# Cairn and Landscape Interaction

*A Study of Human Ecodynamics in the North Atlantic*

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Submitted in fulfilment of the requirements for the
Degree of Master of Philosophy (Research) in Archaeology

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SEPTEMBER 2019

# Abstract

Cairns are very versatile constructions, used for a variety of human activities. For this reason, this master's thesis focuses on the analysis of navigational and agricultural cairns as a way to further the study and understanding of human ecodynamics in the North Atlantic. The project was developed within the wider framework of DataARC, a ciberinfrastructure that interconnects several North Atlantic datasets while facilitating access to them. This master's thesis aims to connect its results and datasets to cyberinfrastructure's concept map. The study uses a variety of interdisciplinary data, methodologies, tools, and approaches in its analysis. It is divided into two case studies. Case Study One analyses the role of navigational cairns and their relationship with the roads and the general landscape while creating proposed routes between late medieval/early modern farm networks in Iceland. The methods used in this case study are least cost path and intervisibility analysis. The results support the hypothesis that cairns were being used as road markers, and suggests a dependence between landscape features and cairn positioning, indicating landscape agency. Case Study Two focuses on analysing the position and effect of clearance cairns in the Scottish landscape. Archaeological and landscape data (i.e. soil quality, land compaction, erosion levels, and continued use in agricultural practices) were combined in a newly created dataset that was examined with statistical analysis. The results show a correlation between the presence of cairns and a high erosion risk while proposing three effects of clearance cairns on soils: so exhaustive they are no longer cultivable, they are cultivable but have a risk of erosion, and so non-exhaustive that they can still be cultivated. Overall, the project's findings highlight cairns' usefulness in the study of human ecodynamics. In both case studies, cairns are the physical representation of an active and ever-changing interaction between humans and their environment, and the relevance and agency of landscape. These are based on Case Study One's feature-dependant cairns, and Case Study Two's observation of human adaptation to the landscape's changes. This opens the possibility of an expansion of the area of study, including other areas and continents, and/or a focus on developing studies that focus on cairn multifunctionality.

# Acknowledgements

I would first like to thank my thesis supervisors Dr Rachel Opitz and Dr Colleen Batey for their input, support and help throughout the project. Thanks to Dr Opitz for her invaluable guidance and help throughout the year. Thanks for listening and providing excellent input, for being patient and supportive. Thanks for teaching me a lot about GIS, especially when it would not work and I became very frustrated. Thanks for letting me do my GIS analysis with your computer so that my laptop would not crash. it has been an incredible experience and I have learned a lot both on a practical and theoretical level. Thanks to Dr Batey for teaching me about the Viking and Icelandic worlds which I had barely gone into before this project.

I would like to extend my gratitude to DataARC and Dr Opitz for making this project possible. I am gratefully indebted to them for giving me this opportunity and to Dr Opitz for believing in me. I would also like to thank the DataARC experts who were involved in this research project: Dr Gíssli Pálsson, Dr Emili Lethbridge, Dr Philip Buckaland, and Dr Thomas McGovern. Without their participation and input, this research would not have been the same.

I would also like to acknowledge Dr Michael Given of the Archaeology Department at the University of Glasgow and Dr Stephen Davis of the School of Archaeology at University College Dublin as the examiners of this thesis. I am very grateful to them for their very helpful and valuable comments on this thesis.

Thanks to my friends who made this process a thousand times better. Pablo, my partner in crime, who made days fun and something to look forward to; I miss you and I miss the memes. To Manoli, for being so lovely and friendly, and an amazing person all around. To Aicha for reading every single word of this dissertation for a year, and for keeping me sane through the research and writing process while I talked about cairns endlessly. To Andrea for teaching me how to use R Studio and starting my love-hate relationship with it. To Tereza and David for reading chunks of this thesis and for listening to how fascinating cairns are every time we went hiking or, basically, anytime for no reason whatsoever. To Cosimo, for always helping me when LaTeX or R made me want to throw my computer out of the window, you saved my laptop and me.

To my family for supporting and listening to me speak about cairns too passionately for too long. Thanks to my father Toni for teaching me to love books and history. Thanks to my mother Lina for cheering me on through every step of the way.

Lastly, I would like to acknowledge my grandparents, Rafael and Victoria, who raised me and played a big part in my education. To my grandmother for teaching me how to read and to be resilient. To my grandad for taking me to school every day, for telling me stories and *rondaies* even when you were tired, for sneaking sweets into my school backpack, for your music and paintings, and for supporting me even if you never understood why I studied "piles of rocks and bones".

Thank you for so much. Grandad, this is for you.

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# Chapter 1

## Introduction

Human Ecodynamics is based on the study of the relationship and interactions between humans and their landscape. Due to the complexity of human-landscape interactions, human ecodynamics cover a wide range of aspects and take an interdisciplinary focus to yield a better understanding of interactions, how to enhance them, their sustainability, and their impact on both humans and their ecosystem (see Fitzhugh et al., 2019; Newell et al., 2005, pp.300-304). This research study focuses on the aspects of human ecodynamics related to the interactions between humans, cairns and North Atlantic landscapes. In particular, this master's thesis will assess two cairn roles through two case studies, navigational cairns in Iceland and clearance cairns in Scotland, to establish the impact of different uses of cairns in diverse North Atlantic landscapes. This combined approach provides different ways to study cairns through the analysis of a variety of datasets from multiple disciplines, offering a wider understanding of their role within diverse landscapes. The methodology and project designed provided the opportunity to engage with raw data and create new cairn datasets for each case study which were later linked to DataARC, an online infrastructure (see beta.data-arc.org). Overall, this is an innovative way of approaching cairns and will provide new information regarding their use in the North Atlantic as well as the human-landscape dynamics in the area and how they are studied.

