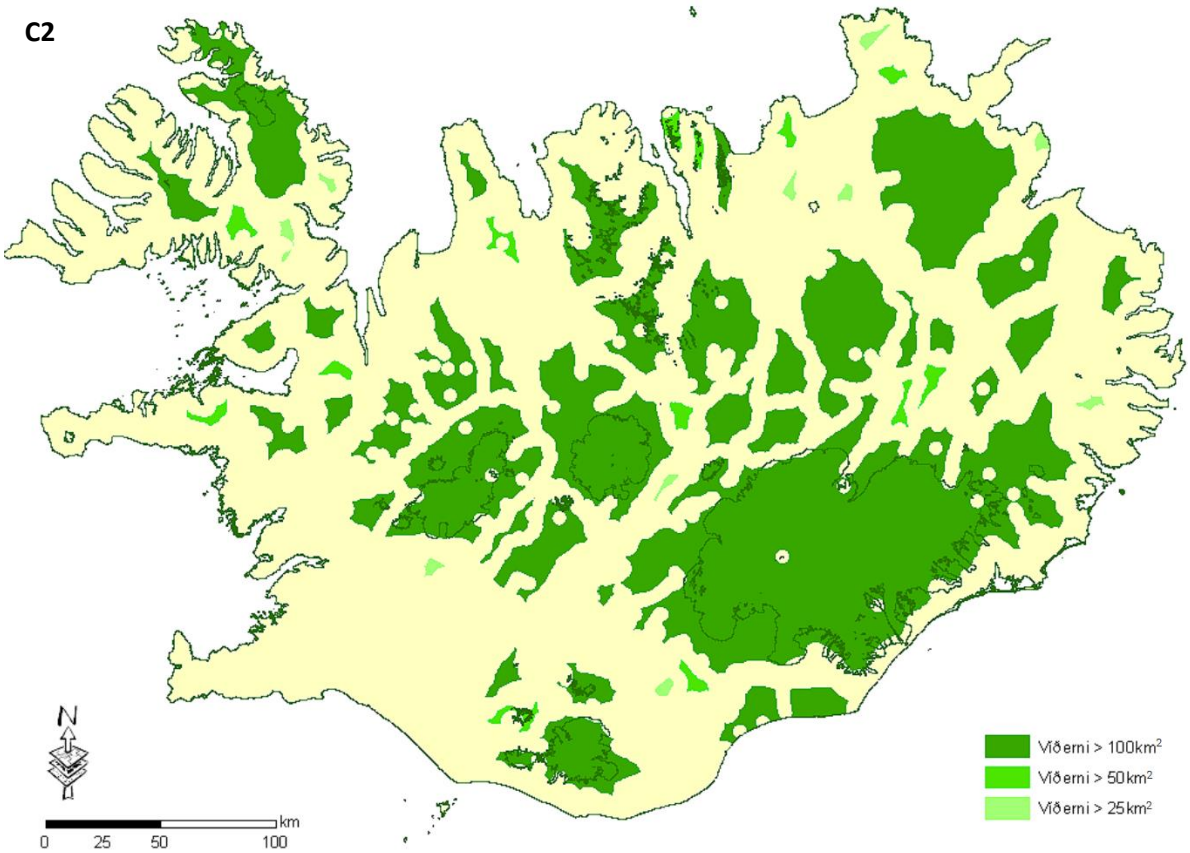


Figure 7: Map of untouched wilderness C2, using variable buffer sizes (2011). Source: Ólafsdóttir and Runnström (2011a)

3.1.4 - Incorporation of naturalness (2018)

An unofficial updated version of the 2009 map from the EAI (i.e. B3) was prepared by the IINH based on more recent geodata, using for the most part the same criteria, with the addition of naturalness of land-cover. The following criteria were used to produce Map E1 (Figure 8):

- Distance of 5 km from:
  - Structures except those classified in the category 1340 (e.g. emergency shelters, herding cabins, mountain huts, etc.)
  - Paved roads and other roads except public gravel roads and private gravel roads
  - Urban areas, power lines, and airports (*i. flugvellir*)
  - Reservoirs[10]
  - Cultivated lands, planted forests, and lupine fields
- Area threshold of 25 km²

An alternative, unpublished version of the map was also prepared with a 3 km buffer instead of 5 km around 132 kV power lines and unpaved roads, based on the method used by Árnason et al. (2017, see Map D1 - Figure 10), for comparison purposes (not included, but referred to as E2).

Coverage (Map E1): 34.433 km², or about 34% of the country as a whole.

Coverage (3 km buffers, Map E2): 38.615 km², or about 38% of the country as a whole - unpublished.

Figure 8: Unofficial map of uninhabited wilderness E1, by the IINH (2018)

[10] Confirmed by Hans H. Hansen (IINH) during the reviewing process.

3.1.5 - Buffer-allocation based on multi-criteria scoring system (2019)

A work group from the INPA and the EAI used two criteria based on the distinguishing features of IUCN 1b areas (see Table 2, p. 6). A 5 km buffer was calculated from structures considered inappropriate (*i. í ósamræmi*) or excessive (*i. óhófleg*). Modest structures designed to serve the wilderness experience can be in the wilderness, as opposed to the larger ones which are considered excessive. Those which do not serve the wilderness experience are considered inappropriate, e.g. those mentioned in Article 5.19 of the Nature Conservation Act 60/2013. The method was applied to the Central Highland using the following criteria to produce Map F1 (Figure 9):

- 5 km distance from inappropriate structures
  - Large scale structures, e.g.
    - Power lines
    - Substations
    - Power plants
    - Reservoirs
    - Significant utility structures
    - Large wind turbines
    - Upbuilt roads
    - Industry
    - Significant mines/quarries
  - Underground cables and tunnels may be consistent with wilderness if traces on the surface are insignificant
- 5 km distance from excessive structures
  - Structures related to tourism and outdoor recreation that are very extensive, attract significant attention or cause pressure on the environment (e.g. busy non-upbuilt roads, hotels or other large-scale tourism facilities, large-scale telecommunication facilities and year-round farms). Based on:
    - Built surface, using 100 m² per building if no data is available
    - Weight due to the use type (not used in the report due to lack of data):
      - Mountain hut = 1
      - Guesthouse or similar = 1,2
      - Shop, restaurant, gas station and other services = 1,3
      - Hotel or similar and farm operations buildings, e.g. housing = 1,5
    - Impact of roads/tracks and traffic:
      - Gravel roads and jeep tracks tolerated (no impact calculated)
      - Traffic (average number of cars per kilometer per hour), using:
        - Daily summer traffic (*i. sumardagsumferð*)
        - Average driving speed
        - A time period of 16 hours per day
        - 100 m road segments
    - Visibility, using surface from which buildings and traffic can be seen,[11] with a 2m offset for both feature types.

Assessing the overall impact of outdoor recreation and tourism-related buildings and mountain tracks was based on an impact score. A car driving on a 100 meters road section was considered to have an impact equivalent to a 100 m² house, each being considered a unit. If within a 3 km radius of the site, the sum is beyond 10 units, the excessiveness threshold is reached, corresponding to 1000 m² or 10

[11] Further information on the use of visibility analysis can be found in the dedicated section p. 23

cars or some combination, as was the case for Hrauneyjar and Hotel Háland. If not, visibility analysis is computed[12] and weighted by the score of each visible feature. A total is calculated and if it is beyond the excessiveness threshold, the site is considered as incompatible with wilderness. This was the case for Hólaskjól, Hrauneyjar, Hotel Háland, Kerlingarfjöll, Landmannalaugar, Möðrudalur, and Þórsmörk.

Coverage (Map F1): 33.316 km² in the Central Highland (84% of the studied area).

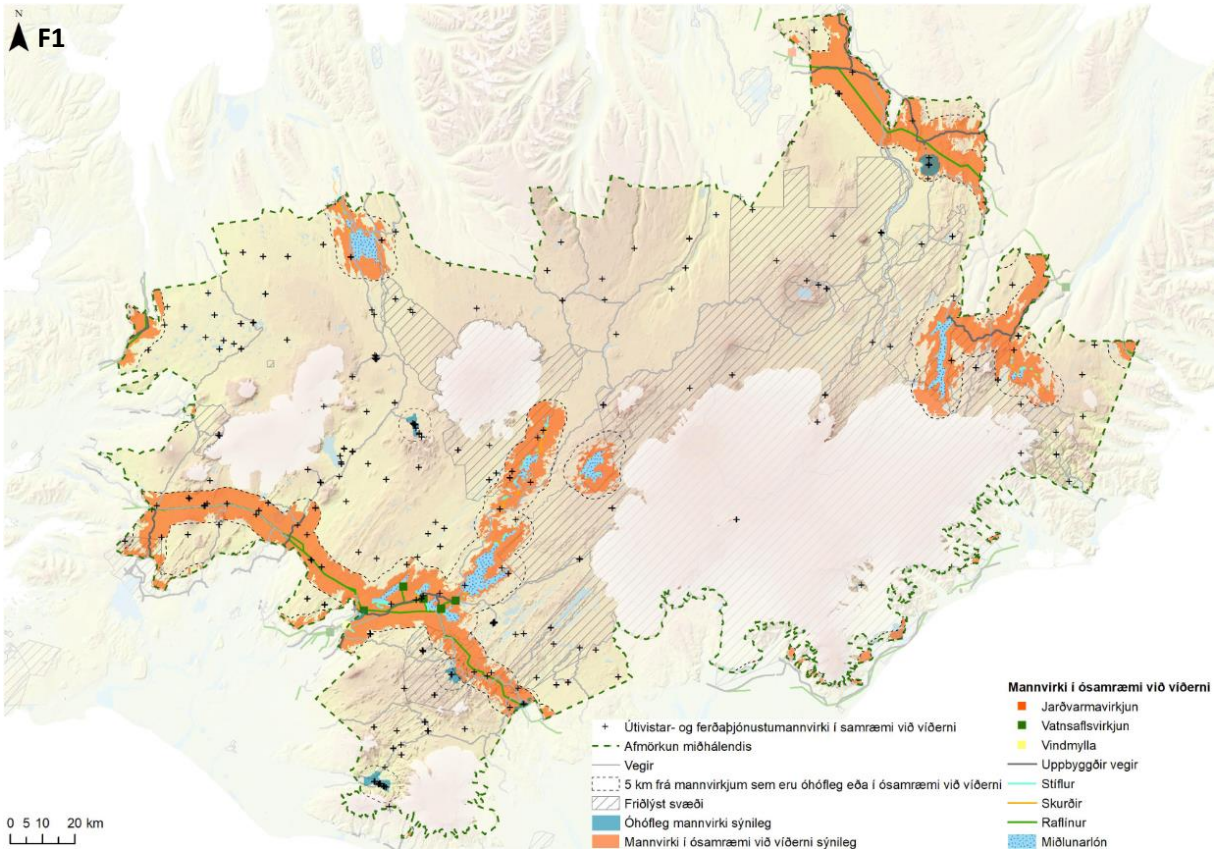


Figure 9: Map of uninhabited wilderness F1, from the report of the workgroup from INPA & EAI (2019)

Considering that there may be objective reasons to adjust the 5 km distance in cases where structures are not visible or if interference are not felt at a certain distance, the result was presented as a map with 5 km distance from structures, while displaying the effects of terrain and visibility. It however needs to be emphasized that the output remained a working map, and that among others, roads that were not paved but upbuilt were not included due to lack of data, which is likely to further reduce the extent of wilderness once taken into account. As this method was only applied to the Central Highland, related analysis involving this dataset in this report is performed using the same area of reference, e.g. when comparing coverage extent or when mapping boundaries overlays.

[12] See p. 23 for further details.

3.1.6 - Buffer-size variation for buildings based on multi-criteria scoring system (2017, 2020, 2021)

A scoring system for buildings was developed by researchers from Hornafjörður Research Center so that the buffer sizes would be relative to the level of impact on wilderness (Árnason et al., 2017). The following criteria were used to produce Map D1 (Figure 10):

- 0-7 km distance from buildings, based on impact score on a scale of 0-120, using non-linear intervals [0; 1; 4; 8; 13; 20][13] for each sub-criteria listed below:
  - Type of use
  - Building surface area in m²
  - Cluster size (number of buildings within 1 km of each other)
  - Distance to the nearest road
  - Type of road near or connecting to the building
  - Visibility (number of cells from which the building is visible)
- 5 km from reservoirs
- 3-5 km from power lines based on the voltage
- 5 km from paved roads
- 3 km buffer on four of the main highland roads (*i. stofnvegir á hálendinu*)

Coverage (Map D1): 32.513 km² in the Central Highland (81% of the studied area).

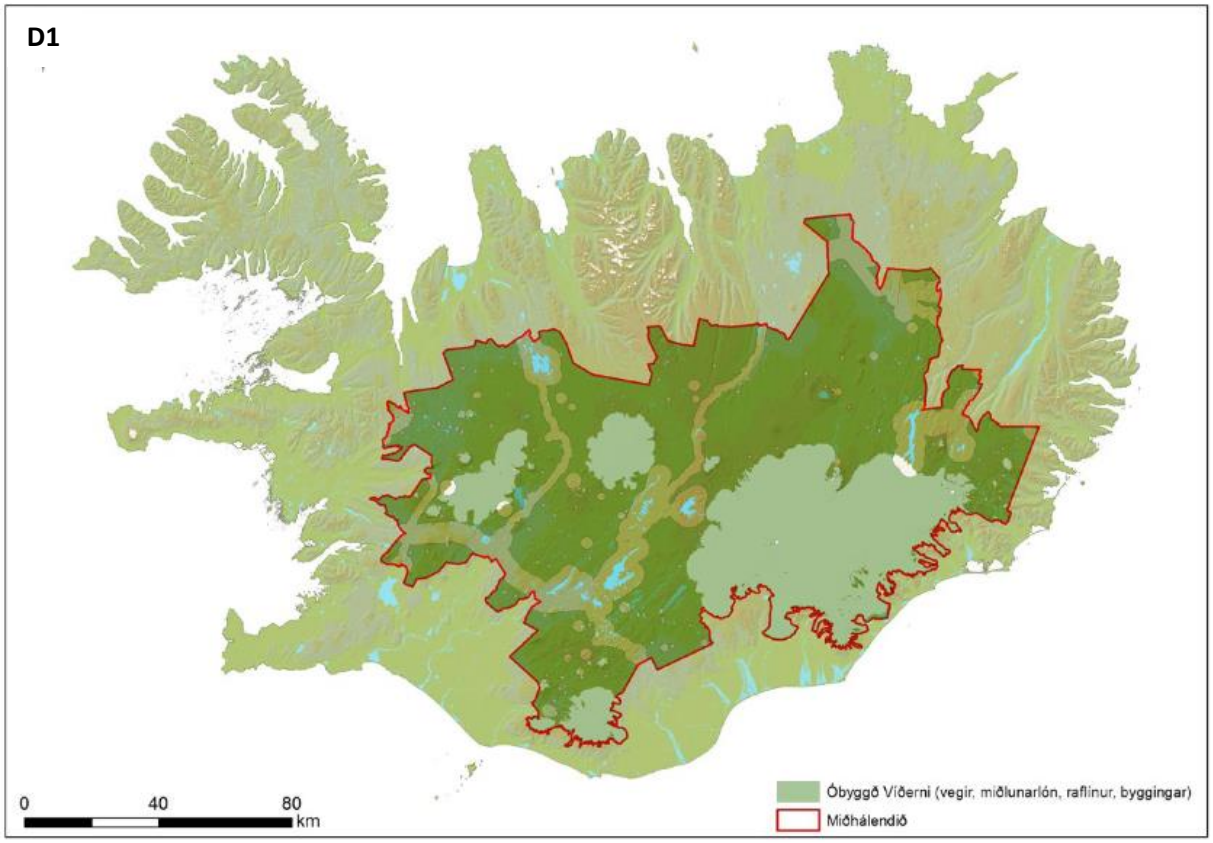


Figure 10: Map of uninhabited wilderness D1, using impact scores for buffer size (2017). Source: Árnason et al. (2017)

The report was updated in 2020 (Ostman & Árnason, 2020) with the addition of 152 data points identified (INPA, 2018). However, all unpaved roads, including the unpaved parts of the four main highland roads aforementioned were excluded from the analysis, primarily due to the lack of a legal defi-

[13] Emphasis added by D. C. Ostman on the non-linear impact scoring/intervals corresponding to the one used in the Icelandic Master Plan for Nature Protection and Energy Utilization.

nition of the term *upbuilt roads* (*i. uppbyggðir vegir*) used in the new law. Lack of data (e.g. physical characteristics of roads and tracks, network extent, traffic and seasonal usage) further limited the scoring possibilities. The output (Map D2) was incorporated in the latest map (Map D3 – Figure 11)

Coverage: 33.199 km², in the Central Highland (83% of the studied area).

The analysis was extended to the rest of the country (Ostman et al., 2021; Map D3 - Figure 11), by:

Step 1. Defining an exclusion area, i.e. where wilderness is not expected to be found. This was done to simplify step 2:

- 5 km distance from power lines
- 5 km distance from paved roads
- 2 km distance from urban areas
- 0 km distance from cultivated lands with exclusion of these surfaces

Step 2. Applying the scoring system to the buildings in the remaining areas:

- 0-7 km distance from buildings, based on impact score on a scale of 0-120, using non-linear intervals [0; 1; 4; 8; 13; 20] for each sub-criteria listed below:
  - Type of use
  - Building surface area in m²
  - Cluster size (number of buildings within 1 km of each other)
  - Distance to the nearest road
  - Type of road near or connecting to the building
  - Visibility (number of cells from which the building is visible)

Coverage (Map D3): 56.115 km² or about 55% of the country as a whole.

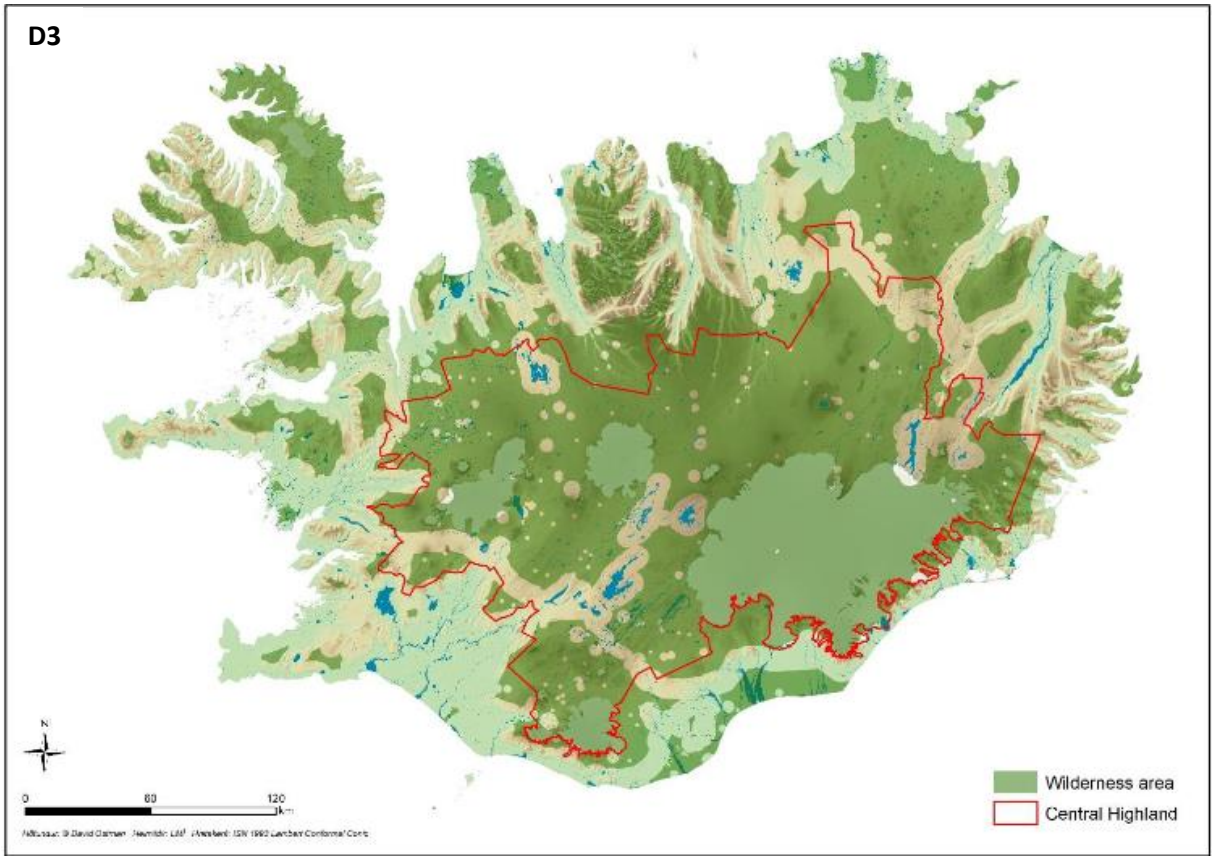


Figure 11: Map of uninhabited wilderness D3, using impact scores for buffer size (2021). Source: Ostman et al. (2021).

Methodological changes took place between the 2020 mapping of *uninhabited wilderness* in the Central Highland and the 2021 extension to the rest of Iceland. The 132 kV power lines received a 3 km buffer in the Central Highland and 5 km buffer in the lowlands, and reservoirs had a 5 km buffer in the Central Highland while not considered due to their smaller size and influence in the lowlands. The methodology is primarily centered on buildings, while some other features, in particular unpaved upbuilt roads and potentially other roads or tracks (Árnason et al., 2017), remain to be incorporated in the analysis upon legal definition of the term *upbuilt* (*i. uppbyggðir*) and related data collection.

3.1.7 - Summary of buffer-based approaches

Wilderness mapping methods based on the use of distance buffers have initially consisted of using fixed 5 km buffers, based on the legal definition, around features considered incompatible with the *untouched* or *uninhabited wilderness* (e.g. A1, B1, B2, B3, B4, E1). This was for the most part based on the features that are specifically mentioned in the legal definition of wilderness, such as power lines, power plants, reservoirs, or main roads[14]. In some cases, only certain sub-features were considered impactful while others were tolerated, based on existing classifications, e.g. building types. A major methodological development was the introduction of multiple buffer sizes (e.g. C1, C2), adding more nuance to reflect different levels of impact on wilderness. These buffer sizes, or allocation thresholds, could also be based on pre-existing classifications (e.g. C1, C2), or more complex scoring systems (e.g. D1, D2, D3, F1). Aside from the features mentioned in the law, other criteria related to naturalness of land-cover were sometimes used, e.g. to exclude agricultural lands (e.g. D3, E1), as well as lupine fields or planted forests (e.g. E1). The sizes used for the buffers around specifically mentioned feature types in the latest version of the law (e.g. power lines, power stations, reservoirs and upbuilt roads) were as follows:

- Power lines:
  - 5 km buffers, e.g. A1, C1, C2, D3 (outside of the Central Highland).
  - 5 km buffers for those above ground, e.g. B1, B2, B3, B4, E1, F1.
  - 5 km buffers beyond a certain voltage, e.g. C1.
  - 3-5 km buffers depending on voltage, D1, D2, D3 (within the Central Highland).
- Power stations:
  - 5 km buffers, e.g. A1, B1, B2, B3, B4, C1, C2, E1.
  - 5 km buffers with exceptions, e.g. F1.
  - Tailor-made buffers, e.g. D1, D2, D3.
- Reservoirs:
  - 5 km buffers, e.g. A1, B1, B2, D1, D2, E1.
  - 5 km buffer with exceptions, e.g. B3, B4, D3, F1.
  - Not considered, e.g. C1, C2.
- Upbuilt roads:
  - 5 km buffer, all main roads (*i. þjóðvegir*),[14] e.g. A1, B1, B2, B3, B4, E1
  - Variable buffers, all registered roads, e.g. C1, C2.
  - 3-5 km buffers, main highland roads and paved roads, e.g. D1.
  - 5 km buffers for paved roads, e.g. D2, D3, F1.

[14] Note that these were based on the term “main roads” from the definition of wilderness in the Act 44/1999, which was replaced in the Act 60/2013 by the term “upbuilt roads”.

3.2 - Inventory of topography-based approaches

3.2.1 - Binary outputs from viewshed analysis (2011, 2019)

Viewshed analysis can be performed to map the areas from which relevant features can be seen based on the topography. This produces a binary output (i.e. visible or not visible), directly dependent on the resolution of the digital elevation model. This was done by Ólafsdóttir and Runnström (2011a, 2011b) to map areas with no anthropogenic features in sight and compare their distribution (C3) with the *untouched wilderness* (C2). The following criteria were used to produce Map C3 (Figure 12):

- Maximum sight distance: 10 km (25 km near larger settlements)
- Features included:
  - Major roads; collector/country roads; highland roads
  - Urban nuclei; Industrial and service facilities; Farms, single houses
  - Power lines; power/telecommunication constructions; water/drainage system facilities
  - Mountain huts
- Observer offset: 1,8m
- Feature offset not used

Coverage (Map C3): 33.731 km², or about 33% of the country as a whole.

Coverage with 25 km² area threshold: 28.521 km², or about 28% of the country as a whole (80 areas).