The project is developed within the framework of the online cyberinfrastructure DataARC. Specifically, it is outlined within the study of human-environment interactions through the use of cairns which offer a very good opportunity to examine this relationship due to their versatility and constant use through history, even today. The project's interdisciplinary approach was chosen to provide a better understanding of these relationships whose complexity and nuance is better represented by the combination of various disciplines (see Section 3.2). It is also designed to fit within the wider DataARC project which aims to connect datasets from several disciplines and to establish conceptual relationships within them to facilitate data analysis and visualisation regardless of the researcher's field of expertise (DataARC, 2019). The role of this master's thesis within this cyberinfrastructure is to interact and contribute to its ontology by adding new connectors and/or relating the project's results to pre-existing connectors.

The division of the project in two different case studies and its relation to DataARC required the creation of a general framework in which to develop the research as well as individual ontologies to better understand the results. Ontologies are the definition of explicit hierarchical relationships between single concepts designed to aid in the understanding of the connections between said concepts and facilitate their future analysis (see pp.2-3 in Noy and Mcguinness, 2001; Ehrig and Sure, 2004, p.77). These were laid out with the use of concept maps that linked the most important concepts, the data, and the resources necessary for the research (see Section 3.2.2). Their establishment allowed for a contextualisation of the data and the results, which facilitated an integrated analysis and provided a better basis for each case study's discussion. Considering the complexity of human ecodynamic studies, establishing a specific ontology and conceptual framework was key to ensure the project remained focused on the research aims. It also helped create stronger links between the DataARC concept map and the datasets created for this project (see 3.2.2).

The first case study focuses on mapping the movement across the Icelandic Westfjords by studying cairns as road markers. Through an assessment of their role and interaction with the roads themselves, the study furthers Aldred (2014a) and Mizin's (2013) idea that cairns can also be used as navigational markers. It analyses movement through the Icelandic landscape during late medieval/early modern times. This is done through the creation of a navigational cairn dataset from aerial images and data on past farm locations and economic networks drawn from historic records (see Pálsson, 2018). The main methods used in this case study are least cost path analysis and intervisibility. The results support the hypothesis of cairns being used as road markers to orientate people through the landscape and point towards an interaction and a dependence between landscape and cairn positioning. This shows an interaction between humans and their environment in the use of a combination of navigational markers and the landscape to move through it. The study can help in the understanding of human movement through the landscape and how people interpreted and used it in their travels. It also suggests the physical representation of the relevance of the landscape in normal human activities such as movement.

On the other hand, the second case study analyses the position of clearance cairns within the Scottish landscape and their impact on it. This is done through the examination of a variety of landscape and archaeological data such as soil quality, land compaction, erosion levels, and pertinence to cairnfields, amongst other variables. These were used to create a combined soil and clearance cairn dataset which were analysed through statistics and processing in R to better understand and display the connections between the raw data. The results show a correlation between the presence of cairns and high erosion risk. The study observed three different effects of clearance cairns on soils: exhaustive to the point of not being cultivable, those that are cultivable but with a risk of erosion, and non-exhaustive and therefore cultivable. This deepened the understanding of human engagement with the landscape via agricultural practices in Scotland. Furthermore, it showed the effect that these practices had on the landscape and how these relationships adapted to a changing environment through time.

The assessment of different aspects of cairn functionality and the analysis of different types of landscape-cairn interactions are the main explanations of how well these two case studies complement each other. The comparison and contrast of two very different North Atlantic landscapes offer a more diverse look into the different roles of cairns. Navigational cairns offer the possibility of studying movement through the landscape while agricultural cairns allow for the study of agricultural exploitation and land use. These activities are closely linked to the environment and are still undertaken today, offering an opportunity to observe how these human-landscape interactions have changed.

As part of these two case studies, the project has produced two datasets created from raw data that was gathered and processed as part of the research. Although the synthesis of the general literature has been provided, the preferred method of study for this master's thesis was a direct engagement with the data. This engagement allowed both case studies to produce unique datasets that can help develop the state of the current cairn and human ecodynamics research. This project and its case studies offer a new way to engage with the data available and can, therefore, stimulate new research questions and methodologies.

One of the main reasons for the variety in geographical areas for the case studies is the type and frequency of cairns in Iceland and Scotland. In Iceland, cairns are mostly used to mark roads, *things* and farm boundaries while in Scotland they mostly mark burials and have agricultural purposes. This project's hypothesis regarding the different cairn uses in Iceland and Scotland is based on cairn multiuse. Many cairns could have a potential multiphase and multiuse (see Case Study One and Case Study Two), but these are not always compatible. For example, Scottish mountains and hills have navigational cairns which are still used today, as a matter of fact, recently built cairns will appear and mislead travellers (Webster, 2008). Similarly, it could be argued that the use of navigational cairns in areas with clearance cairns could confuse the travellers by marking the wrong path and leading them into the fields. This, in addition to the difference in soil conditions and agricultural practices, could explain why clearance cairns are so uncommon in Iceland and so common in Scotland. Likewise, it could also explain why navigational cairns are only prominent in Iceland and in high areas of Scotland, away from fields with clearance cairns to avoid confusions.

This master's thesis is divided into the following chapters:

- **Literature Review:** provides a brief background of landscape archaeology, human ecodynamics, and the role of cairns. It intends to offer a contextualisation of the project within the wider literature.

- **Methodology:** gives a comprehensive explanation of the study design and mentions the main methods and datasets used in the master's thesis. It also explains the project's engagement with DataARC.

- **Case Studies:** expanding over two chapters, this will provide a breakdown of each one of the case studies. Each chapter includes an introduction, literature review, results, discussion, and conclusion.