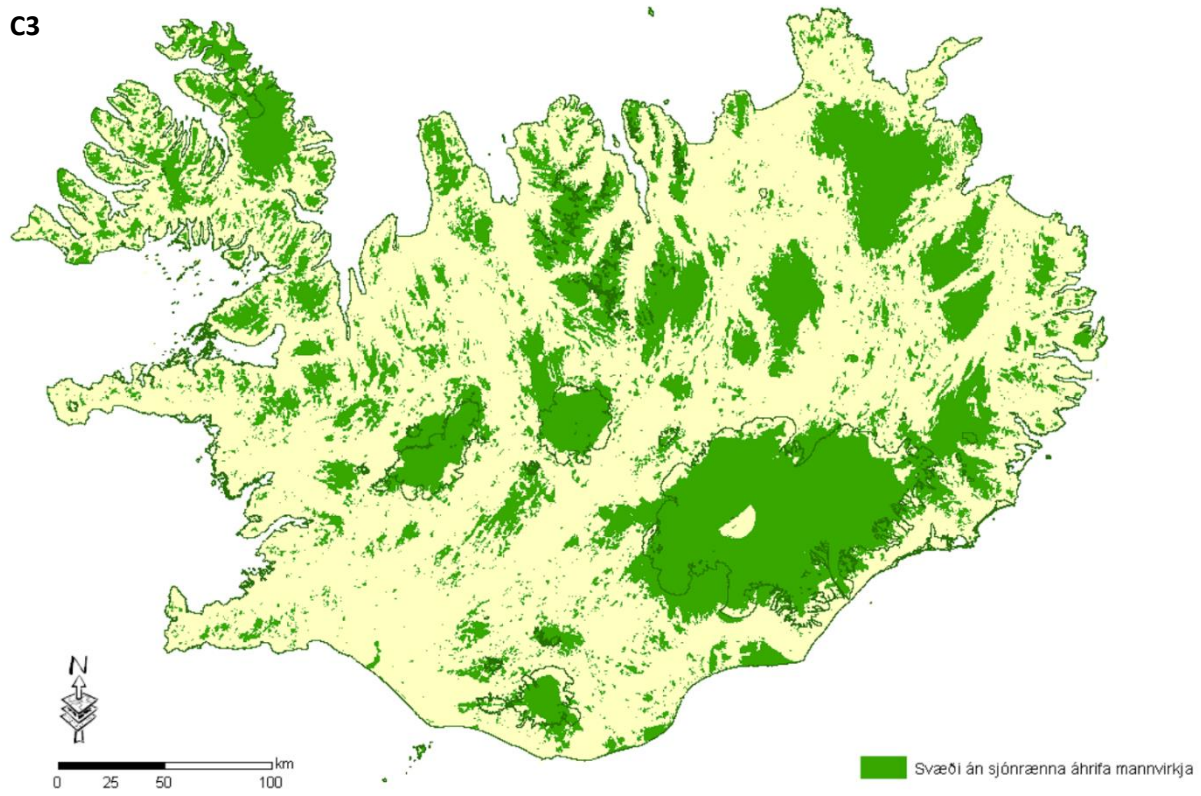


Figure 12: Viewshed analysis based on anthropogenic structures, 2011. Source: Ólafsdóttir and Runnström (2011a)

Another use of binary viewshed outputs was incorporated to the report from the INPA & EAI (2019), where inappropriate features received a 5 km buffer, and within that area, visibility analysis was carried out to assess the spatial extent of the visual disturbance. The results revealed that 5 km buffers

were consistent with the level of visibility in the case of power lines but were much smaller in the case of lower elevation features such as reservoirs, as can be seen in Figure 13.

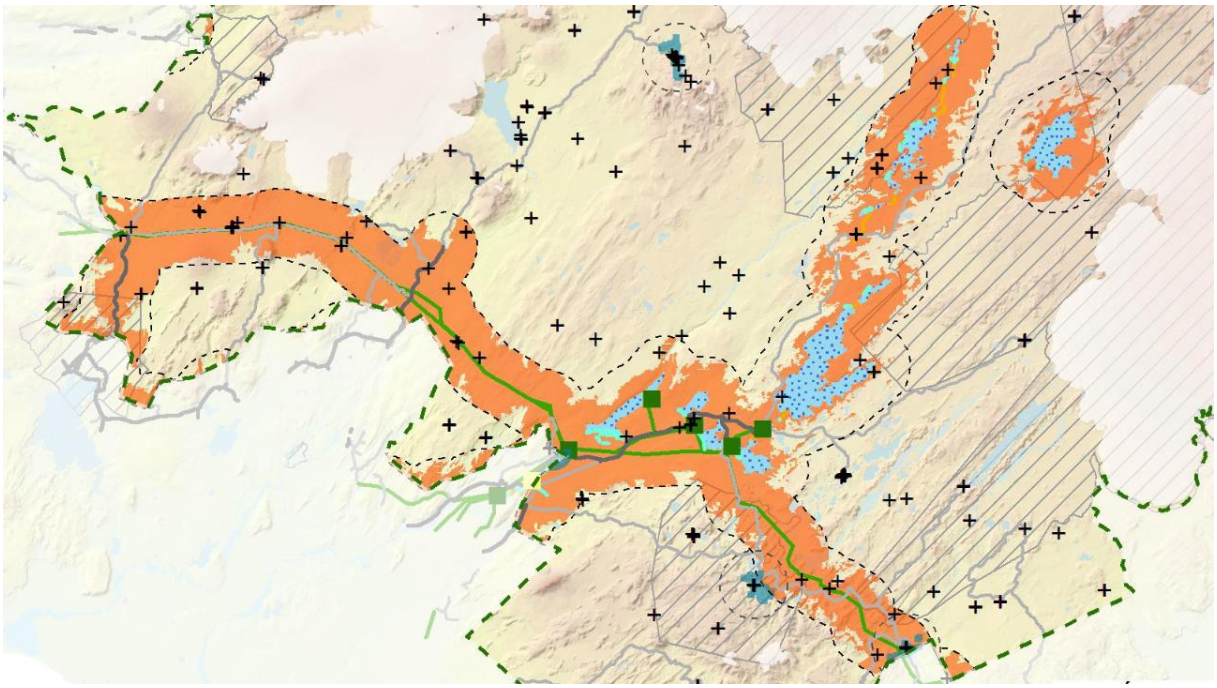


Figure 13: Map (part of Map F1) showing the buffer areas due to inappropriate structures (thin dashed line) and the area from which such structures can be seen (colored area). Source: INPA & EAI (2019).

Coverage: 4.371 km² where inappropriate structures are visible, within a buffer area of 6.317 km², representing 11% of the Central Highland (studied area) and 69% of the buffer area.

3.2.2 - Quantification of visual impacts in other approaches (2017, 2019, 2020, 2021)

Among the buffer-based mapping methods reviewed, all multi-criteria approaches incorporate indirectly some topographic elements through quantification of visual impacts, either through counts of visible cells, or using more complex scoring systems.

Visible cells count (2017, 2020, 2021)

The impact scores calculated for buildings in the maps D1, D2 and D3 incorporate a visibility criteria based on a count of visible cells to reflect how visible the structure is in the surroundings, using:

- Maximum sight distance: 50 km
- Features included:
  - All buildings in the database (623 points in 2020, 924 additional points in 2021)
- Observer offset: 1.75m (average eye level height)
- Feature offset: 3m due to lack of data (height of the structure)

The resulting cell count would be used to allocate an impact score based on the range in Table 3.

Table 3: Cell count classes used for the impact score related to visibility. Source: Ostman et al. (2021)

Range (visible cells count)	Impact score
0 – 299.999	0
300.000 – 599.999	1
600.000 – 899.999	4
900.000 – 1.199.999	8
1.200.000 – 1.499.999	13
> 1.500.000	20

When applying this method near or along the shorelines, the authors note that the visible cell counts were significantly higher than in areas where topography played a larger role in limiting visibility, posing the question of including sea coverage in the analysis. They further quote that 49% of structures outside of the Central Highland received the highest visibility impact score of *20*, compared with only 4% of structures inside of the Central Highland.

Combining structure and road traffic visibility (2019)

In the report from the INPA & EAI (2019), the structure excessiveness is based on their visibility as well as the impact of vehicle traffic. This was only performed for the study sites that were not considered inappropriate, e.g. by serving outdoor recreation and tourism purposes. The criteria used were as follows:

- Only applied to study sites outside of areas already excluded due to the proximity of inappropriate structures.
- Maximum sight distance: 3 km from the study site.
- Features included:
  - Built surface and score (1 unit per 100 m²), using:
    - 100 m² surface per building if no data is available
    - Weight related to use type (e.g. hotel, hut, etc. – no data available yet)
  - 100 m road segments score (1 unit per car per kilometer per hour), using:
    - Daily summer traffic (*i. sumardagsumferð*)
    - Average driving speed
    - A time-period of 16 hours per day
- Observer offset: 2m (the surface from which the features are visible)
- Feature offset: 2m (the height of the visible features, e.g. buildings, cars)

The scope of visual impacts calculated within a 3 km radius can be substantially different depending on the surrounding topography, as can be seen with the example of Landmannalaugar and Möðrudalur in Figure 14), which illustrates well the limitations of relying on buffers in areas where the topography can substantially affect the level of intrusiveness.

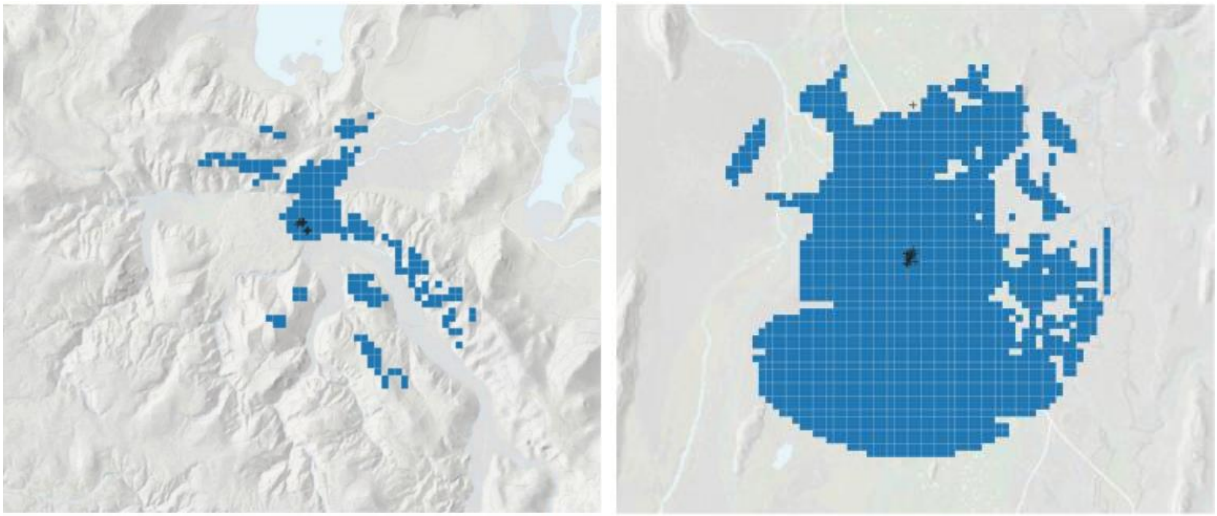


Figure 14: Visibility of buildings and traffic beyond excessiveness threshold within a 3 km radius in Landmannalaugar and Möðrudalur: INPA & EAI (2019, pp. 31-32)

It is however somewhat unclear to which extent the visibility affects the final score when using this methodology, although it is mentioned that each cell is weighted based on the impact score of visible structures and road segment.

3.2.3 - Wilderness Quality Index (2022, 2023, 2024)

Since 2022, the WRI has conducted large-scale wilderness mapping in Iceland (Carver et al., 2023; WRI, 2022; WRI & ÓFEIG, 2024; see Map G1 - Figure 15 and Map G2 - Figure 16), after two local-scale case studies in 2019 and 2021 (WRI, 2019, 2021). The method involves a Wilderness Quality Index (WQI) based on three criteria, two of which are influenced by topography:

- Remoteness from mechanized access (time to walk from a motorized vehicle):
  - Calculated from all roads and tracks that provide vehicular access via private car
  - 2-5 km/h for most terrains except river crossings (0.06 km/h, 20 min per crossing). Based on distance, relative slope and ground cover
  - Use of barrier features, such as open water, large rivers, crevassed areas, very steep terrain
- Absence of modern human artefacts:
  - Cumulative viewsheds weighted based on full/partial[15] visibility, artefact type and distance, based on:
    - A Digital Surface Model (DSM) derived from the ArcticDEM
    - Roads, tracks, pylons, dams, reservoirs, buildings, and other built structures
    - Assignment of height values (e.g. 5 m for single buildings;[15] 3 m for roads - average vehicle height; estimated from DSM in urban/industrial areas,[15] pylon height data[15])
    - Maximum distance of 15 km
  - Calculating the significance of visible cells:
    - Relative vertical area occupied by human artefacts in the viewer's field of view (360°)
    - Using distance decay and intervening terrain into account
- Perceived naturalness of land cover:
  - Using first the Agricultural University of Iceland's Farmland dataset (G1); then the UN Land Use Change Database (G2)[15]
  - 5 naturalness classes (Carver et al., 2023):
    0 No Data
    1 Built
    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
  - Mean naturalness class value within a 250 m radius (i.e. sphere of influence/personal space in which the casual observer can distinguish human influences on naturalness of land cover)

The scores of remoteness are based on walking time needed from the nearest road or track that provides vehicular access. This incorporates the topography and terrain with relative slope, cost surfaces and barrier features, but it is independent from the road type or condition. The visibility analysis creates a score representing the proportion of the visible surroundings occupied by human artefacts, therefore depending on the distance too. The lowest score is not 0 as even in urban settings there tends to be a part of the natural environment that remains visible. The perceived naturalness depends on an average value within a 250m radius of various features belonging to defined naturalness classes as presented above. The values are then normalized and rescaled on a 0-255 scale with equal interval and lower values being lower wildness. The values are then equally weighted in a multi-criteria analysis, resulting in a WQI indicator, which is then classified in 5 categories using Jenks natural breaks. A first large-scale map of WQI classes was produced in 2022 (G1), but the analysis was then extended to the rest of the country in 2023 and has now been available online since 2024 (G2).

[15]Based on discussion with S. Carver during the expert interviews conducted as a part of the reviewing process.

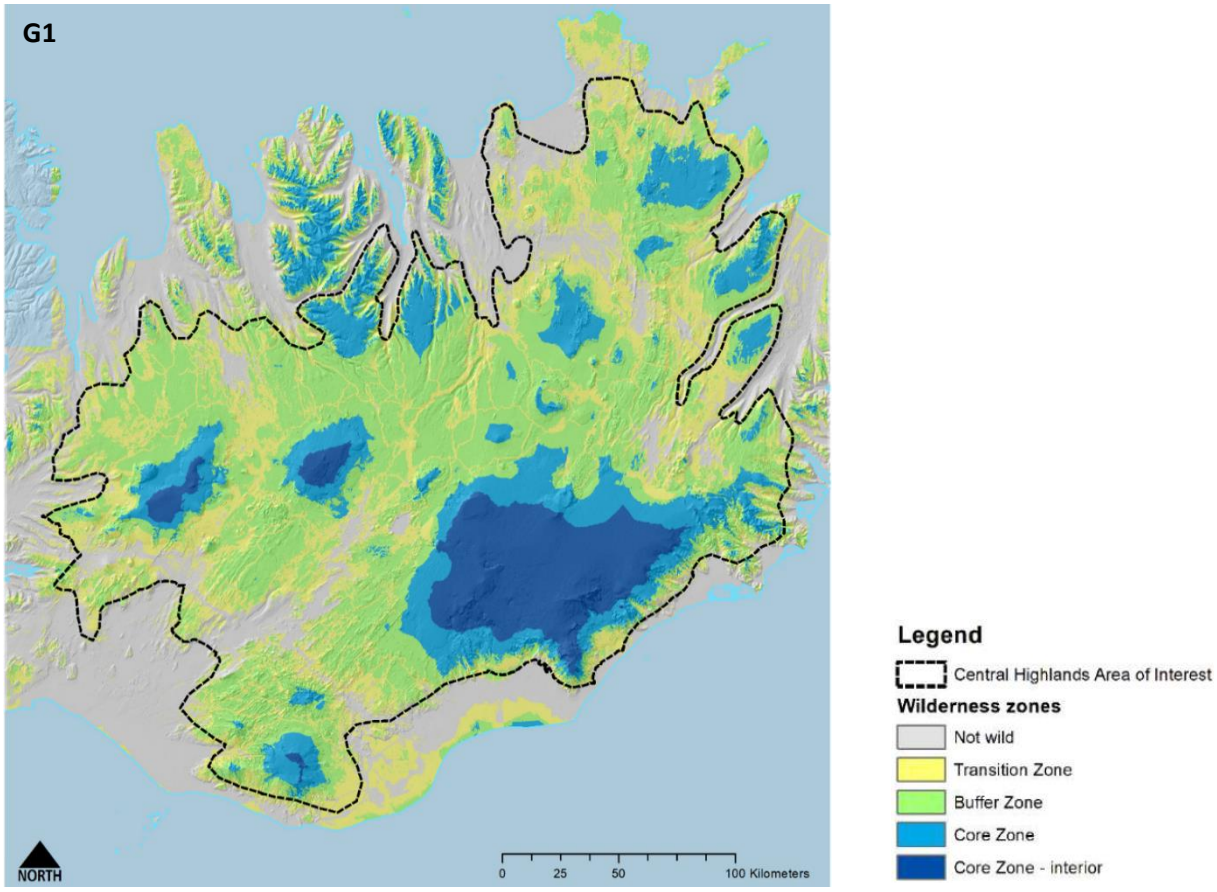


Figure 15: Map G1 showing the distribution of Wilderness Quality Index classes. Source: WRI (2022)

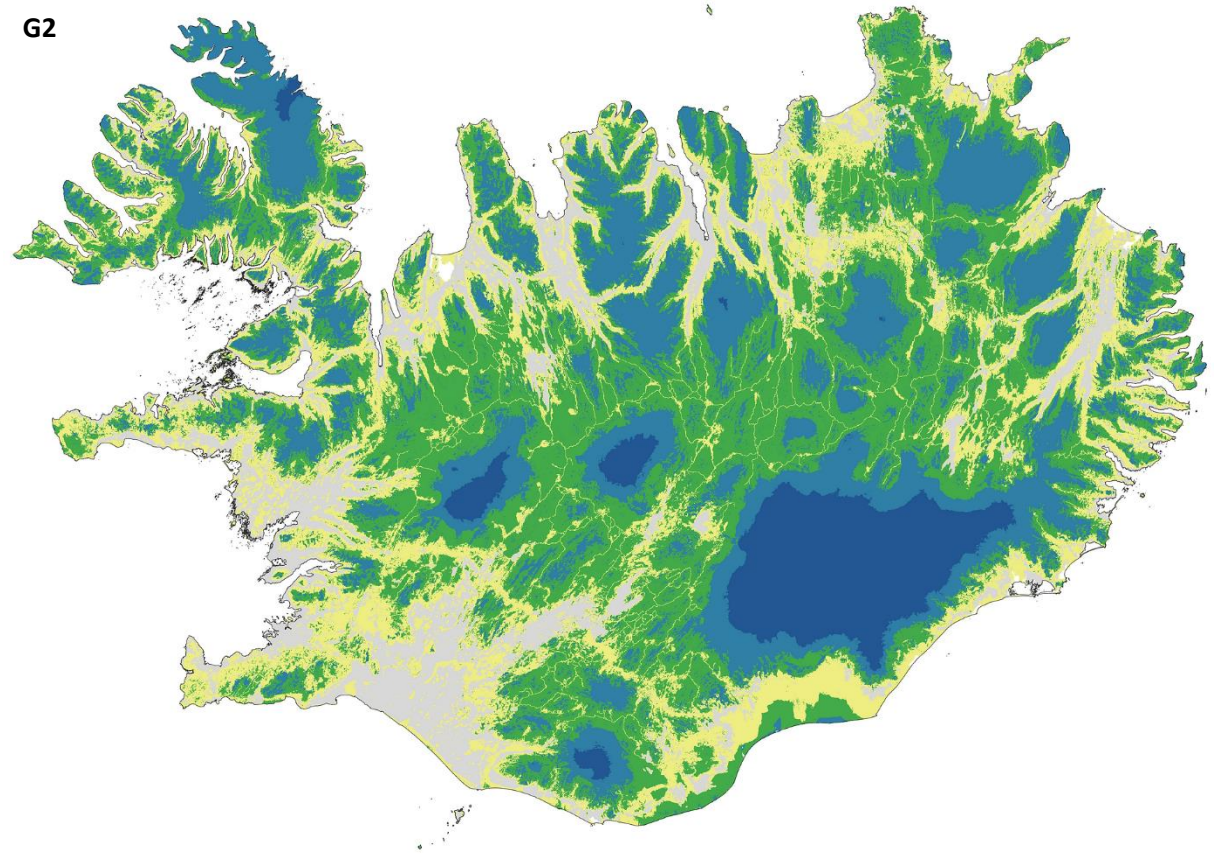


Figure 16: Map G2 showing the distribution Wilderness Quality Index classes. Source: WRI & ÓFEIG, (2024)

The WQI indicator was further used by the authors to identify IUCN 1b compatible areas, by applying an area threshold of 30 km² on the surface area covered by the top two classes with highest WQI values to identify wilderness cores. Around these cores, contiguous areas from the buffer zones were included if the combined coverage was over 100 km², leading to the identification of 17 IUCN 1b compatible wilderness areas (WRI, 2022) in the *Central Highlands area of interest*. However, the number of such areas is much higher in the country-wide application of this method in 2023. Other indicators were also mapped, such as openness, ruggedness, accessibility, mobile phone coverage, livestock grazing, and landscape character, but kept separated as wilderness character indicators.

3.2.4 - Summary of topography-based methods

Wilderness mapping methods accounting for the topography usually involve visibility analysis (e.g. C3, D3, F1, and G2), and one of them uses a remoteness indicator based on slope and barrier features as well as terrain. The visibility maps consisted either of an area calculation or cell-count for visible features (e.g. D3, F1), a binary output (e.g. C3, F1), or a visibility score based on the proportion of the view occupied by modern human artefacts (e.g. G2), all using maximum sight-distance (Table 4).

Table 4: Settings used for the visibility analysis in terms of maximum sight distance, surface and observer offset

Year	Map	Max. sight-distance	Observer offset	Feature offset
2011	C3	10 km	1,8 m	Not used
2019	F1	3-5 km	2 m	2 m
2021	D3	50 km	1,75 m	3 m
2024	G2	15 km	1,8 m	3-5 m[16]

These were based on the following features:

- Roads:
  - Major roads; collector/country roads; highland roads, e.g. C3.
  - All roads open to public access, using 3m height for traffic, e.g. G2.
  - Upbuilt roads, but only paved ones due to lack of data, e.g. F1.
- Buildings:
  - All buildings, e.g. G2.
  - All buildings in the database outside of exclusion areas, e.g. D3.
  - Urban nuclei, industrial and service facilities, farms, single houses, mountain huts, e.g. C3.
  - Substations, power plants; industry, and separately outdoor/tourism buildings, e.g. F1.
- Power lines:
  - All power lines, e.g. C3.
  - Power lines above ground, e.g. F1.
  - Pylons, every 300m along the power lines, e.g. G2.
- Reservoirs:
  - All reservoirs, e.g. F1, G2.
- Other features:
  - Power and telecommunication constructions; water and drainage system facilities, e.g. C3.
  - Significant utility structures, large wind turbines, mines/quarries (upon data access), e.g. F1.
  - Dams and other built structures, e.g. G2.
  - Road segments of 100 m depending on traffic intensity, e.g. F1.

[16] e.g. single buildings, average vehicle height

Most mapping methods presented above use buffers as a proxy for remoteness, with the exception of G1 and G2, which use the walking time from the nearest road or track providing vehicular access. This also incorporates cost surfaces based on terrain and topography, and barrier features, such as crevasses, cliffs or large glacial rivers. While this is a better indicator of remoteness than road distance, some places might feel more remote due to the driving time, means, or skills required to reach them.

4. Comparative analysis of wilderness mapping methods in Iceland

Six maps and related methods were selected for the comparative analysis: B3, C2, D3, E1, F1 and G2 (Table 5). This section explores the differences and similarities between these maps in terms of legal assumptions, mapping criteria, methodological choices and resulting coverage.

Table 5: Characteristics of the selected mapping methods

Year	Map	Authors	Law	Method	Wilderness coverage Surface area	%	Buffer size	Area threshold
2009	B3	EAI	1999	Fixed buffer	37.962 km²	37%	5 km	25 km²
2011	C2	R. Ólafsdóttir & M. C. Runnström	1999	Variable buffer	34.161 km²	33%	3-25 km	25 km²
2018	E1	IINH	Update of B3	Fixed buffer	34.433 km²	34%	5 km	25 km²
2019	F1	INPA & EAI	2013	Fixed buffer Scoring system	N/A	N/A	5 km	N/A
2021	D3	D. C. Ostman, et al.	2013	Variable buffer Scoring system	56.115 km²	55%	0-7 km	N/A
2024	G2	WRI & ÓFEIG,	2013	WQI[17] (IC+C) (IC+C+B)	29.659 km² 66.781 ²	29% 65%	N/A	N/A

4.1 - Incorporation of the legal definition and international guidelines

Some of the wilderness maps are exclusively based on the Icelandic legal definition while other, more recent outputs also incorporate some international guidelines such as those from the IUCN.

The 2009 map from the EAI (Map B3) seems to be the closest to a direct interpretation of the legal definition, with 5 km buffers around power lines, power stations, reservoirs, and main roads. Most buildings also received a 5 km buffer, without being specifically mentioned in the law. Some reservoirs did not get any buffer, as opposed to earlier versions of the map (B1, B2). This was among the reasons for the IINH to use more recent and comprehensive geodata and make a revised map (Map E1). Despite changes in the legal definition of the term *main roads* which was replaced by *upbuilt roads*, the same data was used as the map only aimed to provide an update to the one from 2009. Yet, artificial surfaces also received 5 km buffers (e.g. planted forests, cultivated lands, and lupines).

Buffer-based mapping by Ólafsdóttir and Runnström (2011a; 2011b, Map C2) was also mostly based on the legal definition, while accounting for anthropogenic structure types beyond those specifically mentioned in the law, such as industrial and service facilities, farms and single houses, power and telecommunication constructions, water and drainage system facilities, mountain huts and highland roads. Another difference is the use of variable buffers, e.g. 25 km from permanent settlements, and 3 km from mountain huts and highland roads instead of the distance of at least 5 km mentioned in the legal definition. Reservoirs were, however, not considered despite being mentioned in the law.

The mapping approach by Ostman et al. (2021, Map D3) was also closely related to the legal definition in Article 5.19 where the expression *usually at least 5 km* enables the use of variable buffer sizes. This was mostly used for buildings. Buffers around reservoirs, power lines, and paved roads were also

[17] Wilderness coverage extent based on the top two (Inner Core areas + Core areas) and top three (Inner Core areas + Core areas + Buffer areas) WQI classes.

based on the legal definition, though unpaved roads were not considered due to the lack of data and definition of the term *upbuilt road*. The main deviation from the legal definition is the exclusion of cultivated lands which are not specifically mentioned in the law. The use of a different method for the Central Highland and rest of the country for reservoirs and power lines (as well as the use of exclusion zones) does not seem to have a legal basis and seems more related to practical considerations. Last, size requirements of *usually* at least 25 km² were not considered during the mapping process.