- **Discussion:** offers an interpretation of how both case studies' results relate and connect, as well as of what its implications are.

- **Conclusion:** summarises the project and proposes suggestions for further research.

# Chapter 2

## Literature Review

This project engages in a variety of subjects such as human ecodynamics, cairn use, movement study, and soil survey. For this reason, each case study includes a literature review (see Sections 4.1 and 5.1). These are more specific to each study and provide a more detailed review of the pre-existing literature in each area. This General Literature Review will provide a general yet brief synthesis of the meaning and state of landscape studies, human ecodynamics, and general study of cairns.

### 2.1 Landscape Archaeology

The concept of landscape can often be defined in many ways and is, thus, complex to describe. Overall, landscape is a combination of the environment surrounding humans and the social constructs attached to it. Landscape is seen as a "series of interconnecting systems" which is better understood as the fusion of material and symbolic elements (see p.20 in Aston, 1985; A. M. Miller and Davidson-Hunt, 2010, p.402). The material aspect of landscape can be understood as the environment and natural features surrounding humans, such as vegetation, rivers, mountains, etc. On the other hand, the symbolic aspects of landscape relate to the value and experiences that humans attach to their surroundings. This is a combination of historical events, and social constructs such as a society's worldview, values, institutions, practices, relationship with non-human beings such as plants and/or animals, as well as the personal experiences attached to human's surroundings (Miller and Davidson-Hunt, 2010, 402; Tilley, 1994, 24-25 and 59; Witcher, 1999, 13). Due to this, the concepts of landscape and how it is understood and approached differ depending on the culture and history of the area.

Within archaeology, the study of the landscape can provide a lot of information regarding a culture, its characteristics and its history. This study has been approached differently over the years. Due to the complex nature of the landscape, interdisciplinary approaches are often preferred to obtain a better understanding of historical and environmental characteristics (see Dallai, Donati, and Volpi, 2018; Aldred, 2014a; Eve, 2014). The techniques employed in the study of the landscape are often non-destructive, and are of a computational or exploratory nature, mostly using Geographical Information Systems (GIS) and/or fieldwalking (Eve, 2014; Williamson, 1998). As for the theoretical approach, this has been the object of much debate. The Processual, New Archaeology, approach was based around a scientific view of the landscape and relied heavily on the use of GIS and maps (see p.11-12 in Eve, 2014; Witcher, 1999, p.14). On the other hand, the Post-Processual approach, influenced by phenomenology, was based on an exploration of the landscape that did not isolate the body from its surroundings and concentrated on the different ways in which people may have experienced the space around them (Tilley, 1994, 1994, 11-12; Witcher, 1999, 15-16; and see Eve, 2014, 12-13 for an explanation of the theoretical backgrounds of both currents of thought). Two of the methods used in this project, Least Cost Path (LCP) and Visibility Analysis, are ways in which the use of GIS has responded to this post-processualisation of landscape analysis and are based on the idea of experiencing the landscape through movement and vision, without taking the physical and sensory engagement of a person with its surroundings into consideration (Witcher, 1999, pp.14-16).

One of the main reasons why the landscape is an object of study is because it does not remain static. Humans and their actions cause constant changes within the landscape. These changes can come from a reassessment of the way in which humans interact with their environment. When examined from a phenomenological perspective, landscapes are "subjectively experienced" spaces intimately related to human activities such as walking, therefore, a change in the activities undertaken in it or in the way it is experienced would represent an alteration of the landscape itself (Tilley, 1994, pp. 10-13 and 23). These changes are not only of a symbolic nature or found in the relationship between people and their surroundings; they can also have a physical effect. Historical events, changes in the way food is cultivated, or the creation of new roads are some of the few driving forces behind the physical changes in the landscape which often appear as new constructions, agricultural fields, roads, etc. It is important to highlight that the appearance of current landscapes is the result of many social, political, and historical changes leading to the creation and destruction of monuments, gardens, constructions, fields, forests, etc. (see Aston, 1985, pp.11 and 106; Everson and Williamson, 1998, pp.145-149; Tilley, 1994, pp.204-206; Williamson, 1998, p.6).

In fact, Urban et al. (1987, p.126) argue that the way in which humans use the land reflects natural constraints as well as the financial resources and needs of the people in charge of its exploitation. It is expected that with changes in human needs and culture, how they engage with their landscape will change. McGlade (1995, p.114) points out that this relationship is "constantly negotiated and renegotiated" through history. Therefore, this project proposes the use of human ecodynamics as the main approach to studying these ever-changing relationships between people and the landscapes surrounding them. With an interdisciplinary, mostly non-invasive approach, human ecodynamics can inform of the human-landscape dynamics at any given point in time and how they have changed through time. One of the most common aspects of research in human ecodynamics are the effects of the changes in the weather on humans and *viceversa*; for example, Lawson et al.'s (2005) study of the effect of human occupation on Iceland and Greenland. This type of human ecodynamics studies can even inform people on the sustainability of certain practices based on the effect these have had on the environment through time (see Fitzhugh et al., 2019, p.1081; McGovern, 2014; Dugmore et al, 2014, pp.202-205; Ruiz et al. 1992); acting as a useful tool in today's fight against desertification, erosion, and practices that may be detrimental to the environment in the long run.

## 2.2 Human Ecodynamics

Human ecodynamics is a complex term to define due to its broad scope and recent coinage. Many disagree on the specific definition and characteristics of this field of research, the most relevant examples of this are listed below. In general, however, it can be broadly defined as the study of the interactions between humans and their environment, mainly how humans modify and affect their landscape, and *viceversa*.

- "Human ecodynamics [...] is concerned with the dynamics of human-modified landscapes set within a long-term perspective and viewed as a non-linear dynamical system. Human-environmental relationships are thus defined as involving the co-evolution of socio-historical and natural processes, and their time-space intersection." (McGlade, 1995, p.126)
- "Human Ecodynamics seems to be an umbrella term to describe humans and their environments as made up of landscapes and seascapes" (Holm, 2016, p.307)
- "Human ecodynamics research today is a reflection of the theoretical history of ecology and ecological anthropology, insights on human entanglements in ecological processes, new methods, and political and ethical perspectives on how to direct socio-ecological insights toward desirable future environmental and social outcomes." (Fitzhugh et al., 2019, p.1088)
- "It [Human Ecodynamics] delivers the most comprehensive solution to investigate the interactions of human and natural entities, and it proves especially useful in addressing global environmental issues today and in the future." (Maher and Harrison, 2014, p.3)

Human ecodynamics focuses on two aspects of this human-landscape relationship. The first aspect is the human effect on and understanding of their surroundings. This discipline seeks to understand how humans perceive and relate to their environment. It also examines how people's actions and interactions with their landscape can modify it. This ranges from the farming and the construction of roads and buildings altering the way that the landscape changes immediately to long-term effects and changes such as pollution and climate change. An example of this is the soil degradation in Iceland caused from poor land management and excessive grazing practices which led to the lack of forests and trees in the island (see Catlin and Bolender, 2018; Dugmore et al, 2014; Dugmore et al., 2005). These human influences and agency aspects have often been the most focal since research does not tend to consider the relevance and influence that the landscape can have.

The second aspect that human ecodynamics focuses on is the effect that landscape has on people. It seeks to understand how changes in the environment such as volcanic eruptions, changes in vegetation, natural disasters, or global changes can affect humans. These factors influence and shape people's behaviours and actions. Humans need to adapt and react to these phenomena. In human ecodynamics, human actions through history need not be seen as separate or unrelated to their landscape but as reactions to it. As the environment around humans changes, so do we. The landscape shapes how and where people establish roads, cities, farms, monuments, etc. and humans shape it in return with their construction and actions.

In order to best understand these complex relationships between humans and landscape, human ecodynamics adopts an interdisciplinary character. Interdisciplinarity within the context of human ecodynamics is based on the collaboration of disciplines such as archaeology, biology, anthropology, ecology, geology, and geography amongst others (see p.1078 in Fitzhugh et al., 2019;

McGlade, 1995, p.126). This is mostly due to the complexity of the study itself: to create a comprehensive study of these human-landscape interactions, the data ought to reflect both the environment/landscape (i.e. biological, ecological, geological data) and human culture, actions and behaviour (i.e. anthropological, historical and archaeological data). Good examples of an interdisciplinary human ecodynamics approach in research are Finlayson and Carrión's (2007) study of the effects that changes in the landscape had in Neanderthal population in Europe; Barton et al.'s (2011) research on the disappearance of Neanderthals as well as their interactions with other *hominis* in Western Eurasia; Harrison's (2014) study of human adaptability to climate change; and Amundsen's (2014) study of human-sea relations through tomb placements in Norway.

In the North Atlantic area, NABO, the North Atlantic Biocultural Association has been one of the driving entities in forwarding human ecodynamic studies. They contributed to the creation of "Human Ecodynamics in the North Atlantic" (Maher and Harrison, 2014), a comprehensive compilation of human ecodynamic studies in the North Atlantic which focus on different research aspects, with an interdisciplinary character. McGovern (2014, 215-216) states that Iceland's clear pre and post-human occupation differences, and the availability of paleoclimatic records facilitate human ecodynamic research. This, coupled with the efforts of infrastructures such as DataARC is key in the preservation of this data. In particular in the current climate change environment which risks much of the data disappearing (Kohler et al., 2018, p.68).

## 2.3 Cairns

Cairns are stone constructions used all around the world through history, some of which are still in use today. They vary in shape, size and use. Their versatility makes them complex yet informative elements. They are known to have been used for funerary, navigational, and agricultural purposes, to delimit boundaries, and to mark important places within the landscape, amongst other uses. For this reason, they can provide a wide array of human ecodynamics information, representing how humans engaged with the landscape in a variety of aspects. Their continued use through time as well as their presence in a variety of geographical areas offers the possibility of observing changes in human-environment dynamics through time and geographical space. Therefore, they have been widely studied in many countries.

Common elements through cairn uses are their multi-use and re-purposing. Heide (2014, 69) stated that cairns can undertake several functions at the same time. Although he referred to Icelandic cairns, excavations in other areas have shown that some cairns have different phases of construction and are, in many cases, re-purposed for a different use (Graham, 1959; Johnston, 2001, 108; Yates, 1984, 219; Tilley, 2017, 124-125) and, in some cases, for the same use (see Goldhahn, 2009, for burial cairn reuse through the years). This multi-use is considered in both case studies, more strongly in the first one due to the location of certain cairns, suggesting they could have acted as both navigational markers and field boundaries (see Section 4.4.1).

This versatility, multi-use, and shape and size variations complicate the creation of an overarching set of cairn characteristics. They are better understood and characterised when examined within the context of the role they were intended or (re)used for. Specifically, this literature review will briefly assess the state of funerary, boundary, navigational, and agricultural cairns, predominantly, although not exclusively, in the North Atlantic area.

Funerary cairns are used as burials for one or more bodies, and/or cremation remains. They can often have one or more chambers, where the body is laid. Excavated burial cairns have also shown the presence of ritual deposits such as pottery, fossils, etc. (Tilley, 2017, 124-125; McCullagh and Tipping, 1998; Fernández Ganivell et al., 1967, 71-77). Their erection is often related to ritual processes due to their funerary nature as well as the introduction of funerary goods and human remains (see Abu-Azizeh et al., 2014, 175; Tilley, 2017, 33; Goldhahn, 2009; Bouysse-Cassagne and Chacama, 2012, 671-672). Funerary cairns have been thoroughly studied in Scotland (see Section 5.1), however, these and the rituals attached to burial practices involving cairns have also been the focus of study in other areas of the world.