The workgroup from the INPA & EAI (2019, Map F1) derived two criteria from one of the IUCN 1b descriptive characteristics (Table 2, p.6). Structures and traffic, both mentioned in Article 5.19, were assessed in terms of inappropriateness and excessiveness. Structure types mentioned in the law were mostly considered inappropriate, except for the *upbuilt road* which could not be assessed due to the lack of legal definition and data. Multiple criteria were used to define a threshold of excessiveness for structure clusters which serve tourism and outdoor recreation purposes, based on visibility data analysis of structure and vehicle traffic intensity. Inappropriate and excessive received a 5 km distance buffer, due to uncertainty over whether the term *usually* would also apply to the 5 km distance then.

The approach of the WRI (2022, p. 16, Map G1; WRI & ÓFEIG, 2024, Map G2) was primarily based on mapping of WQI abroad and focused on mapping wilderness areas and identifying those that are compatible with criteria from IUCN 1b and Article 46 of the Nature Conservation Act 60/2013. While this involves stricter criteria than those mentioned in Article 5.19, most components of Article 5.19 are incorporated in the WQI main indicators: remoteness from mechanized access (enjoyment of solitude without disturbance from the traffic of motorized vehicles); absence of modern human artefacts (usually 5 km away from anthropogenic structures); and perceived naturalness of land-cover (enjoyment of nature). No incompatibility threshold is used for individual criteria, although some features (e.g. reservoirs) which are classified as modern human artefacts while having a low perceived naturalness and being connected to a road will subsequently receive a very low WQI score. Other features, such as power lines or roads, do not always prevent an area from being considered *wild* to some extent (i.e. not belonging to the *Not wild* WQI class), as the WQI combines all three main indicators. Although the WQI did not involve a size requirement, 30-100 km² area thresholds (for core and core + buffer areas) are used for the identification of potential IUCN 1b areas, based on the Wild Europe Definition.

All the mapping methods reviewed were based to some extent on the legal definition of *untouched/uninhabited wilderness*, which provides a baseline from which variations might occur, depending on legal interpretation and use of additional criteria. This is the case for examples of anthropogenic structures explicitly mentioned such as *power lines*, *power stations*, or *reservoirs*, which have usually been approached with consistency. However, this requires that these terms are well defined and understood, unlike the term *upbuilt roads*, which resulted in leaving unpaved roads unassessed in some cases (D3, F1), or undistinguished from others road types (G2). The mention of specific distance or area thresholds (e.g. *usually at least 25 km²; usually at least 5 km away from…*) also helps orienting the mapping work while allowing for more flexibility. However, the part of the legal definition which mentions the possibility to *enjoy solitude and nature without disturbances from anthropogenic structures or the traffic of motorized vehicles* was addressed differently by the most recent methods developed (D3, F1 and G2). The incorporation of international guidelines seemed particularly present in work derived from the method used in G1 and G2 to identify IUCN 1b compatible areas using Wild Europe area thresholds which are stricter than those laid in the national legislation. The approach used for Map F1 in this respect seems to have consisted in embedding the requirements from the legal definition in broader criteria derived from the IUCN 1b characteristics.

Table 6: Incorporation of components of Article 5.19 within selected mapping methods (note that Map B3 and Map C2 were based on the 1999 definition, where "main road" was used instead of "upbuilt").

	An area of uninhabited land…	***...usually at least 25 km² in size or so…***	***…that one can enjoy solitude…***	***…and nature…***	***...without disturbance from anthropogenic structures…***	***…or the traffic of motorized vehicles…***	***…and usually at least 5 km away from…***	***…anthropogenic structures and other evidence of technology such as…***	***…power lines...***	***…power stations…***	***…reservoirs…***	***…and upbuilt roads.***
B3	N/A	25 km² threshold.	N/A	N/A	5 km buffers. Exceptions for isolated houses and ruins.	5 km main road buffers.	5 km buffers.	Main roads, reservoirs, power lines, buildings except isolated houses and ruins	5 km buffers for all above ground.	5 km buffers.	5 km buffers. Exceptions for some reservoirs.	5 km main roads buffers.
C2	25 km from large urban nuclei.	25 km² threshold.	3-5 km road buffer size based on traffic intensity.	N/A	5 km buffers. Exceptions (3 km) for some roads and buildings.	3-5 km road buffers.	3-5 km buffers, (25 km buffer for large urban nuclei).	Roads, power lines, buildings, telecommunication, energy, and utility structures.	5 km buffers.	5 km buffers.	N/A	3-5 km road buffers.
D3	Exclusion of cultivated lands. Use of building cluster impact factor.	N/A	3-5 km road buffers in D1. Road proximity, road connection, built area and building cluster impact factors.	Exclusion of cultivated lands.	5 km buffers. Exceptions for some power lines and use of 0-7 km buffers for buildings.	5 km paved roads buffers. Road proximity and connection impact factors for buildings.	0-7 km buffers.	Paved roads, reservoirs, power lines, buildings.	5 km buffers outside of the Central Highland. 3-5 km based on voltage in the Central Highland.	5 km buffers. Exception for small power stations.	5 km buffers. Exceptions for reservoirs outside of the Central Highland.	5 km paved road buffers. Other non-included due to lack of data.
E1	5 km from cultivated lands.	25 km² threshold.	N/A	5 km buffers from cultivated lands, planted forests, and lupine fields.	5 km buffers. Exception for building category 1340, e.g. emergency shelters, herding cabins, mountain huts, etc.	5 km main road buffers.	5 km buffers.	Main roads, reservoirs, power lines, buildings except category 1340, e.g. emergency shelters, herding cabins, mountain huts, etc.	5 km buffers for all above ground.	5 km buffers.	5 km buffers.	5 km main road buffers.
F1	Built areas & traffic intensity indicators. Farm & residential use with 1,5 weight if data available.	N/A	Incorporation of traffic data and built surface areas for outdoor activities and tourism-related structures in the assessment.	Structure inappropriateness based on purpose, in relation to the unhindered progress of nature and of the ecosystem, humans being part of it, enjoying, studying & travelling around it.	Use of structure inappropriateness and excessiveness criteria based on usage and scope.	5 km paved roads buffers. Road traffic impact factor in structures' assessment.	5 km buffers.	Paved roads, reservoirs, power lines, power plants, significant utility structures or mines/ quarries, large wind turbines, industry, excessive outdoor/ tourism structures	5 km buffers for all above ground.	5 km buffers. Exception for small power stations.	5 km buffers. Exception for those from small power stations.	5 km paved road buffers. Other non-included due to lack of data.
G2	N/A. Indirectly covered by WQI components.	N/A for WQI. 30-100 km² used for IUCN 1b areas (cores / cores + buffers).	Use of remoteness from mechanized access & visibility of modern human artefacts (e.g. roads, accommodation).	Use of visibility of modern human artefacts and perceived naturalness of land-cover (e.g. reservoirs, cultivated lands).	Use of visibility of modern human artefacts.	Use of remoteness from mechanized access and account of vehicle height for visibility of road structures.	N/A. Cores areas on average at least around 5 km away from nearest roads.	Roads, reservoirs, power lines, and buildings are incorporated in WQI components.	Used in the visibility of modern human artefacts, with a pylon every 300 m.	Used in the visibility of modern human artefacts, possibly weighted.	Used for visibility of modern human artefacts and for perceived naturalness of land-cover	Used in all WQI components

4.2 - Methodological comparison and considerations

Wilderness mapping methods can differ in their design and implementation of criteria, independently from the legal background and database quality. Such differences can relate to the boundary types and mapping designs, the use of tolerance thresholds for disturbing features or buffer size variations, and whether topography and land-cover are incorporated.

1) Boundary types and designs

The vast majority of the wilderness maps reviewed usually focus on mapping wilderness by excluding areas which are incompatible and considering the remaining areas as wilderness, which could be called negative mapping. While this is relatively easy to perform with buffers around incompatible features (e.g. B3, C2, D3, E1 and F1), the resulting boundaries often lack nuance and quality at higher resolution, and might appear rather arbitrary, subjective, and unrelated to geographic features or experiences. The outputs from such maps are typically binary (also referred to as Boolean approaches), where each point on the map is either considered as wilderness or not. According to Ostman et al. (2021), such approaches "*can often overlook the complexities of the wilderness concept and may obfuscate the importance of relative wilderness quality"*. Alternative approaches using more continuous mapping methods or fuzzy boundaries, can be based on indicators similar to the WQI (e.g. G2), where the degree of wilderness is considered as more gradual, in line with the idea of a wilderness continuum (e.g. Lesslie & Taylor, 1985) and human perception. Nevertheless, clearly defining wilderness areas has a certain legal practicality (e.g. for land-use planning and zoning) which seems more difficult to implement with fuzzy boundaries or continuous mapping methods. Some inspiration might be drawn from abroad, such as in Norway where intervention-free areas are also based on distance from intrusive features, but different zones with respective rules will be identified at different distance from such features, e.g. 1 km, 3km, and 5 km (Fauchald, 2016; Norwegian Environment Agency, n.d.). This would be somewhat similar to defining a buffer zone around a wilderness area, where certain rules apply to preserve wilderness, requiring legal adjustments.

2) Tolerance threshold and buffer sizes

Distance buffers are commonly used to extract areas surrounding features that are incompatible with wilderness. However, within a single type of incompatible feature, the level of impact on wilderness can vary substantially (e.g. depending on its size, age, visibility, etc.), which can justify exceptions on the decision to allocate an impact buffer. In such a case, a tolerance or incompatibility threshold is used, typically to allow small structures such as primitive mountain huts or shelters in wilderness areas (e.g. B3, E1, F1), or other features that can be tolerated if they already exist in such areas. An alternative approach is to reflect the degree of impact by adjusting the buffer size accordingly (e.g. C2, D3). In cases where this was done, it has systematically resulted in a more comprehensive assessment, as the use of smaller buffer sizes makes it possible to account for relatively smaller levels of disturbance as well. This can result in a reduction of the wilderness extent (e.g. the wilderness extent in C2 is smaller compared to B3, by over 3.800 km²). Buffer sizes allocation has initially been based on existing classifications for the feature considered (C2), adding more nuance to previous maps (B3). Further adjustments based on the local context emerge from the development of scoring systems, either for excessiveness assessment and the decision to assign a buffer (F1), or to adjust the buffer size accordingly (D3). Indicators such as structure size, number, visibility, road proximity and road connection were used (D3), as well as road traffic data derived from vehicle counters (F1). However, one could argue that transposing wilderness impacts on buffer size isn't always appropriate as some serious impacts can be limited to a very specific location. Visibility analysis partially addresses this issue, e.g. by displaying the proportion of the buffer surfaces where incompatible features can be seen, adding some nuance to the level of visual disturbance.

3) Incorporation of topography

Visibility analysis is among the most commonly used wilderness mapping tools which integrate topography. Identifying areas where features visually interfere with wilderness experiences contributes to quantifying experiential components and accounting for human perception in wilderness mapping in a relatable manner. Visibility analysis has indeed been a powerful tool to communicate about the impact or outreach of very tall structures, such as in the case of wind turbines or telecommunication structures. The quality of such analyses will depend on the resolution of the elevation and terrain data, as well as the available computing resources. Four of the methods reviewed incorporate visibility analysis to some extent, e.g. for quantification purposes (e.g. D3, F1); mapping visible areas (e.g. C3, F1), or mapping the proportion of view occupied by human artefacts (e.g. G2). It is however important to note that visibility is rarely used to define boundaries (with the exception of G2), but rather to inform and quantify visual impacts within and beyond wilderness areas (e.g. C3, F1).

Combining topography and terrain data has been used for remoteness assessment, for instance by combining slope, barrier features, and cost surfaces to estimate average walking speed, and therefore minimum walking time required to reach any point from the nearest road usable by the public (e.g. G2). While such an approach of remoteness from mechanized access provides a valuable human experience and solitude indicator, further incorporation of the type of roads or tracks and the distance from settlements would potentially provide a relevant indicator of perceived remoteness.

4) Incorporation of land cover

Some of the differences that can be found among the mapping methods reviewed relate to whether the land cover is integrated into the analysis. This would imply having a zoning approach to wilderness mapping, by identifying areas where the characteristics of the land-cover are incompatible with wilderness mapping. This could arguably be the case for built surfaces, such as paved roads and buildings which required substantial human interventions. Other types of land cover could also be considered if a naturalness criterion is considered important for wilderness mapping, such as cultivated lands, artificial lakes, land-reclamation areas, invasive species or planted forests. This could also apply to other altered natural processes, such as dried riverbeds, eroded land from overgrazing, etc. While most methods indirectly incorporated land cover in the assessment through feature types mentioned in the law, only D3, E1 and G2 went beyond these cases, e.g. by considering cultivated lands (D3, E1, G2), planted forests (E1, G2), lupine fields (E1), etc. Interestingly, while D3 excluded cultivated lands, they did not receive any distance buffer, raising the question of whether buffers are used as proxy for remoteness, solitude, visual, or ecological impacts, and whether other land-cover types might be excluded without using distance buffers. Using land-cover or land-use categorization and exclusion process could be useful for wilderness mapping, using buffers if appropriate.

5) Other parameters

While much of the work carried out through these mapping methods focuses on identifying wilderness areas, some also involve more descriptive mapping tasks. Wilderness areas derived from G2 were further described by some wilderness character components, e.g. openness, ruggedness, accessibility, cellphone coverage, livestock grazing, and landscape character. These attributes, along with some other planning components such as landownership, administrative or protection status might find their relevance for environmental planning and stakeholder identification purposes, even if their role in identifying wilderness areas might seem secondary. As for the output from visibility analysis, the risk associated with keeping this information separated is that it may be left out from further identification our boundary definition work.

4.3 - Surface area and coverage comparisons

Comparing the spatial extent of wilderness for the selected methods was performed with area calculations and spatial overlays. Two of the maps selected used either a different scope (F1) or a different type of boundaries (G2). This was addressed by using the Central Highland for a regional analysis in addition to the country-level comparison. In the case of G2, the WQI classes aren't sufficient alone to identify wilderness areas as area thresholds were applied on aggregates of WQI classes to define such areas. For simplification purposes, the top two and top three WQI classes were used for comparison of surface area extent in the summary table (Table 7).

The results show that the size of the identified wilderness varies between 33% (C2) and 55% (D3) of the country, depending on the buffer-based approach considered. Aggregates of the highest WQI classes (G2) represent 29-65% of the country, depending on whether buffer areas are included or not. In the Central Highland, wilderness represents between 56% (C2) and 84% (F1) of the area, while the merged top WQI categories cover 38-86% of the area. These results suggest that F1 and D3 are the most inclusive wilderness maps, although they likely overestimate the wilderness extent as all unpaved roads were not assessed due to the lack of definition and data for the term upbuilt roads. Extending the comparison to alternative versions of some of the maps (e.g. B4 and E2) further highlights how the variation of a single parameter (e.g. buffer size) might affect the extent of wilderness. For example, using 3 km buffers for 132 kV power lines and unpaved main roads instead of 5 km results in wilderness gains of nearly 4.2000 km² (E2 compared to E1). Considering ruins as anthropogenic structures with 5 km buffers, combined with the resulting exclusion of areas of less than 25 km², resulted in a reduction of wilderness of about 4.100 km² (B4 compared to B3). Including more features in the assessment (e.g. buildings and roads) resulted in a wilderness loss of about 3.800 km² in C2 compared to B3, despite the use of smaller buffer sizes (e.g. for highland roads).

Table 7: Surface area of wilderness for the whole country and in the Central Highland according to the different methodologies and variations or alternatives assumptions.

			Wilderness coverage					
			Whole country		Central Highland		Buffer size	Area threshold
Year	Map	Method	Surface area	%	Surface area	%		
2009	B3	Fixed buffer	37.962 km²	37%	24.308 km²	61%	5 km	25 km²
	B4	Fixed buffer	33.825 km²	33%	23.555 km²	59%	5 km	25 km²
2011	C2	Variable buffer	34.161 km²	33%	22.172 km²	56%	3-25 km	25 km²
2018	E1	Fixed buffer	34.433 km²	34%	23.095 km²	58%	5 km	25 km²
	E2	Fixed buffer	38.615 km²	38%	26.305 km²	66%	3-5 km	25 km²
2019	F1	Fixed buffer with scoring system	N/A	N/A	33.307 km²	84%	5 km	N/A
2021	D3	Variable buffer with scoring system	56.115 km²	55%	32.699 km²	82%	0-7 km	N/A
2024	G2	Wilderness Quality Index[18] (IC+C)	29.659 km²	29%	15.337 km²	38%	N/A	N/A
		(IC+C+B)	66.781 km²	65%	34.298 km²	86%		

Pairwise mapping overlays of B3, C2, E1, F1 and D3 were also prepared in Appendix A, providing further details on the source of difference in coverage between the various methods. Rather than extracting a wilderness boundary from G2 which would be an oversimplification, WQI classes were therefore mapped within wilderness areas identified by other methods (Appendix B). The extent to which the areas mapped as wilderness present some overlap or mismatches was calculated and summarized in Table 8, which shows for instance that while B3 and E1 use similar methods and are 96% consistent, 4% of the country was considered as wilderness by B3 and not by E1, while less than

[18] Wilderness coverage extent based on the top two (Inner Core areas + Core areas) and top three (Inner Core areas + Core areas + Buffer areas) WQI classes.

1% was considered as wilderness by E1 and not B3. The lowest level of agreement was found between C2 and D3 at a country level (76%), with as much as 22% of the country considered as wilderness by D3 and not by C2, and 2% considered wilderness by C2 and not by D3.

Table 8: Comparison of country-wide wilderness maps in terms of consistent overlaps (i.e. areas identified as wilderness or non-wilderness in both maps: W/W; NW/NW) and differences (i.e. areas identified as wilderness by only one of the two maps: W/NW; NW/W). The consistency ratios reflect the total area with consistent overlaps (W/W + NW/NW).

	W/W		NW/W		NW/W		NW/NW		Consistency Ratio
	Surface area	%	Surface area	%	Surface area	%	Surface area	%	
B3/C2	30.803 km²	30%	7.159 km²	7%	3.892 km²	4%	60.859 km²	59%	89%
B3/E1	34.058 km²	33%	3.903 km²	4%	375 km²	0%	64.377 km²	63%	96%
B3/D3	36.399 km²	35%	1.562 km²	2%	19.716 km²	19%	45.036 km²	44%	79%
C2/E1	28.864 km²	28%	5.831 km²	6%	5.569 km²	5%	62.449 km²	61%	89%
C2/D3	33.077 km²	32%	1.618 km²	2%	23.038 km²	22%	44.980 km²	44%	76%
E1/D3	34.125 km²	33%	308 km²	0%	21.990 km²	21%	46.290 km²	45%	78%

In the Central Highland, the highest consistency was found between B3 and E1 (96%) and between D3 and F1 (96%). This is expected due to the methodological similarities between these approaches. In terms of differences, the lowest rate of consistency was observed for C2 and F1 (68%), followed by C2 and D3 (69%). Indeed, 30% of the Central Highland is considered as wilderness by F1 and not by C2, and an additional 2% is considered wilderness by C2 and not by F1.

Table 9: Comparison of wilderness maps in the Central Highland in terms of consistent overlaps (i.e. areas identified as wilderness or non-wilderness in both maps: W/W; NW/NW) and differences (i.e. areas identified as wilderness by only one of the two maps: W/NW; NW/W). The consistency ratios reflect the total area with consistent overlaps (W/W + NW/NW).

	W/W		W/NW		NW/W		NW/NW		Consistency Ratio
	Surface area	%	Surface area	%	Surface area	%	Surface area	%	
B3/C2	19.402 km²	49%	4.906 km²	12%	2.770 km²	7%	12.796 km²	32%	81%
B3/E1	22.988 km²	58%	1.320 km²	3%	107 km²	0%	15.459 km²	39%	96%
B3/F1	23.448 km²	59%	860 km²	2%	9.868 km²	25%	5.698 km²	14%	73%
B3/D3	23.325 km²	58%	983 km²	2%	9.374 km²	24%	6.192 km²	16%	74%
C2/E1	18.882 km²	47%	3.290 km²	8%	4.212 km²	11%	13.489 km²	34%	81%
C2/F1	21.288 km²	53%	884 km²	2%	12.028 km²	30%	5.673 km²	14%	68%
C2/D3	21.322 km²	53%	850 km²	2%	11.377 km²	29%	6.325 km²	16%	69%
E1/F1	22.948 km²	58%	146 km²	0%	10.368 km²	26%	6.411 km²	16%	74%
E1/D3	22.878 km²	57%	216 km²	1%	9.821 km²	25%	6.958 km²	17%	75%
D3/F1	32.136 km²	81%	563 km²	1%	1.180 km²	3%	5.994 km²	15%	96%

The comparison of G2 with other maps was performed by analyzing the distribution of selected WQI classes in wilderness and non-wilderness areas according to each method. The WQI classes were grouped into Low WQI (Not wild + Edge), Average WQI (Buffer), and High WQI (Core + Interior Core). The results show that wilderness areas according to D3 contain 88% of the High WQI values of the country (Table 10) which suggests a relatively high consistency, though they also contain the highest proportion of Low WQI values as well (13%). Within the Central Highland, wilderness areas according to D3 and F1 include 98% of the High WQI values of the area, and respectively 32% and 38% of the low WQI values. Overall, D3 seems to be more consistent with the wilderness qualities which are reflected in the WQI while F1 encompasses more areas which are somewhat disturbed. Wilderness according to C2 only includes 3% of Low WQI values due to the use of stricter criteria.

Table 10: Proportion of WQI classes which can be found in wilderness and non-wilderness areas in Iceland and in the Central Highland according to the different methods.

			% of High WQI…		% of Average WQI…		% of Low WQI…	
Scope	Year	Map	in W. areas	in NW. areas	in W. areas	in NW. areas	in W. areas	in NW. areas
Iceland	2009	B3	76%	24%	36%	64%	6%	94%
	2011	C2	75%	25%	29%	71%	3%	97%
	2018	E1	72%	28%	32%	68%	4%	96%
	2021	D3	88%	12%	68%	32%	13%	87%
Central Highland	2009	B3	91%	9%	48%	52%	21%	79%
	2011	C2	91%	9%	40%	60%	11%	89%
	2018	E1	90%	10%	45%	55%	14%	86%
	2019	F1	98%	2%	85%	15%	38%	62%
	2021	D3	98%	2%	84%	16%	32%	68%

These results further reveal that 65% of the wilderness according to C2 is classified as High WQI (Table 11), while only 3% of it has a Low WQI, which illustrates well the use of strict criteria. At the same time, 11% of the non-wilderness areas according to C2 have a High WQI value, pointing out that having strict criteria might prevent some areas which are largely perceived as such from being included.

Table 11: Proportion of wilderness and non-wilderness areas characterized by High, Average, and Low WQI classes in Iceland and in the Central Highland.

			% of W. areas with…			% of NW. areas with…		
Scope	Year	Map	High WQI	Average WQI	Low WQI	High WQI	Average WQI	Low WQI
Iceland	2009	B3	59%	36%	5%	11%	37%	52%
	2011	C2	65%	32%	3%	11%	38%	51%
	2018	E1	62%	34%	4%	12%	37%	51%
	2021	D3	47%	45%	8%	7%	26%	67%
Central Highland	2009	B3	58%	38%	5%	9%	63%	28%
	2011	C2	63%	34%	3%	8%	64%	28%
	2018	E1	60%	37%	3%	9%	62%	29%
	2019	F1	45%	49%	6%	5%	42%	53%
	2021	D3	46%	49%	5%	5%	43%	53%

Locally, some discrepancies can also be identified, due to the use of different criteria, data and methods. As the WQI consists of two topography-derived indicators related to human perception (i.e. visibility and remoteness), such inconsistencies highlight locations where boundary adjustments could be performed to better reflect human perceptions. Some differences between WQI and wilderness areas occur in highly contrasted topographic settings where the elevation changes substantially across short distances such as in Hornstrandir, Tröllaskagi, and other deep valleys (e.g. B3, C2, E1), compared with more open environments such as in the Central Highland, especially if smaller buffers are used (e.g. C2, D3). Other differences can result from the naturalness criteria based on the land cover type, which can be identified as low-WQI values within the boundaries of wilderness areas, e.g. in the case of reservoirs such as Hágöngulón, Kelduárvatn and Þórisvatn (B3, C2); areas with high soil erosion and land reclamation such as in parts of Bláskógabyggð municipality or near Blöndulón. Excluding cultivated lands (e.g. D3, E1), planted forests or lupine fields (e.g. E1) tend to reduce the amount of low WQI values in wilderness areas. However, the non-consideration of unpaved roads in some of the methods results in discrepancies (e.g. D3, F1). Last, some apparent inconsistencies can be due to dataset differences in areas where recent land-use changes took place, e.g. Reykjaheiðavegur road construction.

5. Contributions from case studies and perceptions studies

Several wilderness-related studies were undertaken for environmental planning in Iceland. Field work was conducted under the scope of the Master Plan[19] to collect landscape and wilderness data in the assessment area of energy projects. High-resolution wilderness maps using the WQI were also produced to evaluate the impacts of development projects or road access policies. Public opinion research has also been conducted to assess structure appropriateness in wilderness and to map areas perceived as such by the Icelandic public. Visitor perceptions were also surveyed in areas perceived as wilderness, providing valuable insight for mapping purposes.

5.1 - Wilderness field data collection

Field work conducted by Expert group 1 of the Master Plan (Ostman, 2020) to collect wilderness data involved rating some anthropogenic and perceptual attributes on a scale of 0 (non-existent) to 5 (highly present). Anthropogenic attributes include: 1) buildings (number/size), 2) proximity to facilities, 3) roads (number/difficulty), 4) traffic intensity, 5) traffic type, 6) traffic noise, 7) power lines, 8) fences, 9) other infrastructure, and 10) animals/livestock. Perceptual attributes include: 1) untrammeled, 2) primeval, 3) unconfined, 4) ruggedness, 5) solitude, 6) surprise, 7) well-being, 8) peacefulness, 9) wonder/awe, and 10) humbleness. A wilderness score was calculated based on the difference between aggregated perceptual and anthropogenic ratings. Their distribution seems rather consistent with wilderness maps produced in Iceland. While this is valuable and complementary with other wilderness maps, the choice of indicators and the assumption of equal weight can affect the final score.