Boundary cairns are used to establish the limits of territories, fields, properties, farmsteads, etc. These can often be more than a physical separation and turn into a ritualistic and symbolic separation between the wilderness and the domesticated landscape (see p.76 in Heide, 2014; Mizin, 2013, pp.325-8). Due to their positioning around the landscape, field boundary cairns can also act as navigational markers along the landscape (Sanhueza Tohá, 2004, e.g.). Their use is perhaps one of the most continued ones, since, in many cases, they marked boundaries until these were replaced or modified (Aparici Martí and Villanueva Morte, 2019; Sanhueza Tohá, 2004, pp.488-489).

Navigational cairns are located throughout the landscape to mark routes and guide travellers. They are one of the most common uses of cairns and many are still in use. In fact, navigational cairns in the Scottish mountains are regularly controlled and repaired to ensure they can still be used as road markers (Trust, 2016). As mentioned above, they can be reused and/or multi-purposed, mostly as boundaries. Unfortunately, there is not a lot of information regarding navigational cairns, apart from Oscar Aldred's (2014a) thesis. These will be explained in more detail in Section 4.1.

Clearance cairns are agricultural structures made with stones, pebbles, and/or boulders removed from the fields as part of the preparation of the soil for cultivation. They can appear as part of a cluster, a group of cairns, often alongside burial cairns, particularly in Scotland (Graham, 1959; McCullagh and Tipping, 1998). They often include other clearance elements such as small debris, broken up pieces of flint, or pottery shards (Tilley, 2017, 123; McCullagh and Tipping, 1998, 156-157). These will be explained in more detail in Section 5.1.

### 2.3.1 Current Cairn Use

Many cairns are still in use today. While many are used for guidance purposes when hiking, modern cairn-building is a controversial practice in both areas of study for this project: Iceland and Scotland. In the first location, it constitutes an environmental threat while in the second it can be misleading to travellers and put them at risk.

Icelandic cairns constitute a touristic attraction and are present in many of the country's natural parks and roads. Some of these areas, such as Laufskálavarða, are linked to cairn-making traditions which encourage first-time travellers to add stones to the cairns or build new cairns for good luck in their journey (Obscura, 2019, paragraph 2). This practice has become an environmental threat, forcing the Environmental Agency of Iceland, Umhverfisstofnun, to add a rule against building cairns in their Traveller's Guide (Ragnarsdóttir, 2019, paragraph 32). In fact, rangers employed by Umhverfisstofnun are taking these new cairns apart regularly to preserve the landscape and minimise the effects that these cairns may have on it (Ástvaldsson, 2019, paragraphs 1-3).

In Scotland, cairns are still in use both as a touristic attraction, as is the case of commemorative or burial cairns, and as navigational markers that keep hikers on the correct path when on the Scottish mountains. Nevertheless, travellers have started building cairns which can often be misleading and confuse the travellers which could be dangerous. In Ben Nevis, "fraudulent" cairns are often built to hide litter or refuse. As a matter of fact, a group of 15 volunteers who were cleaning the mountain found a piano underneath a cairn (News, 2006; Shute, 2016, paragrapgh 16). The issue has led the John Muir Trust to take control over them, destroying those that could be misleading, and maintaining and building useful navigational cairns (Trust, 2016; Roberts, 2012; Webster, 2008, see).

The presence of newly built cairns also has the potential of misleading archaeological or environmental studies. An example of this can be found in Case Study One, which based part of its data on cairns mapped from aerial images. The presence of newly built cairns that were not part of the original roads and that were created as a tourist activity, to dispose of refuse, or to imitate the pre-existing constructions rather than for navigational purposes can be misleading within the data. It can also be argued that tourists building new cairns, while dangerous to the landscape itself and its travellers, is a modern variant of the human-environment interaction that human ecodynamics seeks to understand. Therefore, when correctly identified, they can further inform the evolution and changes of these interactions (see Section 4.2.3).

# Chapter 3

## Methodology

This project aims to expand the knowledge of human-landscape relations in the North Atlantic in the past through the analysis of cairns and their role within the landscape. In particular, the project focuses on two of the roles cairns undertake in the North Atlantic: navigational and agricultural. It does so with a combined approach that looks at the data from different perspectives and disciplines. The geographical differences offer a wider look into their role in the North Atlantic rather than focusing on only one environment.

### 3.1 Research Design

This project is defined within the concept of human ecodynamics which is broadly understood as the study of human-environment interactions through time and encompasses several disciplines (see Chapter 2). It aims to understand the "constantly negotiated and renegotiated" relationship between people and the nature around them (McGlade, 1995, 114). In particular, this study proposes an examination of this relationship and its renegotiations through the use of cairns. This is the chosen dataset due to cairns' versatility and historical presence in the landscape. Cairns are stone structures that have been built around the world through history, and can undertake several roles within the landscape such as navigational, agricultural, as a marker, to establish boundaries, etc (see Chapter 2).

Navigational and agricultural cairns offer a perfect study of human-landscape relations, as they exemplify two human activities that are intrinsically linked to the environment. Travelling, movement and food production still take place in current societies and have been the subject of improvements and advancements through time. These are often dependent on landscape and environment changes, some caused by human impact, and/or human approach (e.g. advances in transportation, and agricultural tools, technology and practices). Analysing their role and environmental effect in the past, and their changes through time, provides a useful look at human-environment interactions in the long term, as well as how and why these have taken place.