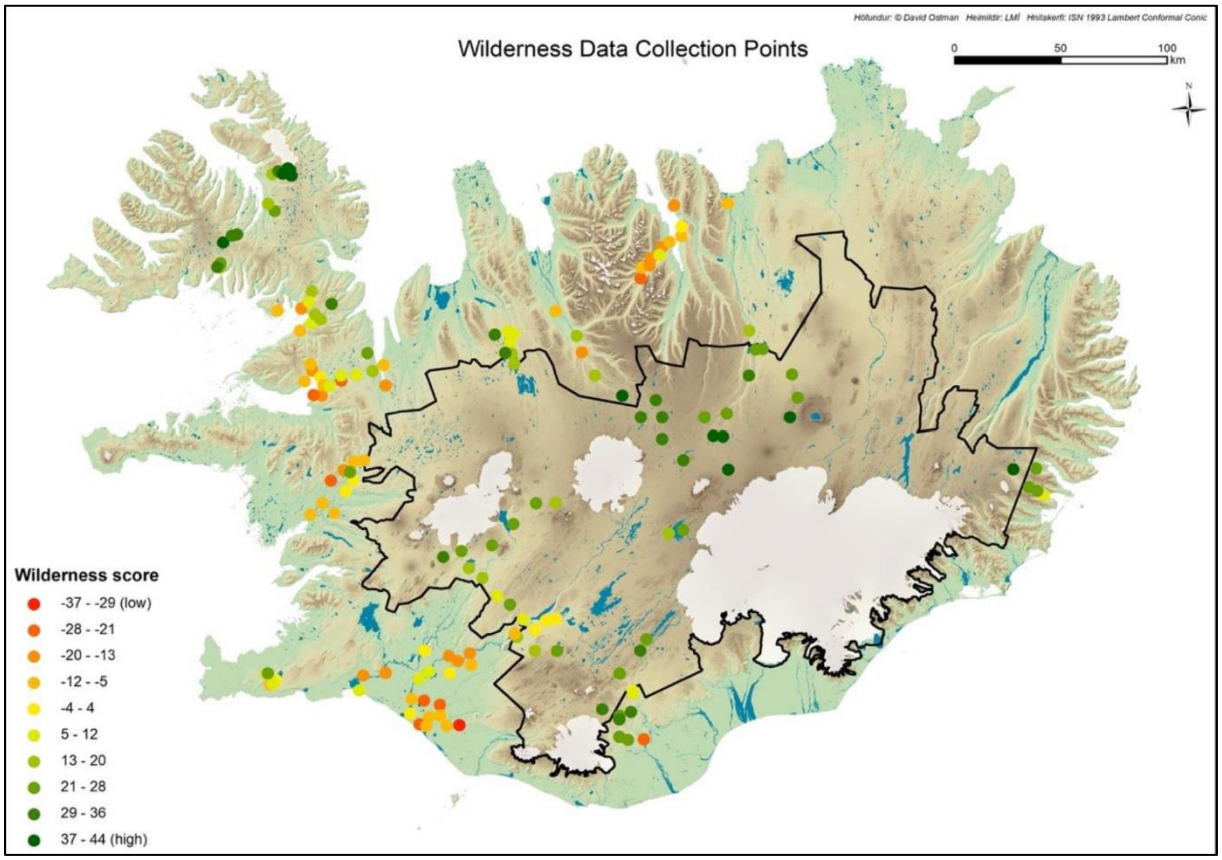


Figure 17: Map of the data-points for which wilderness scores were calculated. Source: Ostman (2020)

[19] The Icelandic Master Plan for Nature Protection and Energy Utilization evaluates the impacts of energy projects over 10 MW, through four expert groups focusing on: 1) the natural values and cultural heritage, 2) uses of natural resources other than energy harnessing, 3) social impacts, and 4) economic impacts.

5.2 - Local application of WQI for impact assessment

Incorporating wilderness mapping at a local level for environmental impact assessments and land-use planning has been particularly challenging due to the lack of methods and data to assess and quantify wilderness loss/gains. Over the past few years, two local case studies have aimed at evaluating different development options using an early version of the WQI developed by Carver et al. (2023) and the WRI (2022; WRI & ÓFEIG, 2024).[20] The first case focused on proposed hydropower development in the Westfjords of Iceland (WRI, 2019), quantifying the loss of WQI (using WQI classes for simplification purposes) and comparing different development options for road access and energy transmission. The authors compare the impact of an overhead powerline with those of an underground powerline, as well as the impacts of a maintenance road open to motorized vehicles (fast access) or not (slow access). Both cases show a substantial reduction of WQI class, due to the presence in both cases of a new road through areas with high WQI (Figure 18). A similar project carried out two years later focused on the hypothetical re-opening of Vonarskarð 4x4 track, in which proportion of WQI core areas that would be downgraded were quantified (WRI, 2021).

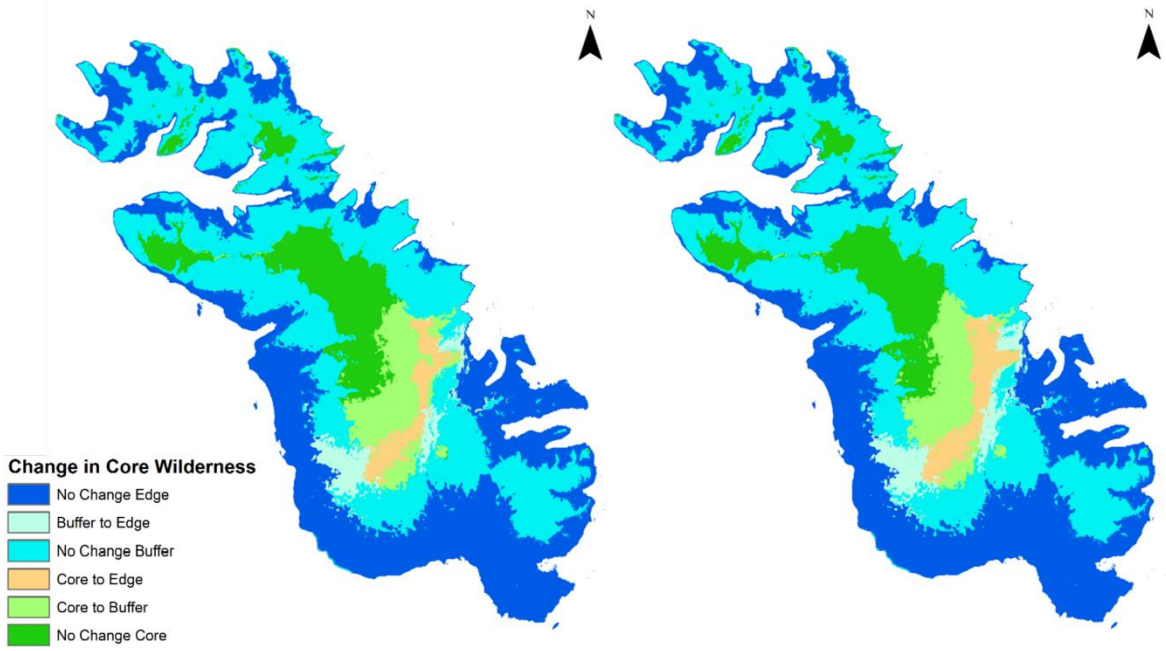


Figure 18: Changes in Core Wilderness WQI class with slow access and underground power line option (Left), and fast access and overhead power line option (Right). Source: WRI (2019)

While these cases reflect well the potential of using the WQI and its sub-components to assess and quantify the impact of various projects, a limiting factor to the broader implementation of such a method lies in its complexity, requiring substantial training and adequate computing capacities to handle basic procedures, increasing the time and cost of such environmental impact assessments. Recent assessments of wilderness impact for proposed power plants have indeed incorporated WQI (Sæþórsdóttir et al., 2024) by simply overlaying distance buffers on the WQI class layer to quantify wilderness quality losses. Developing this tool as an evolutive tailor-made software for environmental impact assessments in the Icelandic context, using the most up-to-date geodata might be more realistic than expecting mapping parties to make consistent choice when using this method, due to the large number of variables and parameters involved.

[20] See section 3.2.3 (p. 24).

5.3 - Qualitative wilderness impact assessment

A recently published report on the wilderness impacts of the proposed Skrokkaldavirkjun power plant provides valuable insights due to its unique location along one of the main highland roads through the interior of the country (Sprengisandsleið), near areas where substantial human modification took place and others where nature seems preserved from visible direct human interferences (Sæþórsdóttir et al., 2024). The proposed construction of buildings and related road developments were assessed to disturb the wilderness experience in that area, by pushing further inland the moment where one feels like entering the Central Highland, as landscape entities can be bounded by human features, such as where the paved road stops and the adventure begins. The report further highlights differences between two highland roads in that area. Sprengisandsleið follows the shape of the land and winds around the hills and dunes where nature allows, without bridges or culverts, connecting the traveler to the country. Kvisluveituvegur road on the other hand, is built up and often runs over some dams, which clearly appear as anthropogenic, as straight lines provide evidence of human activity. These elements constitute direct impacts on the wilderness experience, for which the sense of remoteness is essential, even in areas that are disturbed to some extent. Indirect consequences were also reported regarding road developments: by enabling an increase of visitor numbers, road development would lead to more pressure on the sensitive nature, changing the nature of tourism, attracting new target groups and more visitors, subsequently requiring more increased infrastructure and services, ultimately reducing the natural appearance of the area and spoiling visitors' experience. While anthropogenic structures' appearance, design and visibility involve some wilderness impacts, their usage is also an important factor of disturbance which should not be neglected.

5.4 - Participatory mapping of wilderness in Iceland

In 2016, a nation-wide survey using participatory mapping methods dedicated to wilderness in Iceland was carried out. Respondents were tasked to indicate on a map of Iceland where is wilderness in their opinion (Ólafsdóttir et al., 2016). The results suggest that the Central Highland is largely associated with wilderness in the mind of Icelanders, as well as Hornstrandir and the highlands in the Westfjords, Tröllaskagi, Fjörður, Melrakkaslétta and Reykjanes peninsula (Figure 19). This seems rather consistent with wilderness maps produced in Iceland, although some developed areas are identified as wilderness (such as the Þjórsá-Tungnaá area's hydropower complex), alongside with area in proximity to large settlements (e.g. Reykjanes peninsula) and areas with important vehicular traffic (e.g. ring road between Mývatn and Egilsstaðir). This suggests that there is either some tolerance towards such components, or perhaps a lack of local-scale knowledge regarding the presence of incompatible features. Respondents were further asked about the shared characteristics of these areas which contribute to their wilderness character in an open question. Lack of permanent residence or inhabited character is seen as the first main contributor, followed by the lack of signs of human presence, the pristine nature, openness, and distance from settlements. Respondents were then asked to map the wilderness areas that they had already visited. The resulting map shows clearly the main roads across the Central Highland, and some popular areas, such as Landmannalaugar, Þórsmörk, or Laugafell (Figure 20). The perception of such areas as wilderness despite the presence of incompatible features (e.g. roads, reservoirs, etc.) makes the case for managing them to preserve their wilderness qualities (e.g. by defining "disturbed wilderness" areas) but should not be seen as setting a precedent for further developments in wilderness areas. In total, 70% consider that there is a threat to the Icelandic wilderness (Ólafsdóttir & Sæþórsdóttir, 2020c), and 87% find necessary to protect wilderness in Iceland, by managing tourism and limiting energy-related development in the area, especially in the Central Highland, in Hornstrandir and in the East Fjords (Ólafsdóttir et al., 2016), mainly in relation to power plants (36%), tourism (27%), natural disasters or climate change (8%), upbuilt roads or increased access (7%), followed by some other threats (all scoring below 5%).

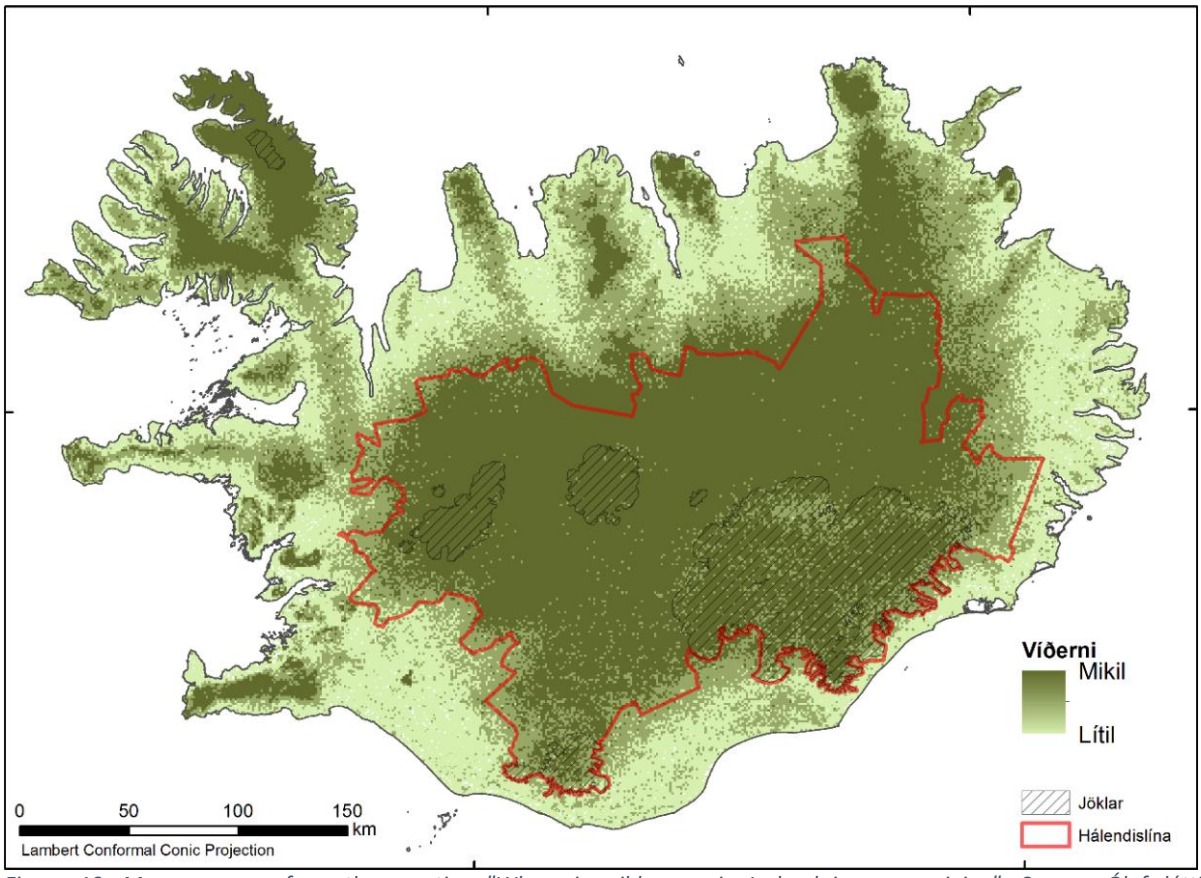


Figure 19: Map-responses from the question "Where is wilderness in Iceland in your opinion". Source: Ólafsdóttir, Sæþórsdóttir, Guðmundsson, et al. (2016)

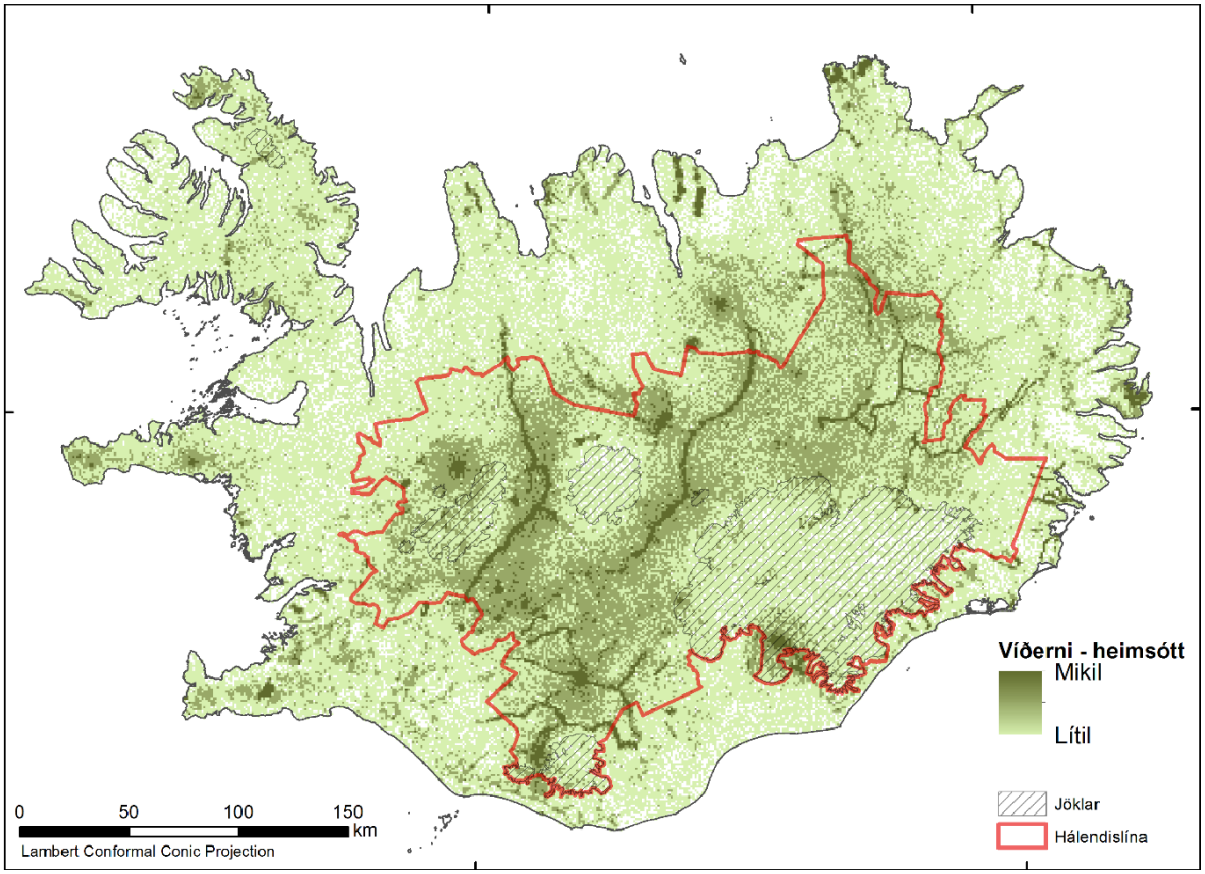


Figure 20: Map-responses from the question "Which of the wilderness areas (which you marked), have you visited?". Source: Ólafsdóttir, Sæþórsdóttir, Guðmundsson, et al. (2016)

5.5 - Public preferences for wilderness management

Perceived appropriateness of structures and other features

Public perception of the appropriateness of various items in wilderness was investigated (Ólafsdóttir & Sæþórsdóttir, 2020a). While basic infrastructure and services are seen as appropriate in wilderness[21] by a majority, more developed infrastructure and services are overall seen as more inappropriate (Figure 21). For road infrastructure, "good access during the summer months" is seen as appropriate by 76% of respondents, "jeep tracks" by 64%, "road bridges over waterways" by 54%, "upbuilt gravel roads" by 53%, and "upbuilt roads with paved surface" by 37%. Likewise, "mountain huts" and "camping grounds" are seen as appropriate in wilderness by 75% and 74% respectively, while "hotels" are seen as appropriate by 20%. In terms of energy harnessing, "utilization of energy resources" and "wind farms/wind turbines" in wilderness are seen as appropriate by about 38-39% versus 31% who find them inappropriate. "Geothermal" and "hydropower plants" are seen as appropriate by 28% and inappropriate by 33-34%, while power lines and reservoirs' perceived appropriateness is lower.

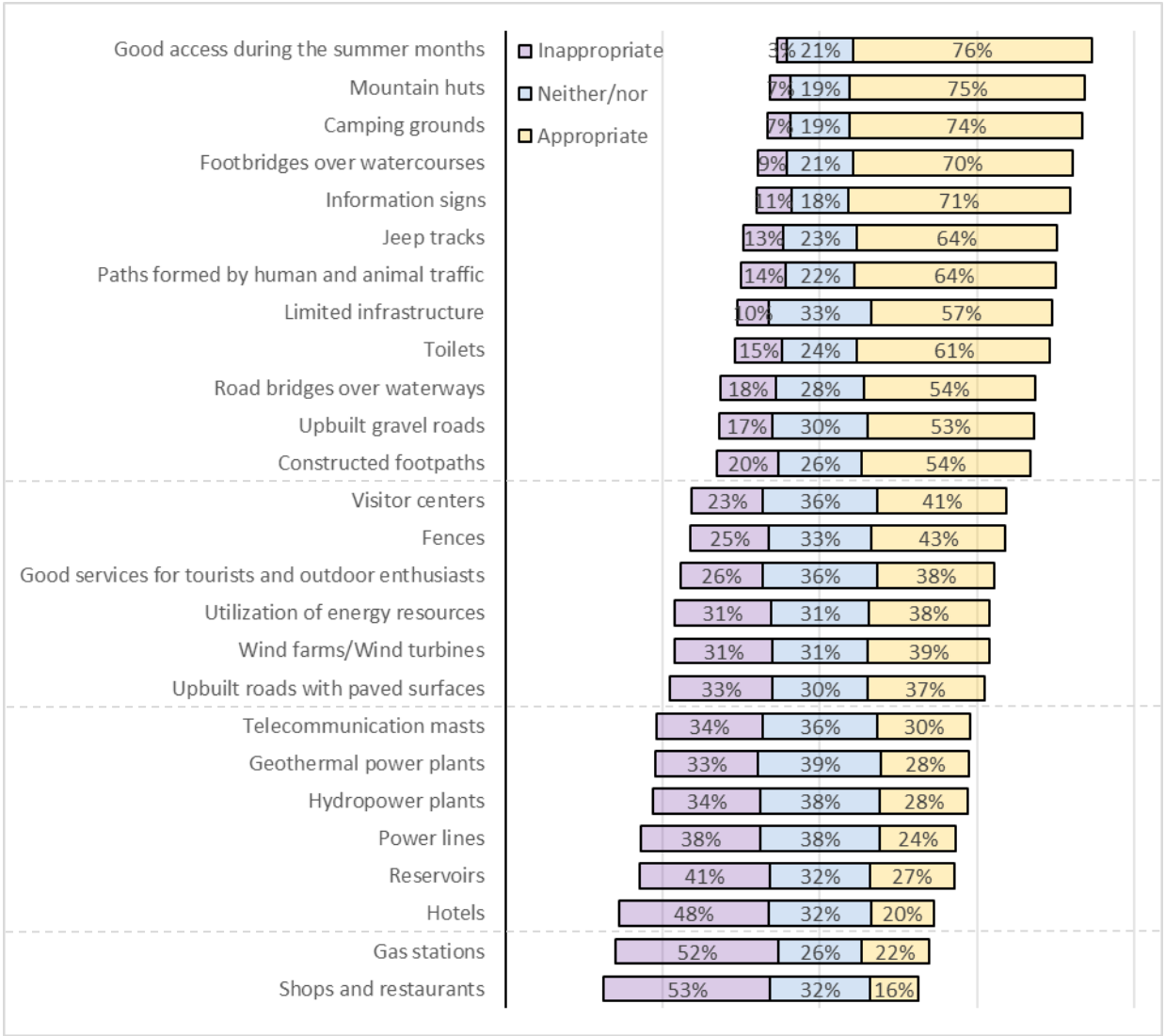


Figure 21: Perceived appropriateness of selected items in wilderness for the Icelandic public. Ranking based on mean score. Cumulated percentages can exceed 100% due to rounding. Data: Ólafsdóttir, Sæþórsdóttir, Guðmundsson, et al. (2016).

[21] Note that these views differ on most items related to travel services if respondents are asked about it for uninhabited areas or for the Central Highland, where they are seen as less appropriate than in wilderness.

This relative ranking is supported by on-site visitor surveys, with overall less than 20% of respondents considering reservoirs, visitor centers, power lines, wind farms, telecommunication masts, dams and hotels compatible with wilderness (Sæþórsdóttir et al., 2017; Stefánsson et al., 2017).[22] Jeep tracks, constructed hiking paths, paths formed by human and animal traffic, and mountain huts are usually seen as compatible. Using photos, another nation-wide survey assessed the perceived impact of anthropogenic structures on wilderness (SSRIUI, 2020): photos with power lines were associated with a high impact (i.e. score of 7-10) by 50% of respondents and those with a wind farm by 35-58% of them depending on the distance from the turbines. Other structures were associated with a lower level of impact: 34-38% considering at least some impact (i.e. score of 4-10) for the photos that are showing cabins, tents and cars, 19-29% for those showing jeep tracks.

Multiple perceptions of wilderness

Wilderness perceptions are very subjective and can range from very strict understanding to much more flexible conceptions. To illustrate this, a "purism scale" (Sæþórsdóttir et al., 2022) has been used to classify respondents according to their preferences for infrastructure and services in wilderness areas, ranging from strong purists or naturalists to non-purists or urbanists. Wilderness according to strong purists covers much smaller areas than wilderness according to non-purists (Figure 22) (Ólafsdóttir, Sæþórsdóttir, & Runnström, 2016). While areas meeting strict requirements would be seen as wilderness by most, partially disturbed areas would only be perceived as wilderness by a few.

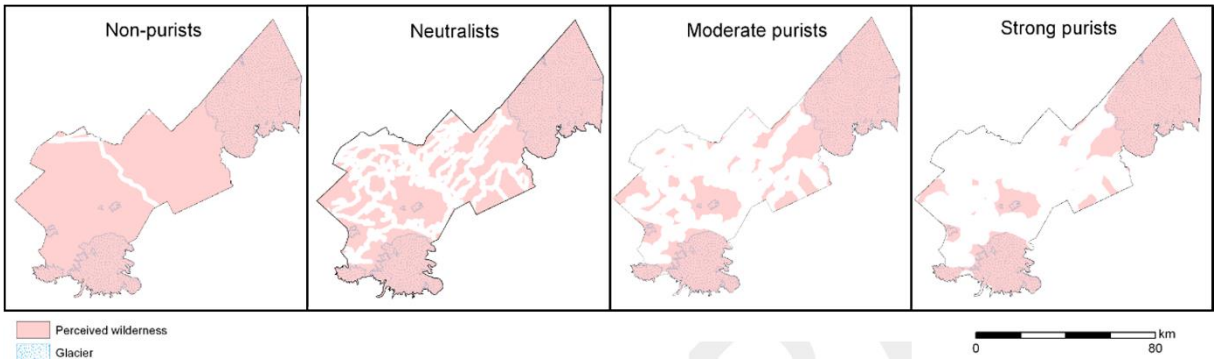


Figure 22: Maps of the extent of the perceived wilderness in the Southern Highland of Iceland, using the criteria expressed by the four purist groups. Source: Ólafsdóttir, Sæþórsdóttir, and Runnström (2016).

At a nation-wide level, it is estimated that about 51,8% of the public qualifies as "Non-purists", 39,8% as "Neutralists", and 7,8% as "Moderate purists" and 0,6% as "Strong purists" regarding wilderness management (Ólafsdóttir & Sæþórsdóttir, 2020b). In contrast, visitor surveys conducted in the interior of the country usually find 5-16% of non-purists, a majority of neutralists, and 20-35% of purists regarding the management of the surveyed sites (Sæþórsdóttir et al., 2017). This suggests that the users of these areas express stricter management preferences compared to the general public (which also includes non-users[23]), as they seem most likely to be impacted by decisions related to wilderness management.[24] Among visitors, Icelanders tend to perceive areas as less natural than others (e.g.

[22] Respondents were asked about which structures can be in an area without the concept of wilderness or unspoiled nature losing its meaning.

[23] About a third (i.e. 32%) of the Icelandic public have never been in the Central Highland (Bishop et al., 2022), only 23% go there several times a year, and 16% only visit natural areas once a year or less (Ólafsdóttir, Sæþórsdóttir, Guðmundsson, et al., 2016).

[24] As an example, nearly half of the users of the Central Highland oppose building up roads there (i.e. 41% disagree with the statement "*Roads in the Central Highland should be upbuilt*"), compared to just over a quarter of non-users (27%) (Bishop et al., 2022). A much stronger opposition (63%) was expressed by respondents of a

Sæþórsdóttir et al., 2017), perhaps due to better knowledge of the area and awareness human pressures (e.g. soil erosion, overgrazing, disturbed river due to hydropower use). They also appear more opposed than other visitors to transmission lines, especially in the highlands (Stefánsson et al., 2017) and their perceived appropriateness of reservoirs, hydropower and geothermal plants in Blandá area is low compared with visitor with other nationalities (Sæþórsdóttir & Hall, 2018). Unfortunately, surveying management preferences of domestic wilderness users at a nation-wide level is costly and therefore limited. In-depth interviews conducted in 2016 with recreational users however provide further insights (Social Science Research Institute of the University of Iceland, 2016). For instance, hikers, bicyclists, horse-riders and jeep enthusiasts seem to experience wilderness in a much more flexible way than what is assumed by the legal definition. All seem to agree that wilderness should be preserved as intact as possible without significantly reducing access and travel freedom for outdoor groups. Other studies have indeed pointed out that safeguarding recreational interests is particularly critical to secure public support for wilderness management in context were public access rights are deeply rooted in the local culture (Bishop et al., 2022).

5.6 - Implications for wilderness mapping

The reviewed case studies, which include field assessment of wilderness attributes as well as impact assessment using both quantitative (WQI impact mapping) and qualitative methods (interviews and ethnographic research) offer relevant insights for wilderness mapping, such as the following:

- Field work conducted to assess wilderness by using perceptual dimensions and anthropogenic components provides ground verification which seems to support existing wilderness maps, as the high wilderness scores are usually located in areas which have been identified as wilderness. Further development of this method and a higher number of data points might be useful for zoning or conservation purposes.
- High-resolution spatial indicators such as the WQI can provide a powerful tool for environmental impact assessments, enabling quantification of wilderness loss beyond simple spatial extent considerations, and accounting for the degree of wilderness being impacted. This is particularly valuable to compare wilderness impacts between multiple scenarios. Further development of this tool embedding relevant geodatabases and minimizing user inputs to facilitate third party use seems necessary for a broader use in Iceland.
- Qualitative assessment of wilderness impacts along a popular jeep track suggests that design can directly impact how an area is experienced. Some highland roads indeed have more artificial characteristics (e.g. Kvisluveituvegur) compared to others (e.g. Sprengisandsleið). At the same time, indirect impacts on the wilderness experience can result from uses facilitated by increased road access which can be an important vector of disturbance. This highlights the need for wilderness mapping to incorporate human perceptions of features and uses and makes the case for considering wilderness in settings which are already somewhat disturbed.

The perception studies, encompassing public opinion research, visitor surveys and interviews, add to the elements mentioned above:

- Nation-wide participatory mapping of areas perceived as wilderness by the Icelandic public seems rather consistent with the wilderness maps reviewed under the scope of this project.
    - Large parts of the interior of the country and of the Westfjords are identified as wilderness, as opposed to coastal areas, which is consistent with other wilderness maps and support these methods.

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parallel identical survey sent out to all registered recreational and environmental NGOs in Iceland (Unpublished survey data collected in May 2018, analyzed by the authors).

    - Discrepancies can however be found, as some large, disturbed areas are perceived as wilderness (e.g. hydropower complex in Þjórsá-Tungnaá catchment area), making the case for considering wilderness attributes in the management of such areas.
    - Areas identified as wilderness that were visited by respondents are distributed along the main highland roads, tracks and mountain huts, suggesting that the use of such features can be related to wilderness experiences, which supports managing them accordingly.
    - The vast majority of respondents consider that the Icelandic wilderness is under threat and requires protection, mainly from tourism and energy developments, highlighting the urgency for wilderness mapping to be completed and effectively incorporated in planning policies.
- Public perception of structure appropriateness in wilderness varies substantially depending on:
    - The structure type considered, e.g. whether they relate to travel purposes, in which case they tend to be seen as appropriate, or if they relate to more industrial uses such as energy harnessing, in which case views are much more nuanced and likely to be context-dependent.
    - The level of development considered, with basic services and structures seen as appropriate (e.g. mountain huts, jeep tracks, information signs), while more complex or developed items are seen as more inappropriate (e.g. hotels, paved upbuilt roads, shops and restaurants).
- There is a broad range of wilderness perceptions and management preferences among the Icelandic public, from a very strict understanding to much more flexible conceptions of wilderness.
    - The majority of the Icelandic public qualifies as “non-purists” according to the purism scale (Sæþórsdóttir et al., 2022), meaning that they have a relatively inclusive and flexible conception of wilderness, and usually tolerate a wide range of structures in wilderness.
    - Data from visitor surveys suggests that wilderness users, however, tend to express stricter management preferences than the general Icelandic public and are more likely to be impacted by developments that non-users would tolerate. They also have a more rigorous perception of what areas qualify as wilderness.
    - Domestic users who took part in visitor surveys perceive surveyed areas as less natural than other visitors. This suggests that local users' perceptions of naturalness are influenced by their knowledge of past human interventions, which supports using their criteria for naturalness rather than those of other visitors. They also seem more opposed than others to transmission lines, especially in the highlands, highlighting their incompatibility with wilderness.
    - In-depth interviews with domestic recreational users reveal high concerns over access restrictions and impairment of travel freedom for outdoor groups, along with an agreement on the need for wilderness preservation. This raises some questions regarding how recreational impacts are to be dealt with in terms of wilderness mapping.

This broad range of perceptions and related management preferences among the Icelandic public can inform wilderness mapping in Iceland, despite the complexity involved. Defining the maximum theoretical wilderness extent in Iceland to provide an “outer frame” within which wilderness should be considered might be a relevant approach. Within that scope, disturbed areas where reversible human modifications already took place could be further identified, as well as areas meeting stricter requirements. Effective management of disturbed areas could be aimed at minimizing wilderness impacts, e.g. by removing traces of modern structures that are no longer in use or putting power lines underground. Management of areas meeting strict wilderness requirements could include their designation as protected wilderness areas according to Article 46 of the Nature Conservation Act 60/2013.

6. Recommendations

This section provides, on the basis of the comparative analysis, a set of recommendations regarding the criteria and assumptions which need to be defined in more detail or clarified to reduce the subjective interpretation of the Icelandic Nature Conservation Act 60/2013 so that consistency can be ensured in the mapping of *uninhabited wilderness* in the country.

6.1 - Clarifying the legal basis for wilderness mapping

The current legal framework allows for multiple interpretations of how mapping should be conducted and whether it should be based on Article 5.19 (defining *uninhabited wilderness*) or Article 46 (corresponding to the protected area category *uninhabited wilderness*) of the Nature Conservation Act 60/2013. Upon further consultation with specialists from the IMEEC, it seems clear that mapping of *uninhabited wilderness* should primarily be based on the definition presented in Article 5.19,[25] while retaining the possibility of identifying areas within that perimeter which are compatible with the requirements of Article 46.[26] In other terms, mapping work based on Article 5.19 could lay groundwork for designation under Article 46 without being sufficient in itself, as additional criteria would apply. This would simplify the mapping task for faster incorporation in land-use planning. Such a clear distinction and legal basis would benefit from being stated in a regulation:

- ❖ Mapping of *uninhabited wilderness* shall be based on Article 5.19.
- ❖ Within the areas mapped as *uninhabited wilderness*, those meeting the stricter requirements of Article 46 shall be further identified.

Referring to the management category as *protected wilderness* would be beneficial to better distinguish the planning concept and management tools under Article 5.19 and Article 46, for example by using the term *Víðernaverndarsvæði* in Article 46 and adjusting the wording to reflect that large *uninhabited wilderness* areas meeting the requirements of Article 46 can be protected as such.

Based on the interpretation of Articles 5.19 and 46, the following implications are pointed out in terms of wilderness mapping:

- It is unclear whether uninhabited wilderness can refer to marine environments such as around archipelago of small islands, due to the use of the term *land area* (*i. landsvæði*) in Article 5.18.
- It is unclear whether cultivated lands can be included in *uninhabited wilderness*.
- Unless they are considered inconspicuous and non-disruptive to the enjoyment of solitude and nature, anthropogenic structures are usually excluded from *uninhabited wilderness*, usually by about 5 km.
- The use of flexible size and distance criteria is intended to protect more areas and allows for tailor-made adjustments to the context, e.g. to account for topographic or barrier features, as well as for the degree of severity of the impacts.
- Thresholds in terms of *inconspicuousness of structures*; of *capacity to enjoy solitude and nature*; and *disturbance from motorized vehicle traffic and anthropogenic structures* all depend on the subject, time-space settings, and are relative, making the mapping task very challenging.

[25] Confirmed by specialists at the IMEEC (personal communication, June 21, 2024): *kortlagning óbyggðra víðerna ætti að vera í samræmi við það hvernig óbyggð víðerni eru skilgreind og sú skilgreining kemur fram í 19. tölul. 5. gr.*

[26] Confirmed by specialists at the IMEEC (personal communication, June 7th, 2024): *Ef friðlýsa á svæði samkvæmt þeim friðlýsingarflokki þá þurfa viðkomandi svæði samt sem áður að uppfylla skilgreiningu 19. tölul. 5. gr. laganna. […] Þannig getur kortlagningin horft til 46. gr. laganna hvað varðar möguleg svæði sem hægt væri að friðlýsa sem óbyggð víðerni en svæðin þurfa alltaf að uppfylla skilgreiningu 19. tölul. 5. gr.*

6.2 - Defining the term upbuilt roads

The lack of legal definition of the term *upbuilt roads* (*i. uppbyggðir vegir*) associated with the absence of data on their extent has posed substantial challenges to all mapping projects. While it is commonly assumed that paved roads are upbuilt, there is substantial uncertainty regarding which type of unpaved roads would fall in this category. In relation to roads, *uppbyggður* is defined by the Modern Icelandic Dictionary as *built from several layers*.[27] However, a legal definition of the term could be more specific to reduce the ambiguity and facilitate the inventory of such roads. This would provide a clear framework for quantifying the intrusiveness of roads and increase consistency in mapping of *uninhabited wilderness* in Iceland. Therefore, it is recommended that:

- The term *upbuilt roads* (*i. uppbyggðir vegir*) should be clearly defined to reflect the degree of human intervention involved. This definition should focus on physical characteristics and appearance to facilitate an inventory of such roads among those that are unpaved for wilderness mapping purposes.

The following criteria could be used or further refined to identify such roads from a legal standpoint:[28]

- The construction of upbuilt roads often requires extraction, transport and deposition of material using road machinery, such as trucks, bulldozers, and levelling machines.
- The surface of an upbuilt road is often substantially different from the surroundings in terms of material and appearance. Paved roads or roads with gravel on top are considered upbuilt.
- The road is often higher than the surrounding grounds to facilitate water drainage and roadsides are accordingly leveled. Hence, the ground is disturbed beyond the area meant for driving.
- The road is often more durable and induces more permanent or irreversible changes. Restoring pre-construction appearance often requires substantial intervention.
- The road designs are often with a higher linearity or larger curves to maximize driving efficiency.
- Upbuilt roads often include bridges or culverts over waterways and streams.

In contrast, non-upbuilt roads and tracks are often formed through repeated driving by the path of least resistance, following the topography so that the least material outtake is required. The distinction between them may be related to whether it is maintained with levelling machines or not, as well as whether there are localized constructed segments (e.g. culverts, bridges). Tracks are also typically less suitable for vehicles other than 4x4 or SUVs, or vehicles with low ground clearance.

6.3 - Considering the INPA recommendations

In the proposed addendum to the INPS 2015-2026, recommendations formulated in the report from INPA & EAI (2019) were included (INPA, 2021, p. 7). These are considered relevant to increased consistency across future mapping of *uninhabited wilderness*:

- The boundaries of *uninhabited wilderness* are generally 5 km from anthropogenic structures and other evidence of technology that are considered intrusive towards the natural quality of uninhabited lands.[29]
- The reduction distance will be longer than 5 km in the case of very large structures and evidence of technology, but shorter than 5 km due to smaller structures and evidence of

[27] Definition of *uppbyggður (vegur)* by the Modern Icelandic Dictionary. Original wording: *byggður upp af mörgum lögum*. Retrieved June 20th, 2024, from: https://islenskordabok.arnastofnun.is/ord/62294.

[28] Criteria list inspired by the descriptions of *Sprengisandsleið* and *Kisluveituvegur* in Sæþórsdóttir et al. (2024)

[29] Original wording: *Mörk óbyggðra víðerna miði almennt við 5 km frá mannvirkjum og öðrum tæknilegum ummerkjum sem teljast ágeng gagnvart náttúrugæðum óbyggða*

technology, which, however, are considered to impair the natural quality of uninhabited lands.[30]

- ❖ The reduction distance is also determined by whether landforms obscure the view of the structure in question.[31]
- ❖ Within *uninhabited wilderness* there may be isolated, small-scale structures and evidence of technology that are compatible with the wilderness experience and the natural quality of the uninhabited lands.[32]

These four criteria clarify the interpretation of Article 5.19 by introducing several concepts:

Intrusiveness: The minimum distance only applies to structures and other technical traces that are considered intrusive. It includes structures and other technical traces mentioned in Article 5.19, while other structures reaching a disproportionate or excessive scope would also be considered incompatible. It could also include some of the features perceived as more inappropriate than appropriate in wilderness by the Icelandic public or by wilderness users.[33] Aside from upbuilt roads, power plants, power lines and reservoirs which are mentioned in Article 5.19, these could also include based on Ólafsdóttir, Sæþórsdóttir, Guðmundsson, et al. (2016) the *shops and restaurants* and *gas stations*, which are considered inappropriate in wilderness by a majority, as well as *hotels* and *telecommunication masts*, overall more considered as inappropriate than appropriate. In areas where multiple buildings are in proximity to each other, their combined effect should be considered to account for cumulative impacts (e.g. building clusters). Intrusiveness could also be considered in terms of level of interference to the unhindered progress of nature and of the ecosystem, humans being part of it, enjoying, studying and travelling around it, based on the report by the INPA & EAI (2019).

Suitable curtailment distance: The 5 km distance mentioned in Article 5.19 must match the level of disturbance associated with the intrusive feature considered. However, an arbitrary minimum distance of about 1 km is suggested for any feature considered intrusive in order to increase the boundary visibility on regional to country-wide maps. Some structures induce higher impact due to their dimensions, location and visibility which can reach far beyond the 5km stated in the law, such as in the case of wind turbines, telecommunication masts, or geothermal power plants. In such cases, the reduction distance could be increased and tailored based on the visibility, the topographic settings and the structure usage intensity. Defining *very large* and *smaller structures* in a wilderness context is needed. In the case of accommodation buildings, this could be based on their surface area, though building height and capacity could also be considered, such as:[34]

- Very small buildings: 0-24 m², only one floor without attic, 0-9 guests, e.g. *Arnarvatn litla*, *Hvannalindir*.

[30] Original wording: *Skerðingarvegalengd verði lengri en 5 km í tilviki mjög stórra mannvirkja og tæknilegra ummerkja, en styttri en 5 km vegna umfangsminni mannvirkja og tæknilegra ummerkja, sem þó teljast skerða náttúrugæði óbyggða*

[31] Original wording: *Skerðingarvegalengd ráðist jafnframt af því hvort landform byrgja sýn að viðkomandi mannvirki*

[32] Original wording: *Innan óbyggðra víðerna geti verið stök, umfangslítil mannvirki og tæknileg ummerki sem samrýmst geta óbyggðaupplifun og náttúrugæðum óbyggða*

[33] Public opinion research focusing on wilderness users is currently lacking in Iceland, while considered particularly valuable for wilderness identification and management policies.

[34] Such thresholds should ideally be grounded on perception studies and are only provided here for demonstration purposes. The size thresholds used are inspired by the 50 m² needed to consider a built surface as artificial in the French Law aiming at achieving a Zero Net Artificialization (ZAN) (e.g. Redon & Mialot, 2024). Other thresholds used include 2500 m² for unbuilt surfaces, 5 m width for linear structures, and 25% of tree cover to qualify as forested areas (French Ministry of Ecological Transition and Territorial Cohesion, 2023).

- Small buildings: 25-49m², only one floor with upper level (e.g. loft, attic), 10-19 guests, e.g. *Geldingafell*, *Sveinstindur*.
- Large buildings: 50-199 m², only one floor with upper level (e.g. loft, attic), 19-99 guests, e.g. *Strútur*, *Nýidalur*.
- Very large buildings: 200+ m², one floor with upper level (e.g. loft, attic) or 100+ guests, e.g. *Hveravellir*, *Drekagil*

Visibility: The third criterion which incorporates visibility seems particularly relevant to justify consideration for the topography, the terrain, and the size of the source of disturbance into the analysis, to better reflect human perceptions. It is however critical that the distance used is based on the maximum theoretical visibility, using appropriate structure height data, while also accounting for distance decay. This might require tailor-made assessments to anticipate the development of taller structures over time, such as in the case of wind turbines which have gradually increased in height as technology evolves.

Exemptions: Some structures and technical traces can be present in wilderness areas under the condition that these are isolated, small-scale cases which are compatible with wilderness. This implies that the exemption would be made based on the result of some tailored assessment rather than an application as a rule for a given structure type. As for the intrusiveness criterion, defining the term *small-scale* in relation to structures and technical traces in wilderness areas would be beneficial, e.g. by using surface area thresholds, height, width or even incorporating usage intensity or capacity.[35] The compatibility with wilderness can be interpreted in terms of level of relation to the unhindered progress of nature and of the ecosystem based on the report by the INPA & EAI (2019). This includes enjoying, studying and travelling around it, though there is some ambiguity regarding commercial usage. Public perceptions can support decisions on exemptions: some of the features perceived as more appropriate than inappropriate in wilderness by the Icelandic public or wilderness users could be considered as more compatible and tolerated in wilderness areas. Based on Ólafsdóttir, Sæþórsdóttir, Guðmundsson, et al. (2016), this could potentially apply to *good access during the summer months*, *mountain huts*, *camping grounds*, *footbridges over watercourses*, *information signs*, *jeep tracks*, *paths formed by human and animal traffic*, *limited infrastructure*, *road bridges over waterways*, *upbuilt gravel roads* and *constructed footpaths*. While many features such as *visitor centers*, *fences*, *good services for tourists and outdoor enthusiasts*, *utilization of energy resources*, *wind farms/wind turbines* and *upbuilt roads with paved surface* are seen by a larger proportion of the Icelandic public as appropriate rather than inappropriate, upbuilt roads and power plants are mentioned as usually 5 km away from wilderness in Article 5.19. Consequently, it seems particularly difficult to justify such an exemption, which would require a very strong basis. This was done for small hydroelectric plants supplying some mountain huts in the report by the INPA & EAI (2019). Data on the preferences of nation-wide wilderness users would be helpful to make informed decisions regarding such features.

6.4 - Incorporating other criteria

The consideration of additional criteria would be relevant to better reflect the characteristics of wilderness areas and increase consistency in terms of mapping. Adjusting criteria derived from the IUCN 1b guidelines to the Icelandic context would be beneficial. Furthermore, incorporation of naturalness and topography would reflect more accurately perceptions, making it more relatable to stakeholders.

[35] See also footnote 34 on the previous page. Considering the built surface of accommodation structures in the Central Highland of Iceland (INPA, 2018), a total built surface area threshold around 50 m² seems appropriate to qualify as small-scale, given that a reasonable height and capacity limit is also used. Perceptions studies should ideally further investigate public and wilderness users' opinion on such a matter.

Integrating and adapting IUCN 1b Wilderness Areas guidelines

Article 73 of the Nature Conservation Act 60/2013 does not refer to any specific methodology nor criteria for wilderness mapping. The explanatory notes however mention that mapping should be carried out based on *internationally recognized methodologies* (IMENR, 2020a). In the absence of further explanation as to what constitutes international recognition in this context,[36] the guidelines for IUCN 1b Wilderness Areas might provide a baseline for wilderness mapping, from which some criteria can be derived, e.g. from their descriptive characteristics (Dudley, 2008, pp. 14-15):

- *Be free of modern infrastructure, development and industrial extractive activity […]*
- *Be characterized by a high degree of intactness […]*
- *Be of sufficient size to protect biodiversity […]*
- *Offer outstanding opportunities for solitude […]*
- *Be free of inappropriate or excessive human use or presence […]*
- *[Can include] somewhat disturbed areas […], smaller areas that might be expanded […]*

These criteria are already somewhat covered by the Icelandic legislation, although they could be further specified or adjusted to the Icelandic context. Adopting the propositions from INPA (2021) presented in section 6.3 would contribute to incorporating these IUCN criteria in wilderness mapping. The following points should also be considered:

- The size requirement which is related to the preservation of ecosystem characteristics might be different from other contexts due to the little presence of wildlife in large parts of the country.
- The intactness criterion was somewhat incorporated in the 1999 definition of *untouched wilderness* but considered too strict or inadequate due to the scope of anthropogenic impacts,[37] resulting in hardly any reference to natural processes in Article 5.19.
- Last, while opportunities for solitude are also mentioned in the legal definition, the emphasis in the IUCN 1b criteria is placed on having non-motorized or highly regulated motorized access out of considerations for the biological objectives of these areas. Whether the area's abiotic characteristics and social acceptance of restrictions on motorized uses provide some flexibility in the application of IUCN 1b criteria remains to be seen. Adequate stakeholder consultation is critical, as this topic seems particularly likely to result in restricted access conflicts which can undermine conservation incentives (Bishop et al., 2022).

Integrating naturalness as a criterion

The legal definition of *uninhabited wilderness* in Article 5.19 does not refer to naturalness as a criterion, aside from the possibility to "enjoy solitude and nature". However, some of the work reviewed has incorporated naturalness, e.g. the IINH (2018), Ostman et al. (2021) and the WRI & ÓFEIG (2024) have either excluded or considered artificial/built surfaces, cultivated lands, planted forests, lupine fields, grazing lands and more generally land cover and land use in their mapping outputs. However, by excluding disturbed areas, mapping of *uninhabited wilderness* somewhat overlooks the qualities that make wilderness valuable, even in such affected settings. Among these qualities, the influence of natural processes and the degree of intactness could be incorporated. This could be done based on the following recommendations:

❖ Naturalness could be incorporated as a criterion to exclude the least natural areas where human interventions interfere most with the experience of nature.

[36] The methods reviewed have been used in many international peer-reviewed studies and contexts, for different purposes, with substantial variation regarding the choice of indicators, weights and thresholds (Ye et al., 2024), making it difficult to claim that a particular method would qualify as internationally recognized.

[37] e.g. in the Central Highland (IMENR, 2012, p. 77)

- ❖ Describing and mapping naturalness sub-components would be valuable to get an overview of the spatial extent of impacts related to specific land-uses.
- ❖ Areas with high naturalness located in *uninhabited wilderness* areas could be considered for further legal protection, such as under Article 46.

In practice, the incorporation of a naturalness criterion for *uninhabited wilderness* mapping would rely on substantial mapping work, which should be conducted

- Identifying features or characteristics that are most inconsistent or incompatible with *uninhabited wilderness* due to low naturalness. Human interventions such as drain ditches, canals, embankments, levees, flood and avalanches barriers could also be considered, as well as other by-products of human activities, such as artificial water bodies, regulated rivers and streams or steam and wastewater from geothermal power plants. However, anthropogenic land degradation (e.g. soil erosion due to overgrazing over past centuries) and climate change (e.g. melting glaciers or ice caps, river systems changes, dust deposition, changes in vegetation, landslides) seem primarily shaped by a readjustment of natural processes in reaction to human activities, such areas might be largely perceived as natural by the Icelandic public. The compatibility of other human interventions with *uninhabited wilderness* might be more difficult to assess, especially in relation to ecological restoration, land-reclamation, soil conservation or wetland restoration. It is highlighted here that only the most visible signs of obvious human interventions should prevent an area from qualifying as *uninhabited wilderness*.
- Mapping of naturalness components is somewhat comparable to the approach used for the *wilderness character* as described by Carver et al. (2023) and the WRI (2022). It would also be in line with INPA recommendations for having detailed descriptions of the main wilderness areas.[38] This might also be useful for environmental impact assessments, as pointed out by the expert group 1 of the Master Plan (2024, p. 23): *Þörf er á þróun aðferðafræði þar sem víðernasvæði landsins eru kortlögð út frá ferlum náttúrunnar*. This could furthermore help identify or quantify attributes related to naturalness in disturbed areas, and support managing such areas to retain wilderness values.
- Identifying features or characteristics that enhance or are highly consistent with the *uninhabited wilderness* due to high naturalness. This could include the intactness of landforms or the presence of relatively undisrupted natural processes, e.g. high proportion of native species and lack of anthropogenic land degradation such as on barren, moss-covered, or vegetated lava fields. This could be a supporting factor for further protection, such as under Article 46.

Integration of topography elements in distance thresholds

One of the clear shortcomings highlighted by the comparative analysis is that the use of fixed distance thresholds (i.e. 5 km buffers) disregards the characteristics of the topography, which does not accurately depict the impacts of various incompatible features, especially on human perceptions. In addition to the INPA recommendations in Section 6.3, it is also recommended that:

- ❖ Topographic characteristics should be used for wilderness mapping, to incorporate their impact on the visibility of structures and other disturbances, as well as on the perception of remoteness due to the presence of barrier features such as large glacial rivers or cliffs.