The chosen methods of study are a combination of interdisciplinary methodologies and datasets intended to provide a complete study of human-environment interactions. Through this interdisciplinary lens, this project aims to expand the knowledge of human-landscape relations and to generate more research questions. It also intends to emphasise the benefits of an integrational practice in the study of human ecodynamics. This approach is particularly useful when studying human behaviour and cultures, something that has been thoroughly discussed in both practical and theoretical archaeology due to its complexity (e.g. Alcina Franch, 1991, 20-21; Hodder, 1995, 13-19; McGlade, 1995, 128; and Romanogli et al., 2018).

### 3.1.1 Framework within DataARC

This project is framed within the wider DataARC project. DataARC is a cyberinfrastructure (CI) that links different types of data within the North Atlantic. CIs are data storage systems which set out to provide and facilitate access to a variety of resources to stimulate research, knowledge, and the discovery of new data (see National Science Foundation, 2007, 2-3; and Stewart et al., 2010). In particular, DataARC is focused on the suggestion of links between a variety of data and resources on a temporal, spatial and conceptual basis (see Kohler et al., 2018, 69). Its main aims are to encourage an interdisciplinary approach to the study and understanding of humans' relationship with their environment as well as its changes through history, as well as to facilitate the access to information and its understanding regardless of the user's background and area of expertise (Buckaland, 2019, paragraph 4).

It is within this interdisciplinary, human ecodynamics DataARC framework that this project was developed. The project was informed by many of the resources and datasets made available by DataARC, specifically Jardabók (Pálsson, 2019) and the Icelandic Saga Database (Lethbridge, 2019). Part of this project was also to contribute to the establishment of links between pre-existing DataARC resources and data, and the datasets created for this master's thesis. This offered the opportunity to contextualise the project and its results within the wider research on North Atlantic human-landscape dynamics. It also allowed the project's data to interact with other types of data that are available in the CI. This was done through the creation of combinators which will be further explained in Section 3.2.1 of this chapter. Furthermore, this constitutes an expansion of DataARC's concept map and available dataset which can be accessed by future users in other projects that further human ecodynamics research in the North Atlantic.

## 3.2 Approach and Rationale

As mentioned above, the project will adopt an interdisciplinary approach. This offers a different and deeper understanding of the cairn-landscape interaction. In addition to this, an interdisciplinary approach brings together data and methodology from other disciplines, expanding the study and offering different perspectives, allowing the same data and/or topic to be observed in a variety of ways. This broadens and deepens the research while forging a series of methodological combinations and creative approaches that go beyond the frontiers and boundaries of a pre-set discipline, stimulating new theories and sparking interest and new research. One of the most positive benefits of an interdisciplinary approach is that many of the study's methodologies complement each other even if they are not often used together, which allows for drawing more accurate conclusions.

The project's focus on two uses of cairns in two different geographical contexts required the creation of a sound research framework. This is key in developing the research and aids in the combination of the different datasets and disciplines. To do this effectively and to connect the project with DataARC's project, a series of concept maps and "combinators" were created. These will be explained further in the sections below.

### 3.2.1 DataARC's Combinators

As established in Section 3.1.1, DataARC facilitates the interdisciplinary use of data and resources through the creation of links. The CI is based on an extensive concept map (see Figure 3.1.1) which establishes links between high-level concepts associated with data and/or resources (Kohler et al., 2018, 69). The connections and concepts that form the concept map are created by the CI's contributors. In order to do this, they use combinators.

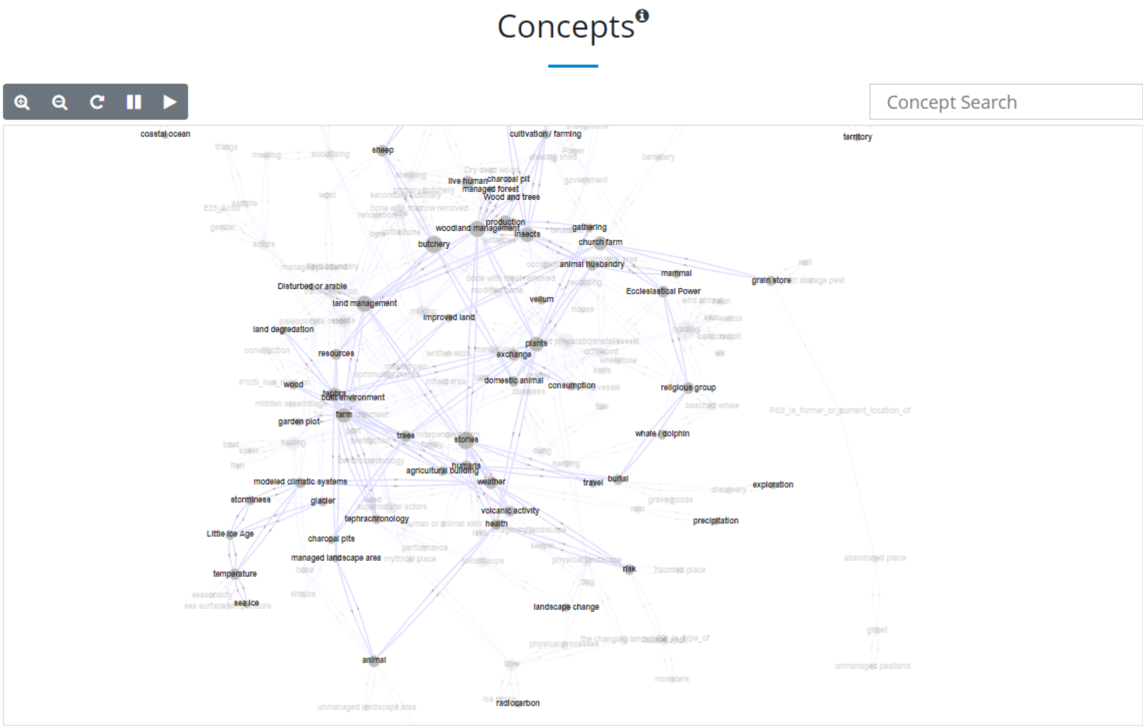


**Figure 3.1:** DataARC's Concept Map which displays the semantic, conceptual and theoretical framework of the project, as well as the connections between the high-level concepts. The map is designed in a way in which it can be explored to discover and analyse the different connections between concepts. It is still under development and expands with each newly added dataset.