This could partly be inspired by some of the methodologies reviewed within this project, e.g. Carver et al. (2023) and WRI (2022).

[38] See INPA (2021, p. 7): *[…] að ávallt sé aðgengilegt uppfært kort af óbyggðum víðernum á landsvísu ásamt lýsingu megin víðernissvæða.*

- Considering visibility. The zone of theoretical visibility could be mapped, based on viewshed analysis, similar to work conducted by Ólafsdóttir and Runnström (2011a, 2011b) or INPA & EAI (2019). This requires precise data on the height and location of structures, in particular for power lines, buildings, telecommunication masts and wind turbines, which is currently lacking in existing databases. Distance decay should also be incorporated (e.g. Ostman & Árnason, 2021), to reflect the fading visual impacts as the distance increases. A power line may be visible from 5 km away (e.g. INPA & EAI, 2019), yet difficult to distinguish. Cumulative effects due to the presence of multiple structures should also be considered to limit visual saturation.
- While clearly relevant, visibility of intrusive features does not fully reflect the impact induced in terms of experience, as the knowledge or awareness of proximity to an intrusive feature can also affect perceptions (e.g. INPA & EAI, 2019). Combining the use of visibility and distance buffers could help account for such perceptual effects, for example by adding a small buffer (e.g. 250 m) beyond the visibility threshold chosen. Defining a proximity radius around intrusive features, proportional to their intrusiveness, could also help identify where awareness of presence may impact the user.
- Considering remoteness. The difficulty of accessing certain areas due to topographic characteristics such as the terrain, slope and barrier features contribute to the perception of an area as wilderness. Remoteness can also be used as proxy for solitude if calculated from features that facilitate travel (e.g. roads, tracks, hotels, huts, or even marked hiking trails). Combining these factors can help quantify the potential impact of such features on solitude opportunities, although usage intensity should ideally be incorporated. High resolution outputs, similar to work by Carver et al. (2023) and the WRI (2022), would be very valuable to quantify wilderness impact. Introducing a remoteness decay (or sense of remoteness) might be particularly relevant to reflect the impact in terms of experience, i.e. gains in remoteness quality would decrease with increasingly remote settings. Incorporating more practical indicators could also be beneficial, using barrier features such as cliffs and large rivers.

6.5 - Other considerations

Boundary type, buffer zones and related mapping work

A key issue with hard boundaries is that areas which are not considered as *uninhabited wilderness* become further exposed to increased development of intrusive activities which might impact *uninhabited wilderness* by edge effect. These areas can have substantial wilderness attributes and be largely perceived as such (e.g. Ólafsdóttir, Sæþórsdóttir, Guðmundsson, et al., 2016). Using buffer zones can contribute to preserving wilderness qualities and values. For example, some areas could be considered as altered wilderness areas, transition zones, or peripheral zones where wilderness would still be considered and subsequent development should minimize negative impacts, e.g. by having an underground power line instead of overhead to reduce visual impacts. This could apply to areas where human modifications are somewhat reversible and where sufficient wilderness attributes are found. Areas within the reduction distance from intrusive features could be considered, while some types of land-cover such as large built or paved areas could be considered as strictly incompatible. Another critical dilemma of wilderness mapping, valid for other protected areas as well, is related to how strict or inclusive the underlying definitions should be. More inclusive definitions of *uninhabited wilderness* may lead to further disturbance due to the development of tolerated features, as it would set a precedent. On the other hand, stricter understandings of *uninhabited wilderness* might prevent the protection of already somewhat disturbed areas and justify further development there, e.g. the presence of a power line could justify constructing more power lines parallel to the existing one, inducing further impacts on the wilderness experience nearby. This stresses the importance of protection beyond the scope of *uninhabited wilderness*, potentially with the use of buffers zones.

As a preparatory step toward mapping *uninhabited wilderness*, uninhabited areas according to Article 5.18 could be identified, as it would include all potential *uninhabited wilderness* areas. Being arguably less complex and time-consuming, it would enable the implementation of wilderness-related planning policies by decision-makers and other stakeholders while wilderness mapping work is still being carried out. Mapping potential protected areas according to Article 46 would likewise be helpful. Lastly, consideration should be given to marine areas and the application of *uninhabited wilderness* criteria in island contexts. Specifically, whether shallow water areas might qualify as wilderness should be clarified, as they currently appear to be excluded by the definition of uninhabited areas outlined in Article 5.18 which describe them as land areas.

Guidelines for wilderness impact assessment

Uninhabited wilderness in Iceland is expected to cover a substantial part of the country, to reflect the intention of the legislator in making the definition more inclusive. Aside from the potential establishment of protected areas, *uninhabited wilderness* areas are to be incorporated in land-use planning, as suggested in Article 73.[39] At a project level, this might require high-resolution mapping of wilderness impacts. It might be sensible that further work would focus on issuing guidance or guidelines for wilderness impact assessments, as suggested by INPA in the proposed addendum to the INPS.[40] The following suggestions are made in relation to such wilderness impact assessments:

- Spatial overlap between areas mapped as *uninhabited wilderness* according to Article 73 and areas considered for project developments (e.g. Sæþórsdóttir et al., 2024, pp. 39-41) provide a strong basis for high-resolution wilderness impact assessments.
- High-resolution wilderness impact assessments should ideally consider impacts on wilderness experience, through both visual and acoustic models, while incorporating traffic or visitor intensity as well as the sense of remoteness.
- Maps of relevant wilderness indicators (e.g. visibility, naturalness components) computed at a country-wide level should be available to enable practical use for impact assessments.

Previous application of the WQI to local case studies (WRI, 2019, 2021) might provide valuable insights on possible mapping outcomes related to wilderness impact assessments.

7. Concluding remarks

Over two decades of wilderness mapping work in Iceland, multiple methods have been applied, producing numerous maps contributing to the knowledge on the spatial distribution of wilderness across the country. The methods used were mostly based on the legal interpretation of the Icelandic Nature Conservation Act 60/2013. It was first issued in 1999 and was later revised multiple times with changes to the *untouched*, then *uninhabited wilderness* as a legal object, which is currently defined in the Articles 5.19 and 46 and refers to a planning concept and protected area category, respectively. Legal interpretation, along with changes in datasets and land-uses over that time period have resulted in some inconsistencies. The most recent mapping attempts have become increasingly precise and tailored to the context, providing highly relevant and complementary approaches to wilderness mapping in Iceland. Inventorying and comparing these methods yielded valuable insights, by pointing out the shortcomings of the current legal definition, based on which recommendations were formulated to increase consistency across future wilderness mapping work in Iceland.

[39] See the following quote (Article 73 of the Nature Conservation Act 60/2013): *Kort með upplýsingum um óbyggð víðerni skal vera til upplýsinga fyrir stjórnvöld við stefnumótun um verndun landslags og aðra landnotkun*

[40] See the following quote from INPA (2021, p. 7): *Skipulagsstofnun gefi jafnframt út leiðbeiningarefni fyrir staðbundna greiningu óbyggðra víðerna við skipulagsgerð.*

Making an explicit distinction between Article 5.19 and 46 in terms of wilderness mapping is seen as a priority, with the suggestion that mapping should be based on Article 5.19 due its broader use than protected area establishment. As a secondary task, mapping areas of *uninhabited wilderness* which would meet additional requirements of Article 46 is also seen as important. Further clarification in the interpretation of the law would result from defining legally the term *upbuilt roads,* as it would clarify which type of roads or tracks should be tolerated in *uninhabited wilderness*, if any. Four propositions which were formulated by the INPA are reiterated, highlighting that some features are considered incompatible with *uninhabited wilderness* due to their intrusiveness while others are tolerated due to their small scale, isolated presence and compatibility with the wilderness experience and natural values. The INPA also suggests basing the minimum distance from intrusive features on their size and visibility (incorporating the topography), potentially reaching beyond 5 km for large-scale structures and corresponding to less than 5 km for smaller structures. These propositions are based on the IUCN 1b protected area characteristics regarding human uses, activities and presence. Despite the largely abiotic characteristics of the Icelandic wilderness, naturalness could be incorporated in wilderness mapping, to exclude the most modified and artificial settings while at the same time contributing to the identification of areas overwhelmingly governed by natural processes.

Implementing these recommendations would increase consistency and accuracy for wilderness mapping while also providing valuable data for wilderness management. In particular, following the definition of the term upbuilt roads, database adjustments should be performed to accurately assess the extent of their impact on wilderness. Likewise, consideration of naturalness for wilderness mapping implies that some naturalness attributes would be mapped separately, providing valuable data to assess the impacts of projects and management policies on wilderness. Making this information accessible could support consistent use. Existing procedures, such as in environmental impact assessments, could incorporate an evaluation of wilderness impacts with specific tools, e.g. high-resolution visibility and acoustic models to quantify disturbance. Usage intensity and its impact on wilderness experiences should also be considered within these procedures. The evolution of such procedures or the setup of a distinct wilderness impact assessment should be accompanied by a set of guidelines to ensure that the method used is thorough and well-suited to perform such evaluations. Independently from such impact assessments, issuing guidelines for local planners to better integrate *uninhabited wilderness* in planning documents and adjust their policies accordingly might be helpful.

Beyond the recommendations issued, this report gathers key findings from perception studies related to wilderness mapping. It reveals that a large part of the country is seen as wilderness, and the most visited wilderness areas are distributed along the travel infrastructure, such as jeep tracks, hiking trails and mountain huts, which may be considered as disturbed areas. There, management and preservation of wilderness attributes seem essential to preserve the qualities of visitors' experience. Public opinion research further highlights that basic travel-related features are seen as much more appropriate than the ones that are more developed or involve more services, as well as the ones serving other purposes such as energy harnessing. In comparison, the users of surveyed areas in the interior of the country seem to express stricter management preference than non-users. However, the views of both groups should be further investigated at a nation-wide level to provide further insights into their wilderness management preferences. As over two thirds of the public consider the Icelandic wilderness to be under threat, and even more find necessary to protect it, it seems urgent to address their concerns. Given that wilderness mapping is a lengthy process requiring ongoing refinement, prioritizing initial efforts is essential for its effective and timely incorporation in land-use planning. This will help establish a solid foundation that addresses urgent conservation needs, ensuring the protection of natural landscapes for future generations, while redirecting development toward more suitable areas.

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Appendix A – Wilderness extent comparisons

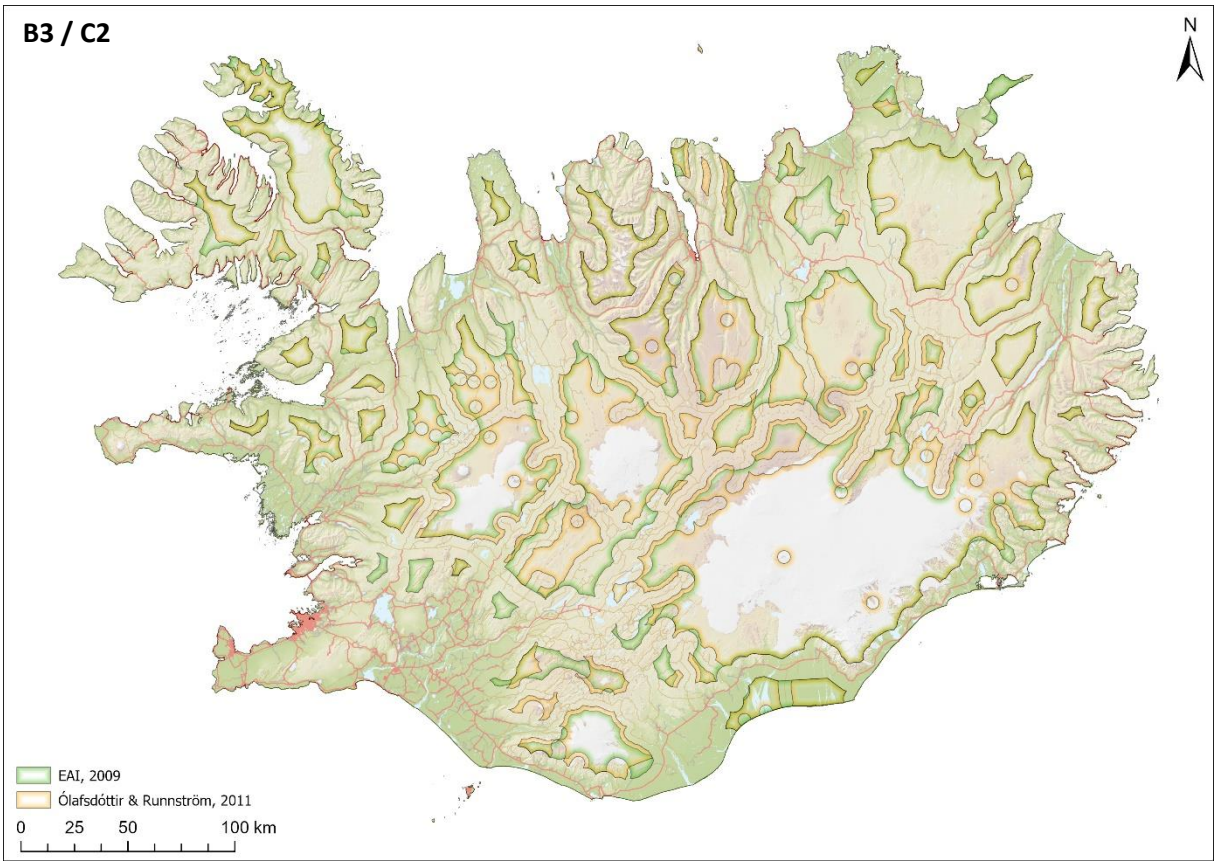

Figure 23: Comparison of Map B3 (2009) with Map C2 (2011). Data: NLSI

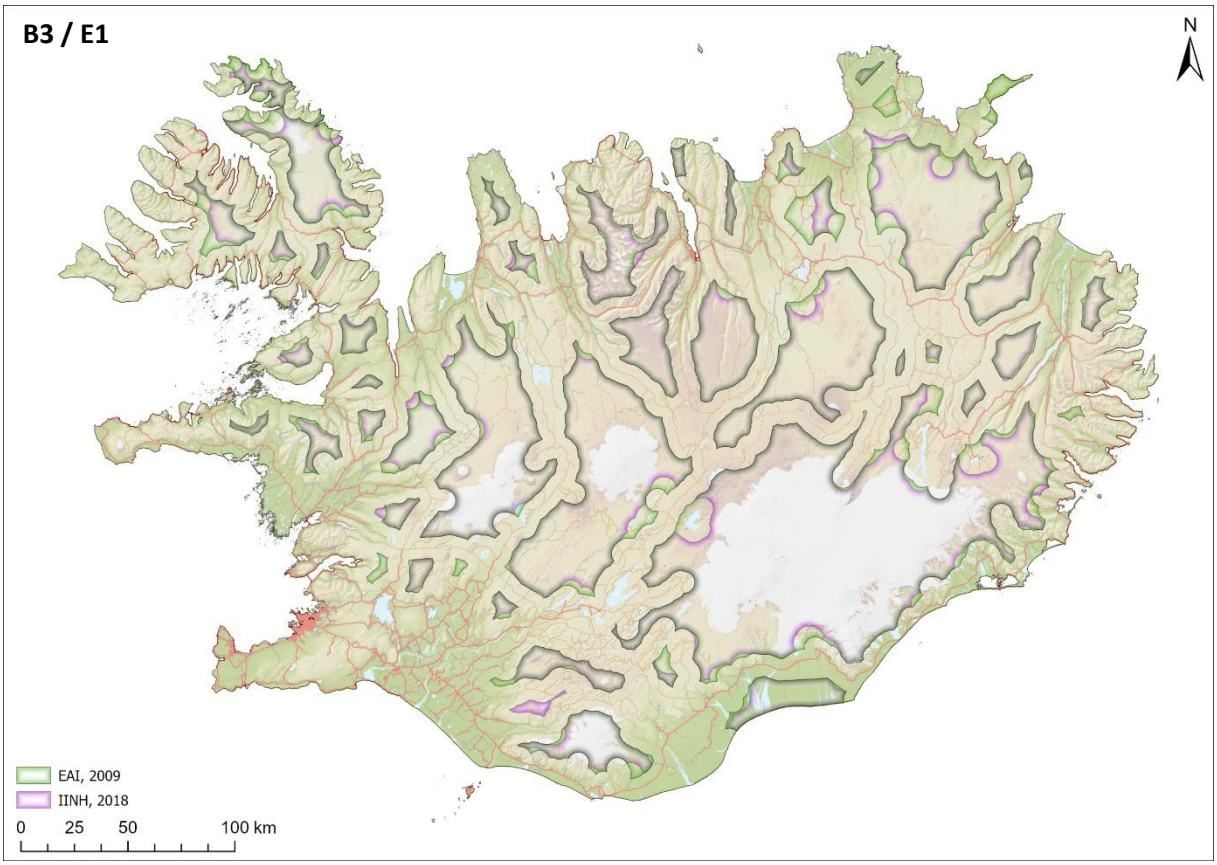

Figure 24: Comparison of Map B3 (2009) with Map E1 (2018).

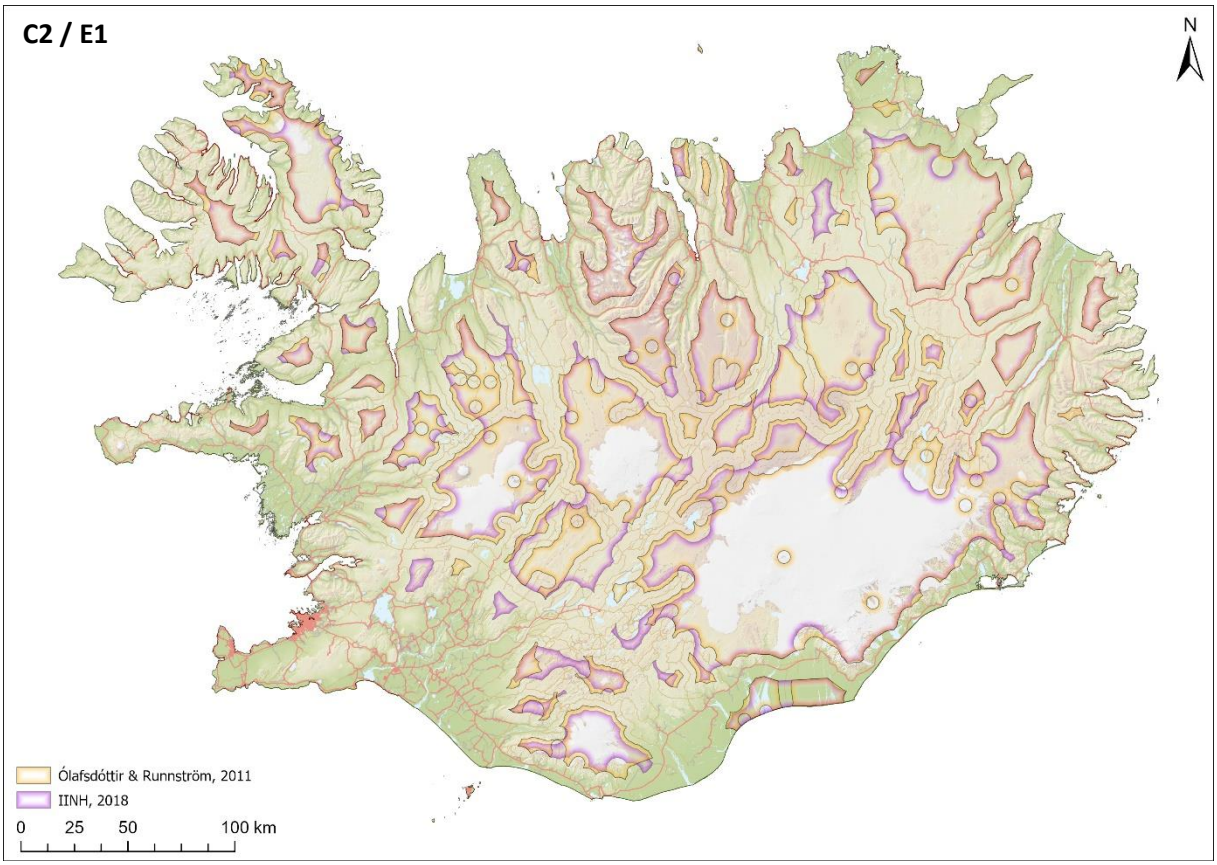

Figure 25: Comparison of Map C2 (2011) with Map E1 (2018). Data: NLSI

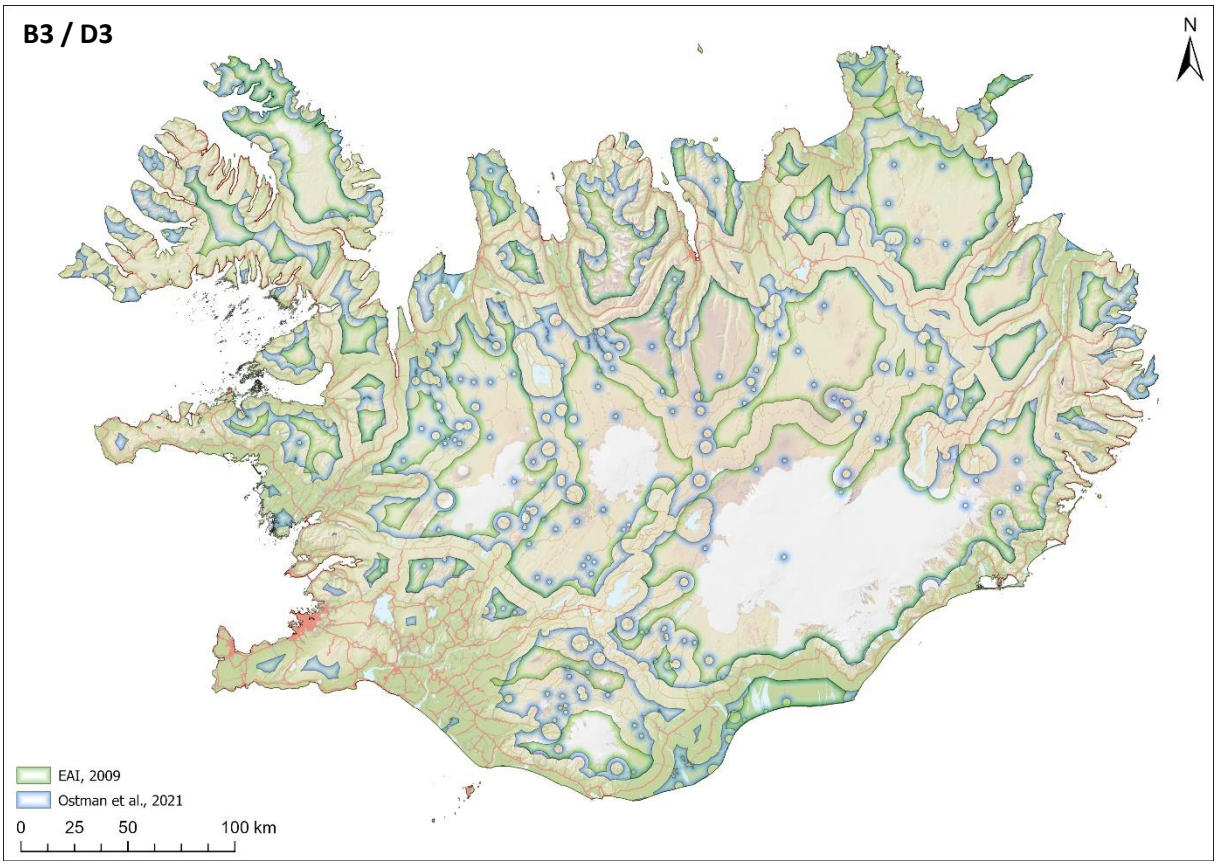

Figure 26: Comparison of Map B3 (2009) with Map D3 (2021). Data: NLSI

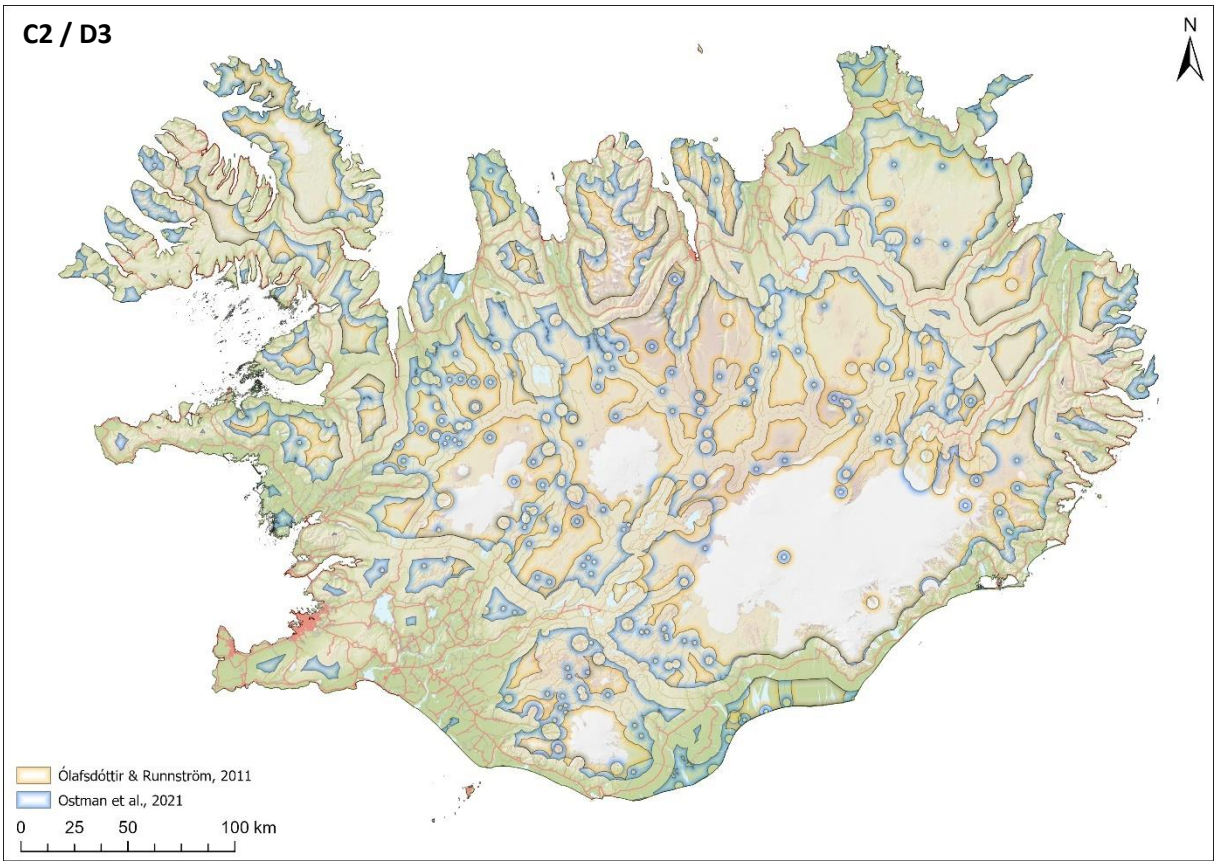

Figure 27: Comparison of Map C2 (2011) with Map D3 (2021). Data: NLSI

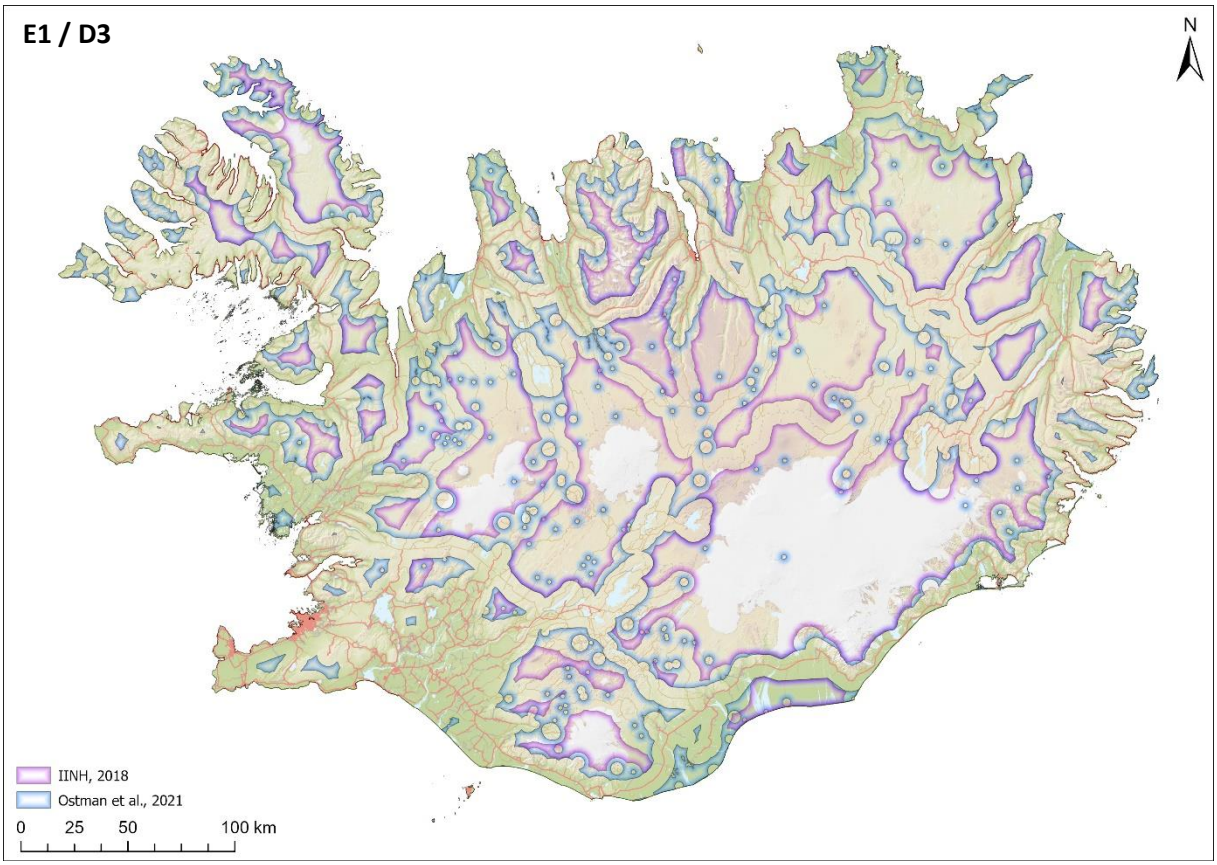

Figure 28: Comparison of Map E1 (2018) with Map D3 (2021) Data: NLSI

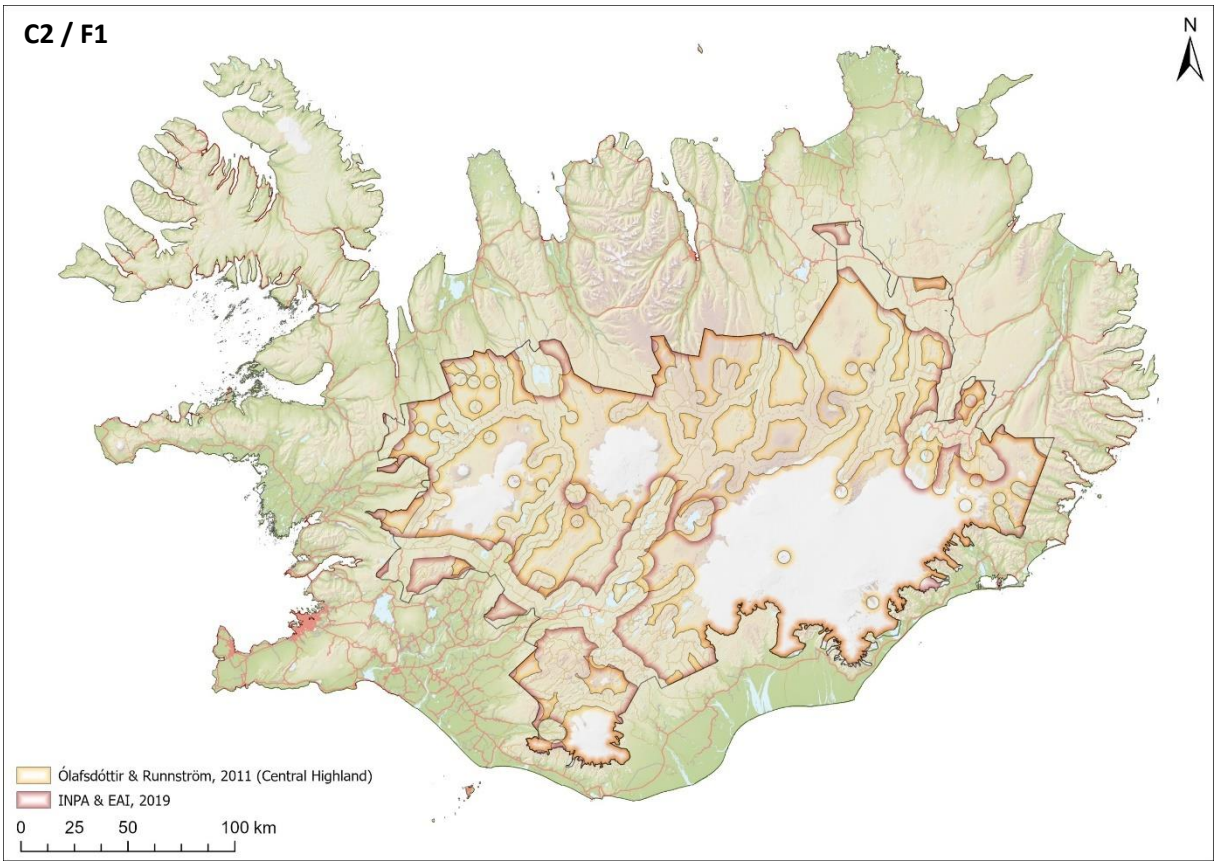

Figure 29: Comparison of Map C2 (2011) and Map F1 (2019) in the Central Highland of Iceland. Data: NLSI, INPA (Central Highland boundary)

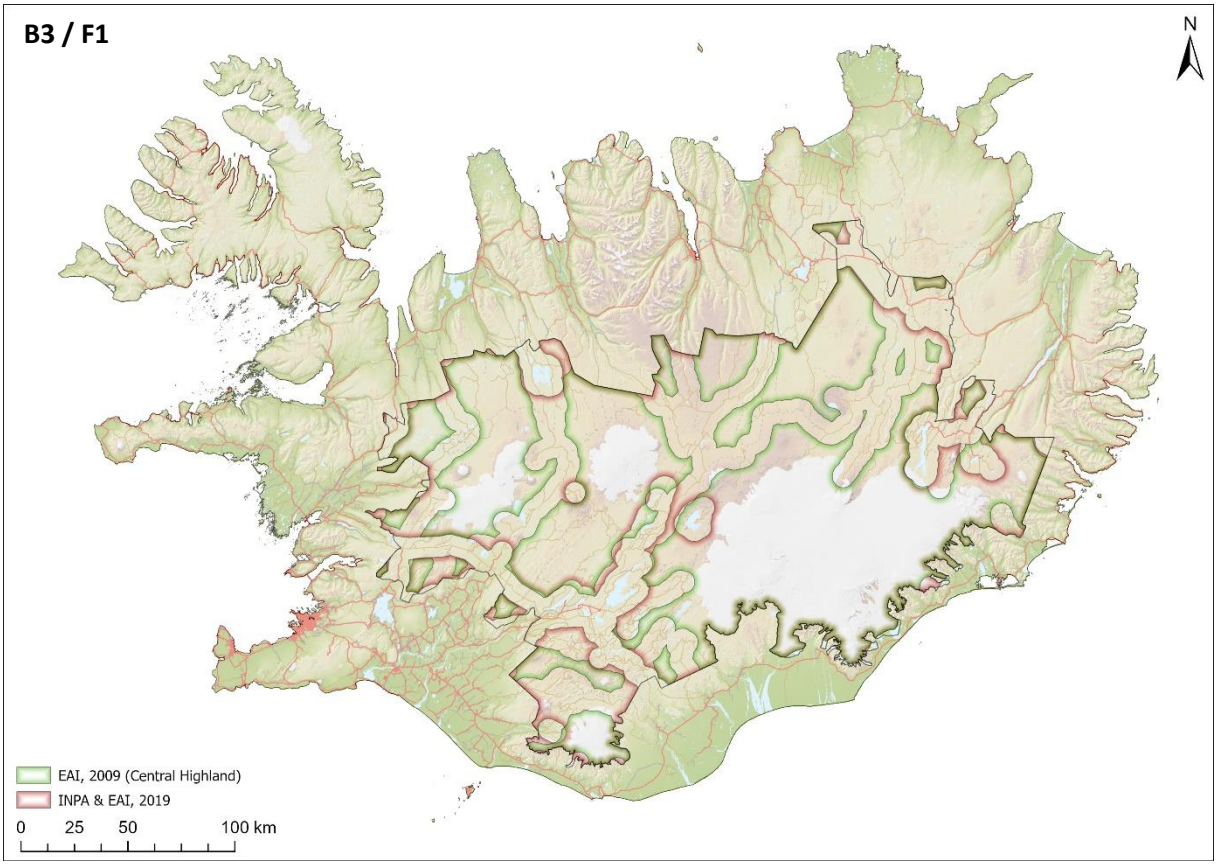

Figure 30: Comparison of Map B3 (2009) with Map F1 (2019) in the Central Highland of Iceland. Data: NLSI, INPA (Central Highland boundary)

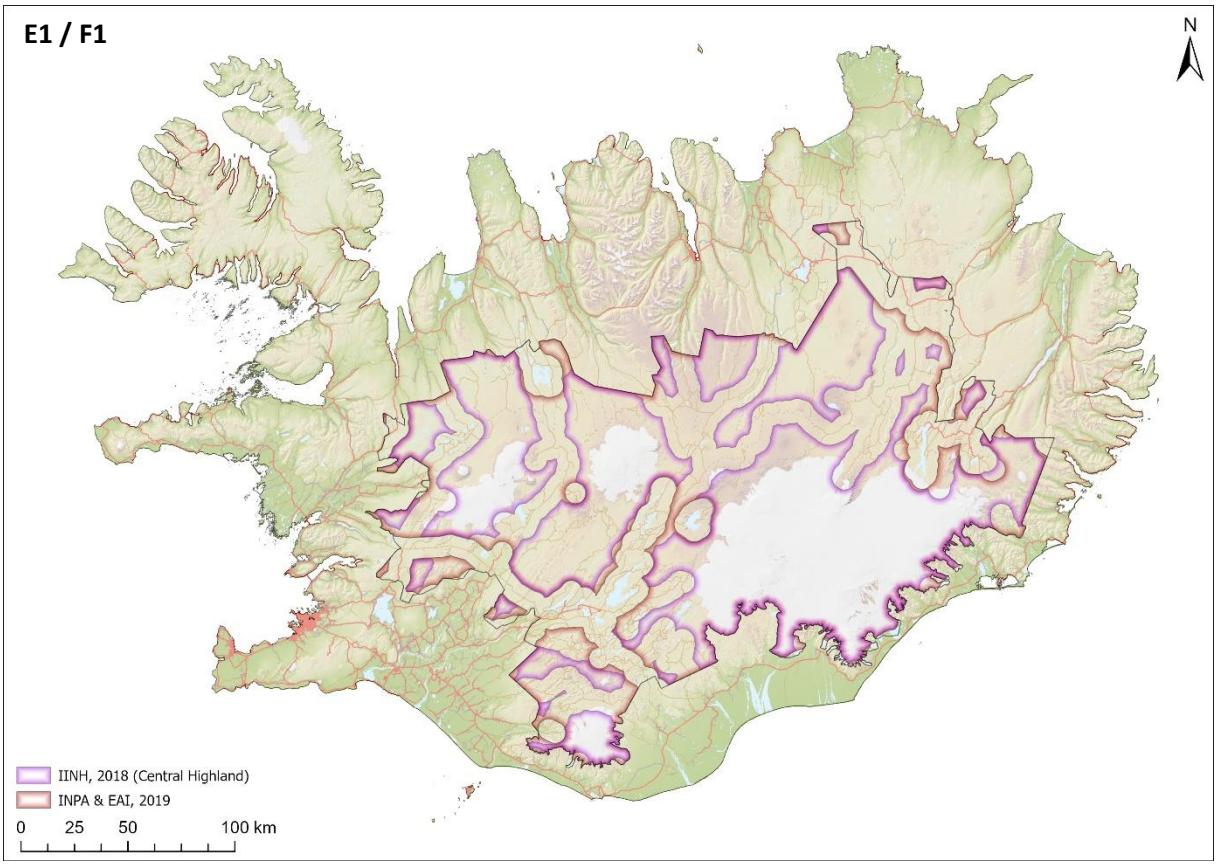

Figure 31: Comparison of Map E1 (2018) with F1 (2019) in the Central Highland of Iceland. Data: NLSI, INPA (Central Highland boundary)

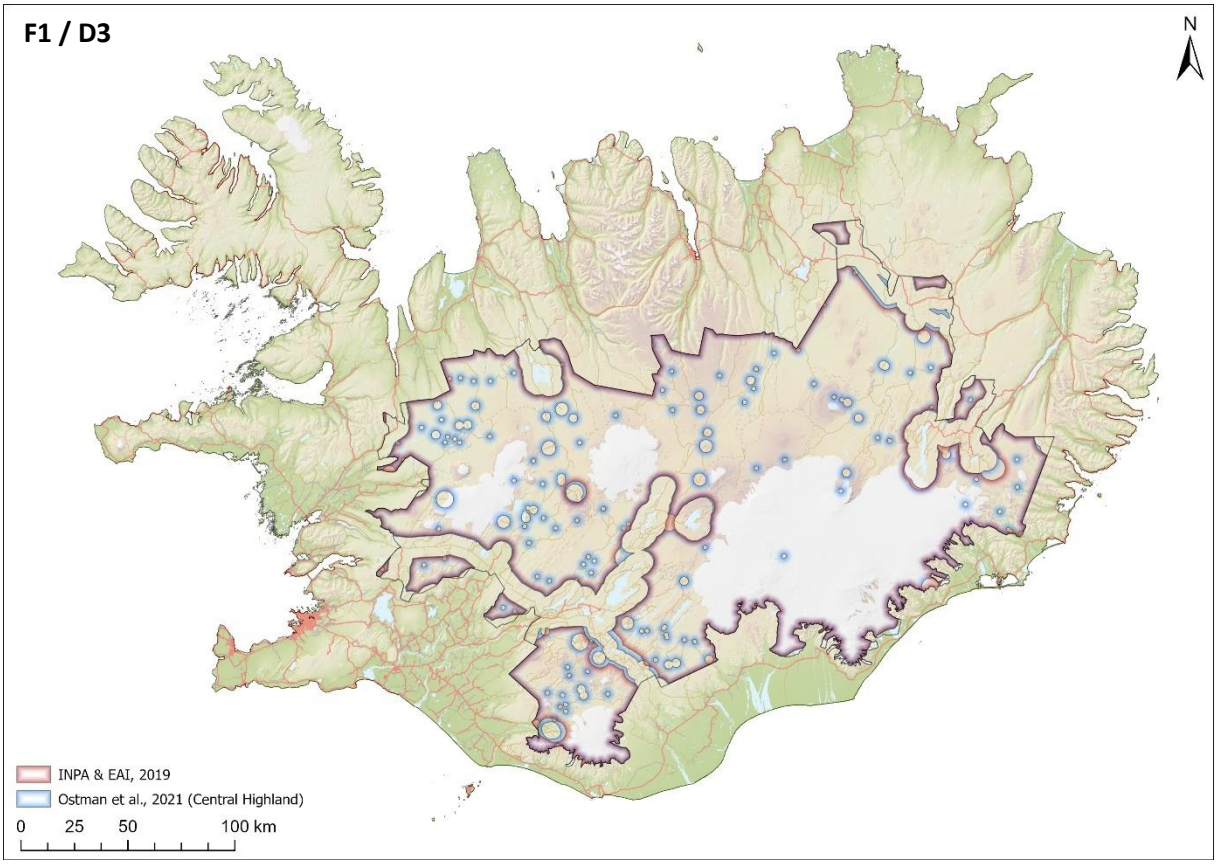

Figure 32: Comparison of Map F1 (2019) with Map D3 (2021) in the Central Highland of Iceland. Data: NLSI, INPA (Central Highland boundary)

Appendix B – WQI classes within and outside of wilderness areas

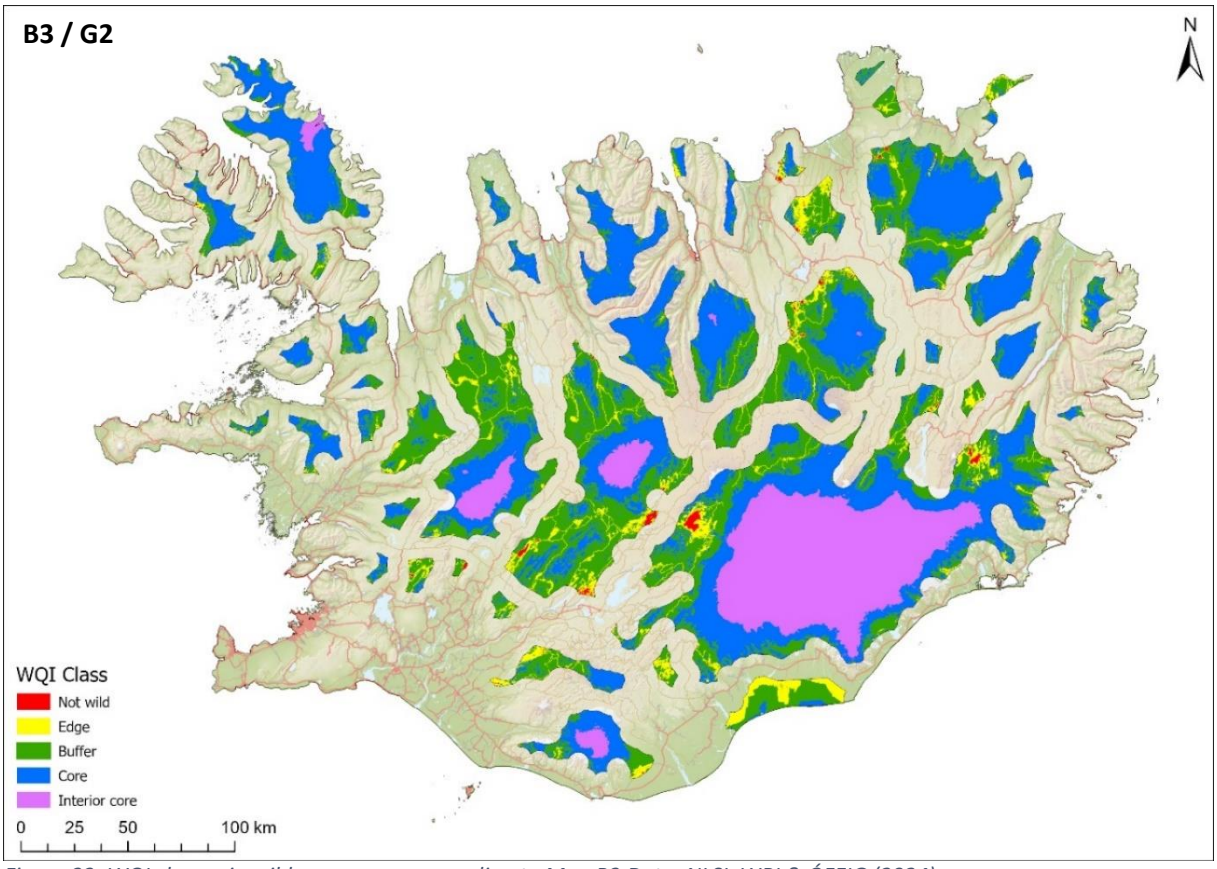

Figure 33: WQI classes in wilderness areas according to Map B3.Data: NLSI, WRI & ÓFEIG (2024).

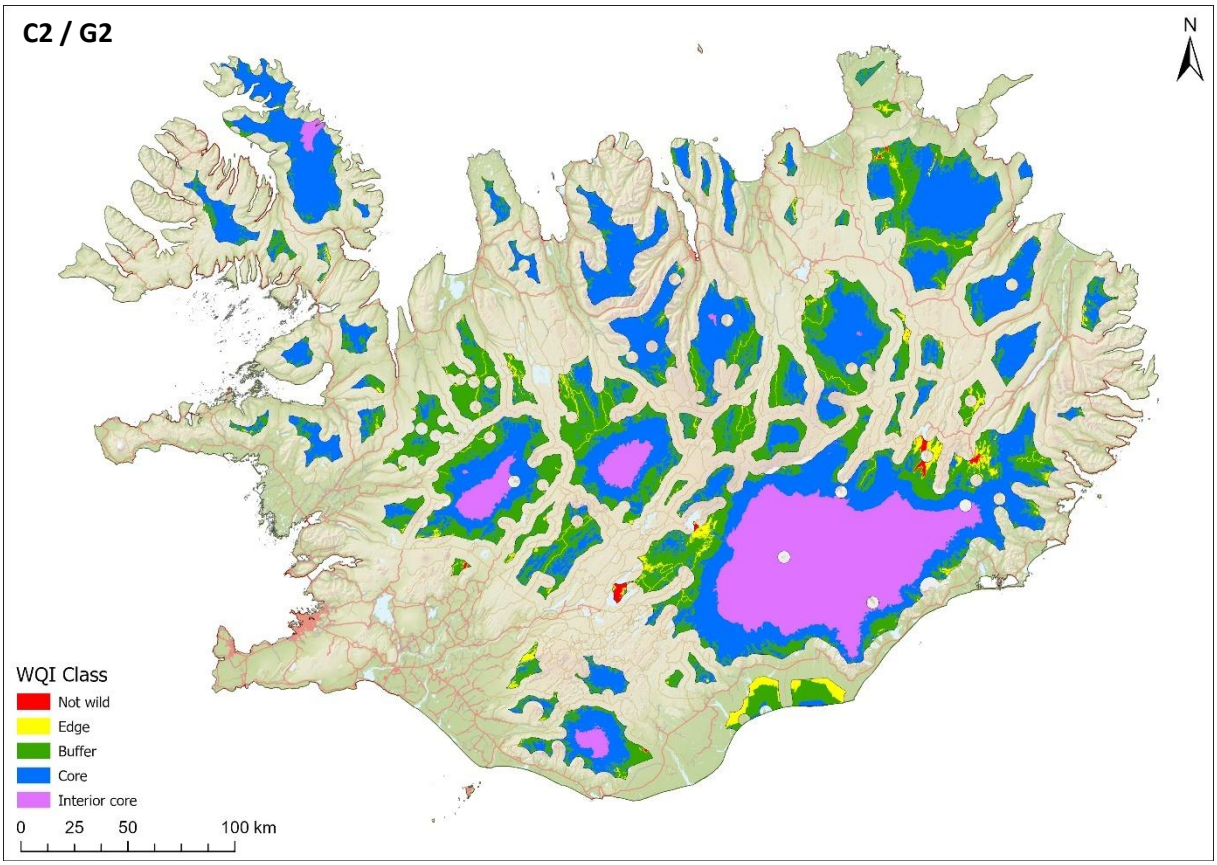

Figure 34: WQI classes in wilderness areas according to Map C2. Data: NLSI, WRI & ÓFEIG (2024).