Combinators are bridges between data and the CI's concept map although they can also link two or more concepts within the project's map. They are a combination of available data that would produce meaningful search results which would be useful to researchers and/or CI users (Opitz et al., 2018). The establishment of these combinators and concept map are key for the correct functioning of the CI since they provide the basis for interdisciplinary data and resources suggestions. They aid researchers in understanding the connections between DataARC's concepts and datasets which is a helpful tool during the analysis of the results obtained when searching the CI. Combinators are connected and described using CIDOC/CRM (see Angel et al., 2018; and Opitz et al., 2018). They include a series of sections: name, definition, references, query, and relating topics. The query is what defines the relationship the link represents (e.g. is a concept equalled by another, does one contain the other?). This is better seen in the table below which is a simplified example of some of the combinators created to link the first case study to DataARC's concept map (Table 3.1).

The process followed in the creation of combinators was based on DataARC's concept map. The main concepts relating to cairns and the created cairn dataset were identified (e.g. "road/travel", "landscape", "farms", "land management", etc). Each of these concepts was then reassessed in relation with the cairn dataset. The ways in which navigational cairns and agricultural cairns

| Combinator Name | Combinator Description | Combinator Query | Relating Topics |
|---|---|---|---|
| Cairns as road markers | Cairns can be used as navigational markers to indicate direction the landscape itself does not make the direction clear. | Title contains "roads/travel" + Title equals "landscape" | Roads/travel; landscape |
| Farm to farm roads | Proposed roads between related farms based on Jardabókin farm connections in late medieval to early modern Iceland. | Title equals "roads/travel" + Title contains "land management", "agricultural landscape", "farms", and "managed landscape" | Farms; roads/travel; land management; resources; tenant farm |
| Cairns as farm boundaries | Cairns within the perimeter of a farm can act as farm boundaries. | Title equals "managed landscape area" and "land management" + Title contains "farms", and "landscape" | Farms; land management; agricultural landscape; managed landscape area |
| Cairns and the landscape | Cairns interact with the landscape to act as landmarks/feature markers, farm boundaries, and navigational markers amongst others. | Title contains "landscape", "land management", "farms", and "assembly sites" | Landscape; land management; assembly site |
| Cairns as feature markers | Cairns can mark specific features (e.g.things). | Title contains “things", "assembly site", "place of worship", "local assembly", and "landscape" | Landscape; things; assembly site; place of worship; local assembly |
| Cairns | Location of possible cairns in the Westfjords based on satellite imagery analysis. | Title contains "landscape", "roads/travel", and "land management" | Landscape; roads/travel; land management |

**Table 3.1:** Simplified table demonstrating the structure of some of the combinators used in the first case study as part of the link of the study to DataARC's concept map.

engaged with these concepts individually were then identified and used as the base for the combinators. For example, in Table 3.1, the combinator "cairns as road markers" is based on the relationship between navigational cairns and the roads they are marking. Primary connectors between DataARC concepts and the cairn dataset were prioritised to secondary connectors. This was to ensure that the connections were meaningful and well-explained rather than strained, excessively complex, and difficult to understand. The combinators created for this project can be seen in the hard drive provided alongside this master's thesis, alternatively, they can be found in an open-access repository (see Roigé Oliver, 2019).

### 3.2.2 Project's Concept Map and Ontology

The project's ontology is based on the connection and organisation of theoretical ideas around cairns. Ontology is the theoretical interrelations of concepts in a study's design which can be organised in a hierarchical manner (Ehrig and Sure, 2004, 77). This project's ontology seeks to relate the different uses of cairns to human behaviours and the landscape to conduct the two case studies on navigational and agricultural cairns. This is better represented in the concept map found below (Figure 3.2) which presents the project's theoretical approach to cairns, more specifically navigational and agricultural cairns, and how they relate with each other. The map provides a clear visual representation of the complex links between the concepts present in the project since ontologies can be complex to design and convey. Concept or semantic maps are a visual graphic tool similar to a diagram which is used to represent the relations between concepts or items. Due to the complexity of the project's theoretical framework as well as the relation with DataARC, which also uses a concept map (see Figure 3.1), this type of tool was deemed the most adequate visual representation of the ontology.

DataARC's concept map is aligned with its ontology. The CI's overall ontology is based around the idea that data should be accessible to users from all disciplines, encouraging them to approach data outside of their area of expertise and to consider the context (for an in-depth discussion of the CI's ontology see Angel et al., 2018; Opitz et al., 2018; and Barruezo Vaquero, in writing). Its main goals, relevant in the development of the ontology, were the enrichment and contribution to the research community studying human ecodynamics in the North Atlantic, the contextualisation of the interdisciplinary data, and the creation of digital tools that encourage and facilitate interdisciplinarity (Angel et al., 2018). DataARC's main challenges, both in the design of the CI, and the development of the project revolve, around the diversity of data and knowledge required to interpret it: from its conception, DataARC has sought to find the correct balance between ensuring data availability and openness, and avoiding the misinterpretation of said data (Angel et al., 2018; Opitz et al., 2018).