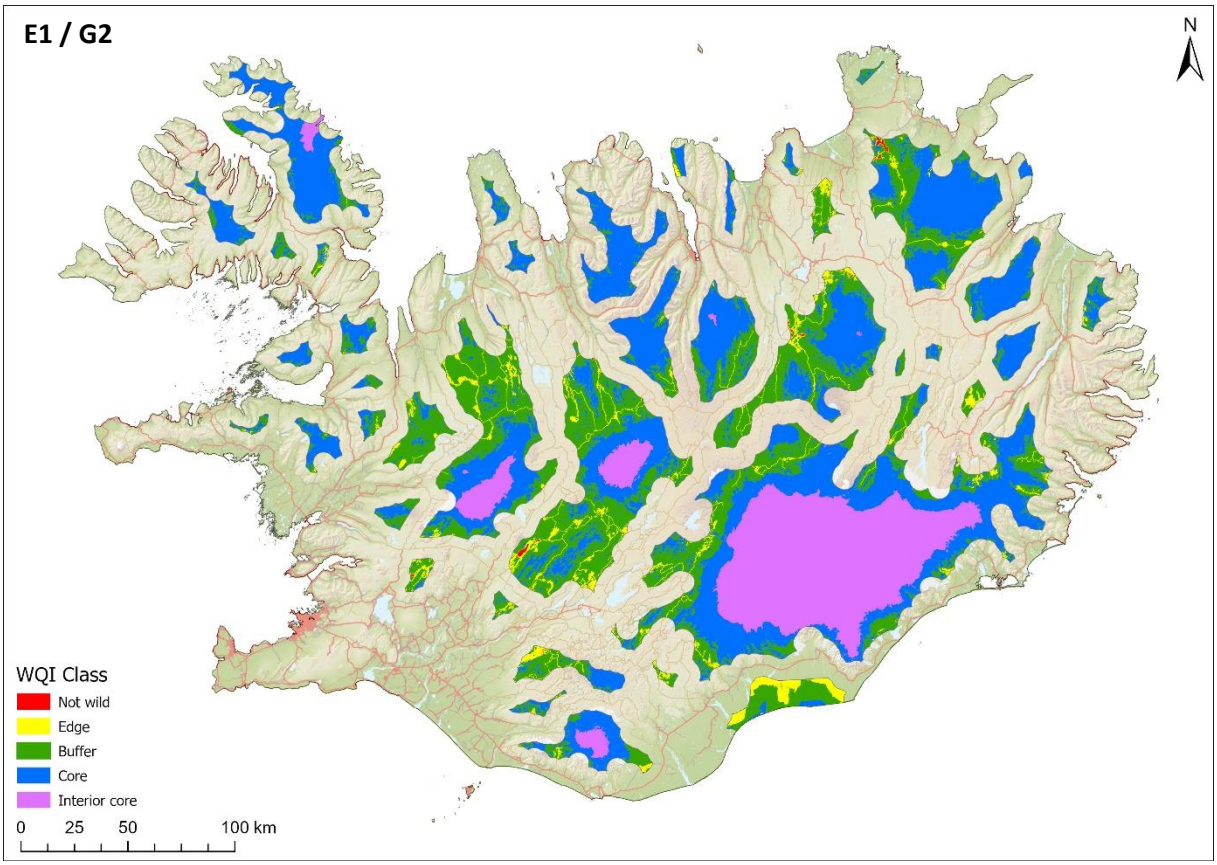

Figure 35: WQI classes in wilderness areas according to Map E1. Data: NLSI, WRI & ÓFEIG (2024).

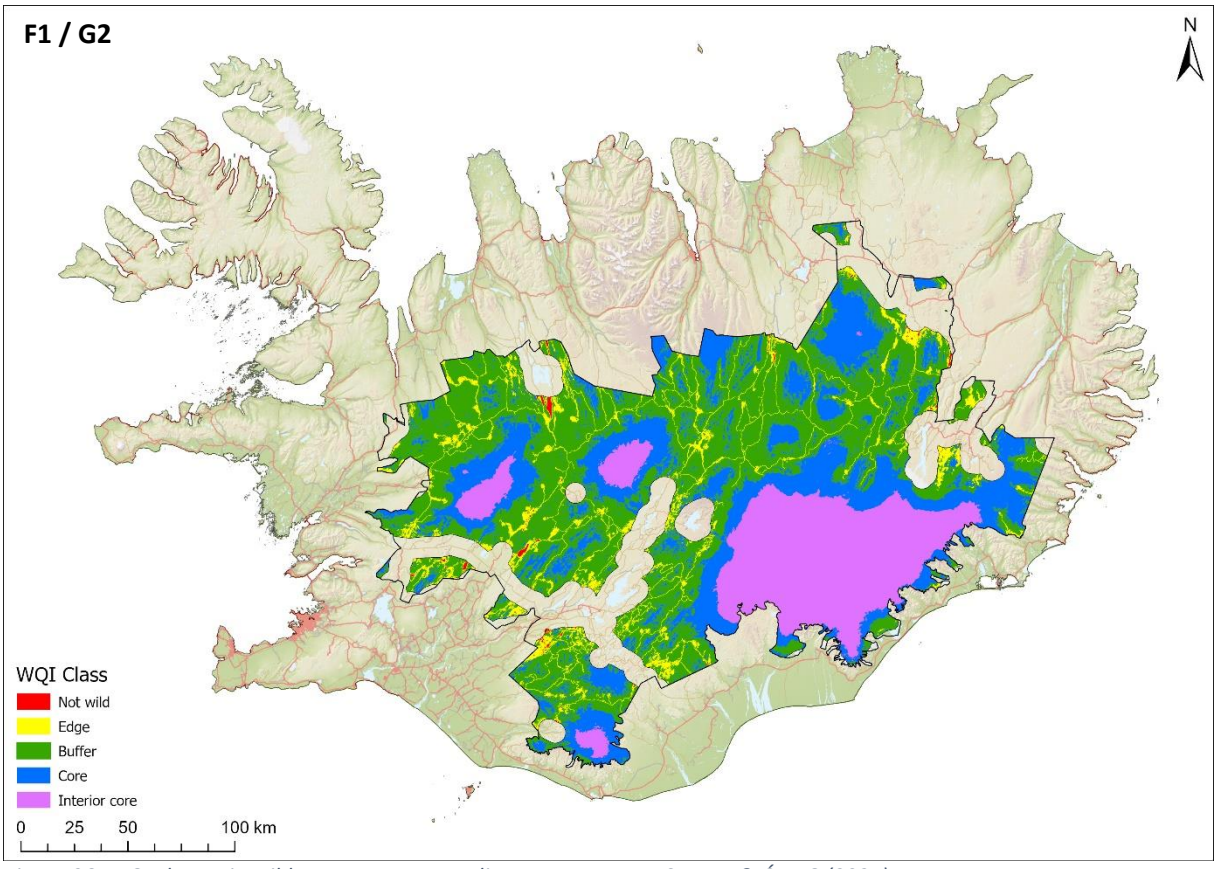

Figure 36: WQI classes in wilderness areas according to F1. Data: NLSI, WRI & ÓFEIG (2024).

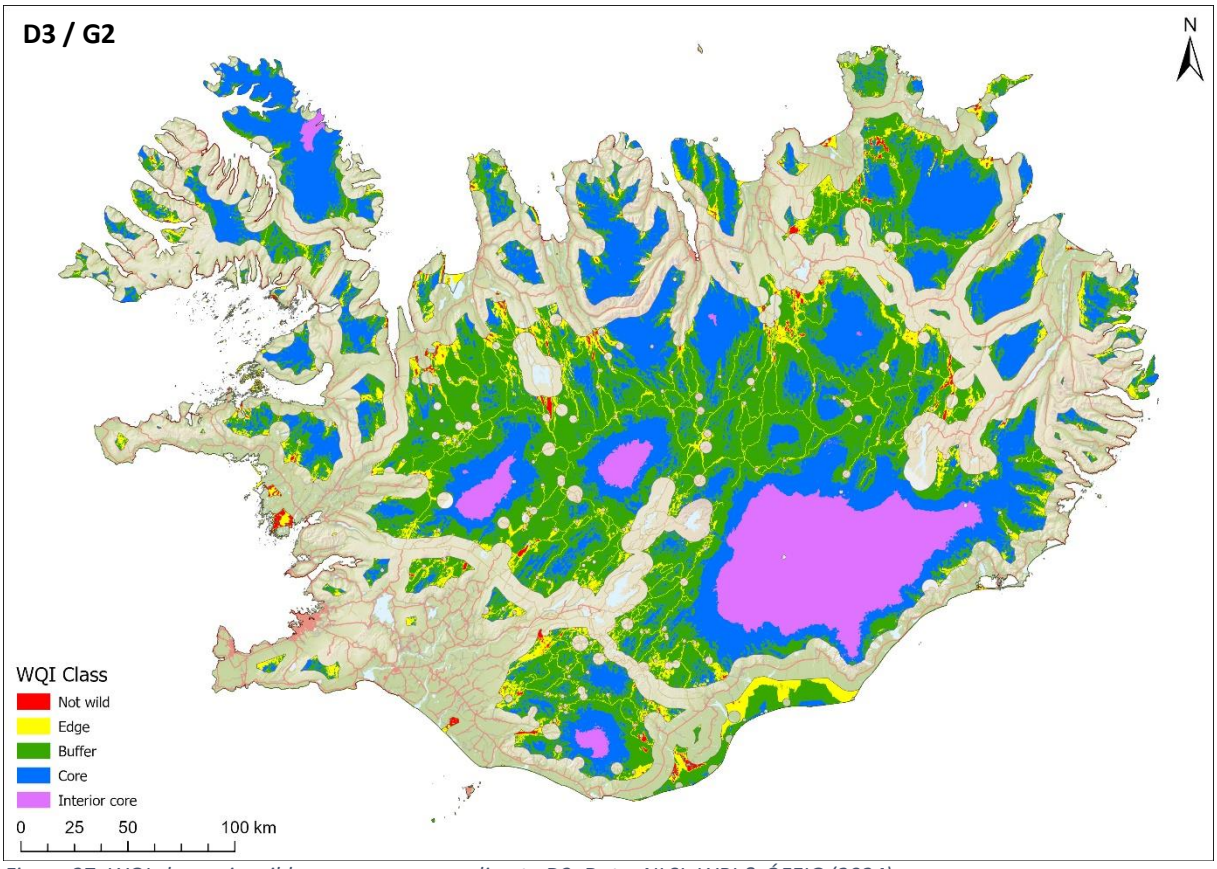

Figure 37: WQI classes in wilderness areas according to D3. Data: NLSI, WRI & ÓFEIG (2024).

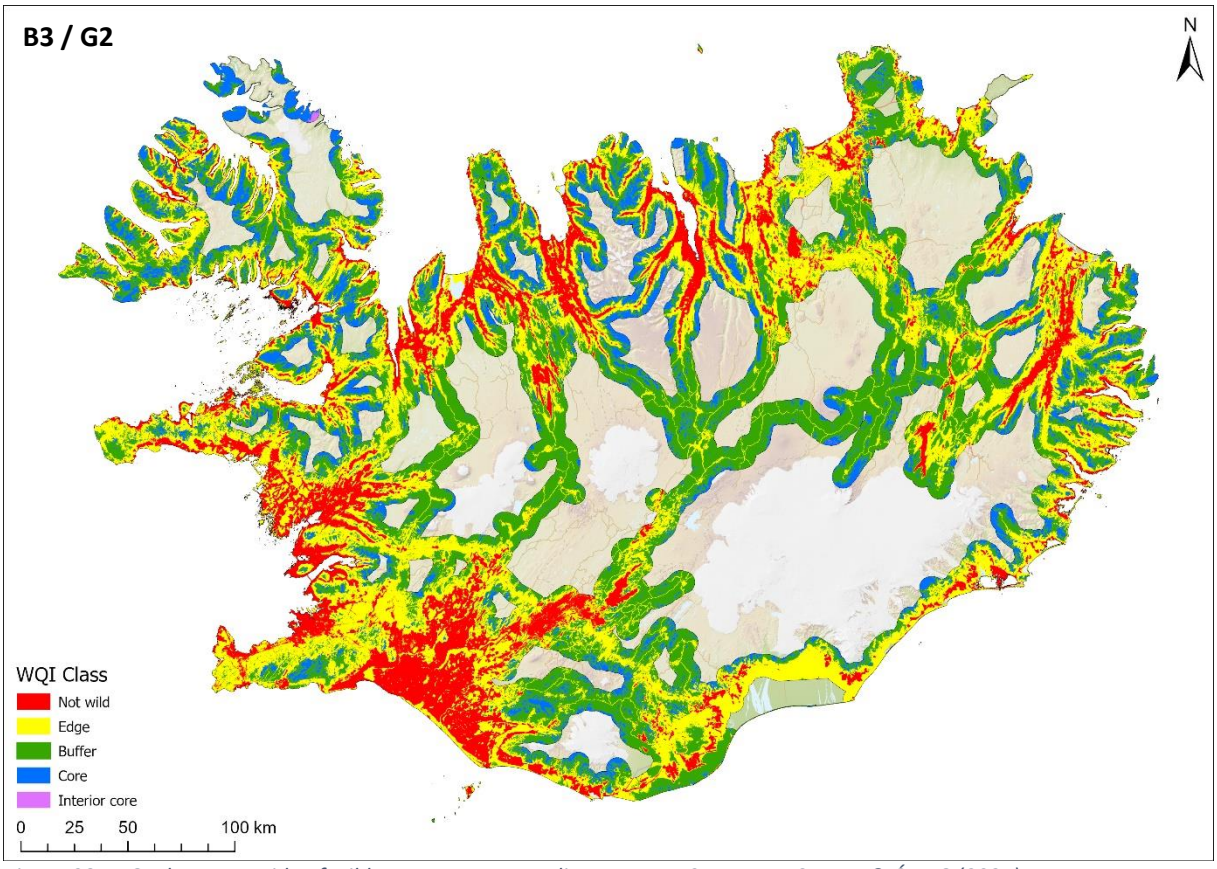

Figure 38: WQI classes outside of wilderness areas according to Map B3. Data: NLSI, WRI & ÓFEIG (2024).

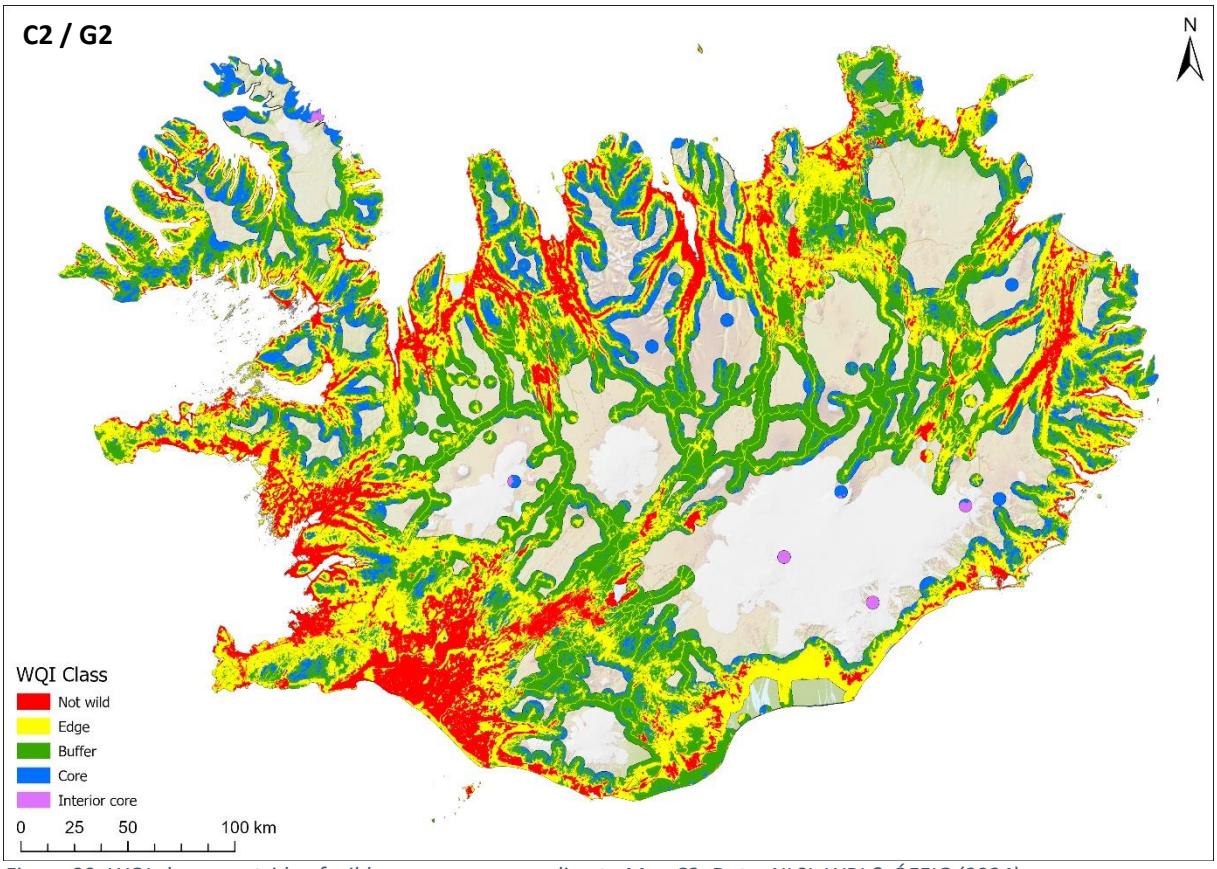

Figure 39: WQI classes outside of wilderness areas according to Map C2. Data: NLSI, WRI & ÓFEIG (2024).

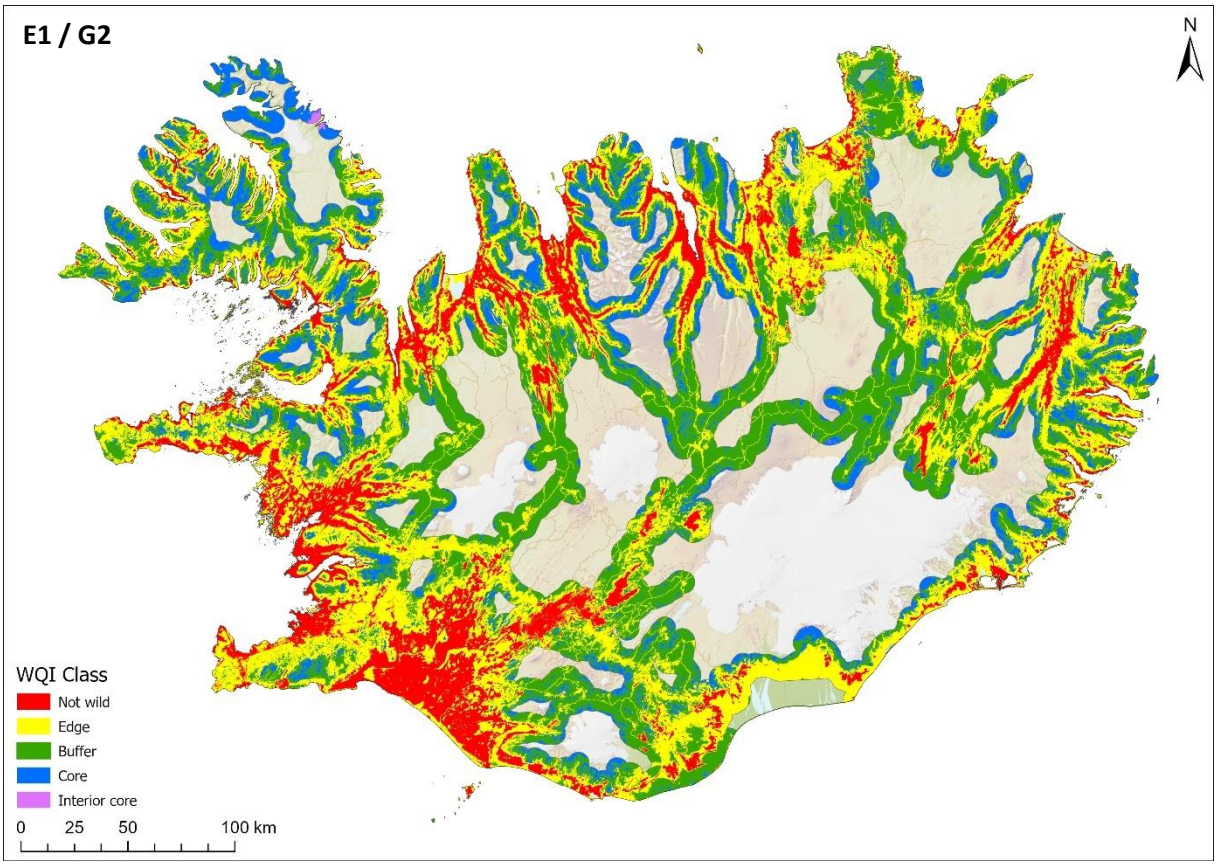

Figure 40: WQI classes outside of wilderness areas according to Map E1. Data: NLSI, WRI & ÓFEIG (2024).

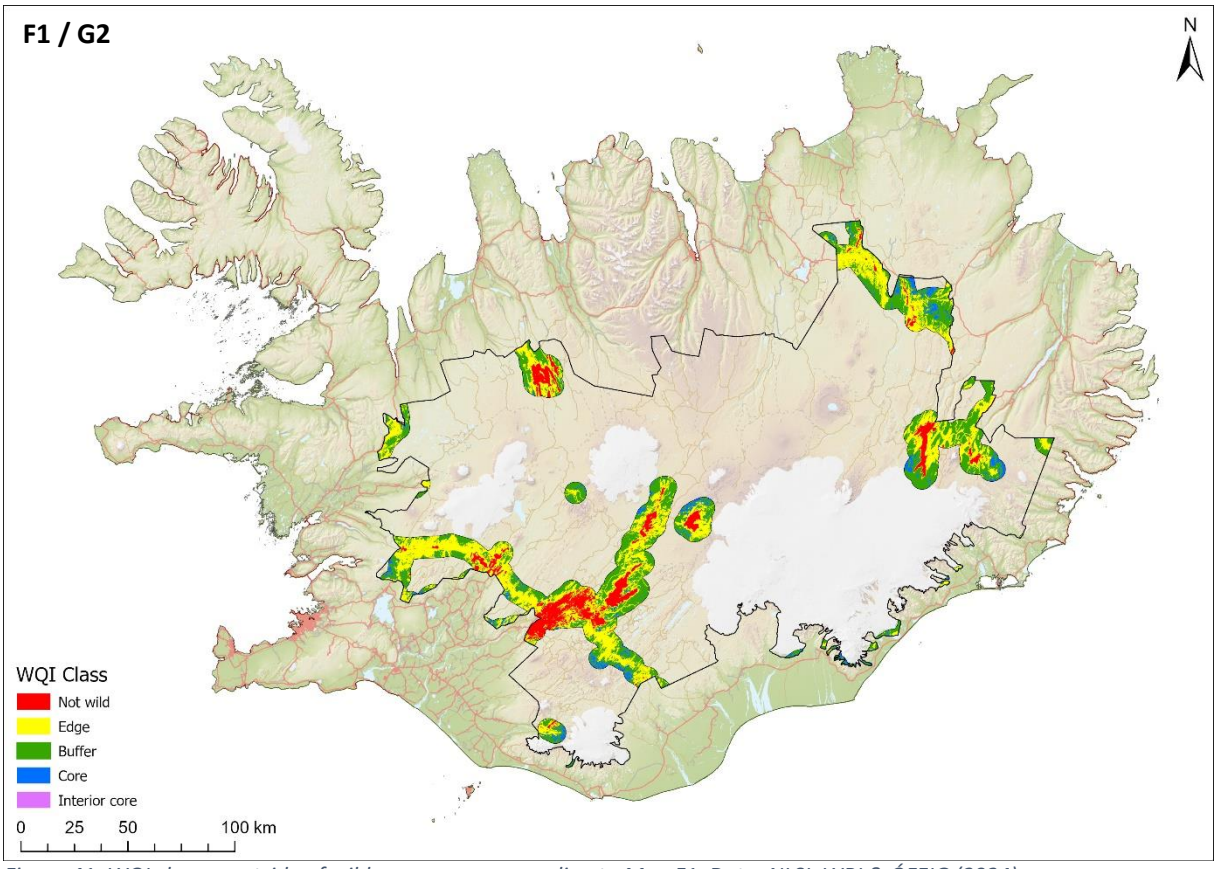

Figure 41: WQI classes outside of wilderness areas according to Map F1. Data: NLSI, WRI & ÓFEIG (2024).

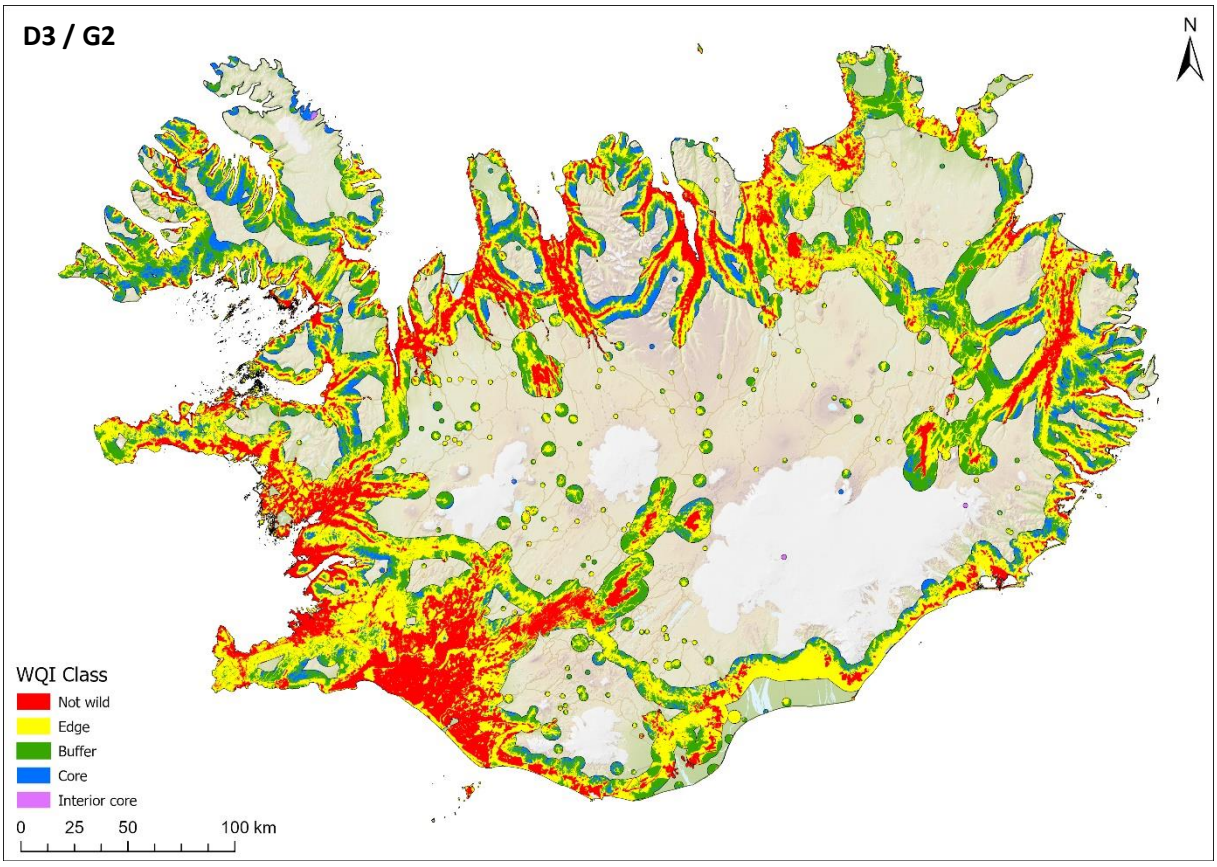

Figure 42: WQI classes outside of wilderness areas according to Map D3. Data: NLSI, WRI & ÓFEIG (2024)