The project's concept map shows the relationship between navigational and agricultural cairns as well as their establishment within the wider cairn framework. These two types of cairns are linked to farm and land management, both of which are very present in the DataARC concept map as well as this project. However, this also introduced new concepts to the CI such as "cairns" which was an aspect that the project had not approached before. The rest of the concepts introduced were sub-concepts of aspects that were already on the map:

- "Object movement" in "exchange"
- "Road markers" and "farm routes" in "roads/travel"
- "Deforestation", "land/soil modification" and "vegetation changes" in "Woodland/landscape changes"
- "Farm boundaries" and "farm networks" in "farms"

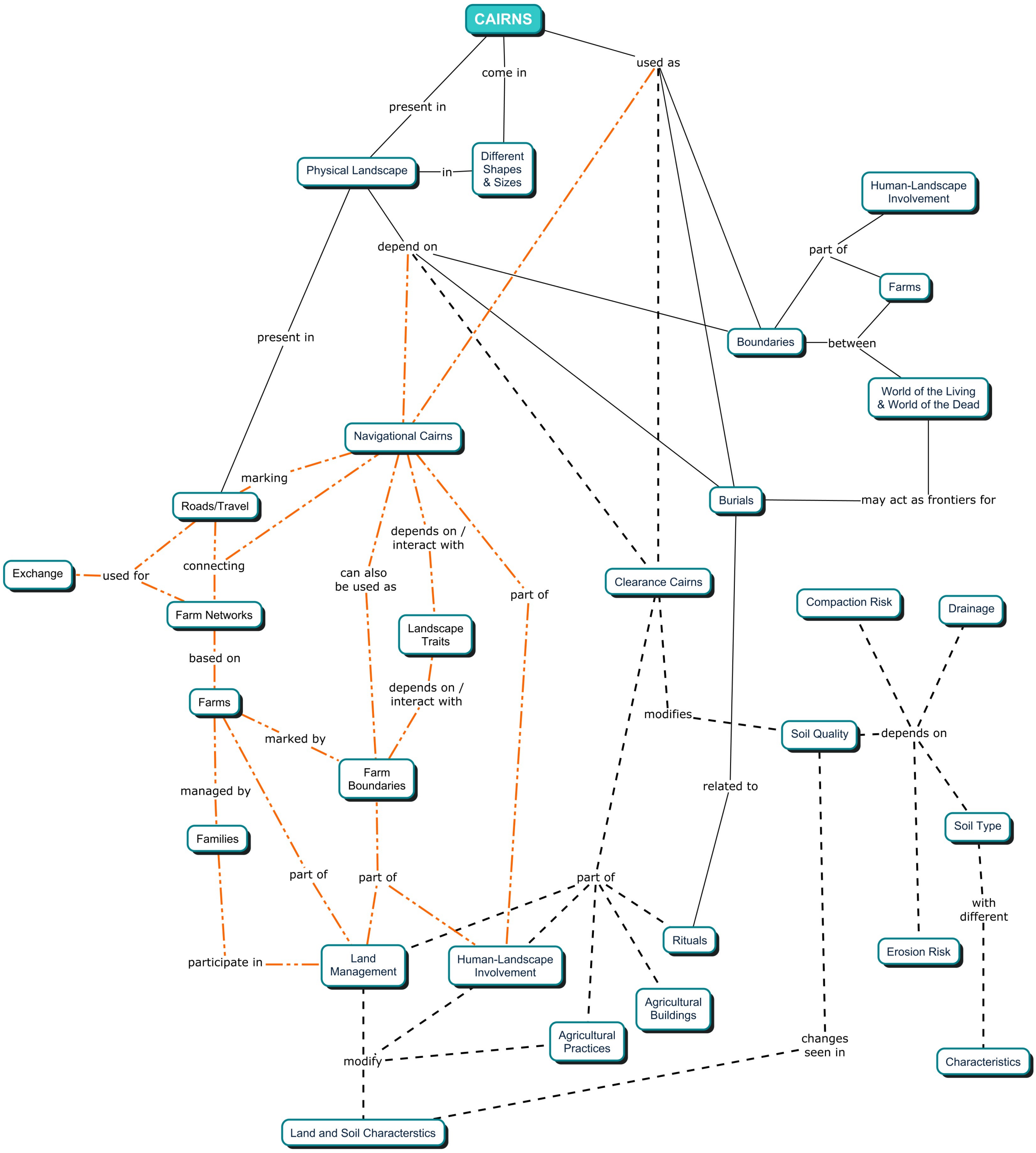


**Figure 3.2:** General Concept Map which displays the conceptual framework of the project and the connections between the two case studies. The connections relating to navigational cairns are represented with an orange dot-and-slash line while those relating to agricultural cairns have a dotted black line.

## 3.3 Data Analysis and Collection

The methods of data collection and analysis used in this project depend on the case study, the data availability and the cairn aspects each study investigates. Overall, the methodologies used are taken from a variety of disciplines, with a predominance of computational archaeology and statistical analysis. Similarly, the data obtained related to different yet complementary disciplines, mainly geography, geology, archaeology, and history. This integrated approached favoured the creation of a completer and a more nuanced dataset which facilitated the final analysis. The limitation of a study to data, methodologies, analytical tools, and/or approaches pertaining to one discipline would not have represented the complexities of human behaviour and human-environment relations correctly. This is better understood when examined within the context of each case study, and where these fit within the broader DataARC project and its interdisciplinary focus.

### 3.3.1 Datasets

Due to the differences in the focus of the case studies, a detailed explanation of the dataset creation can be found in each case study. In general, the first case study relies on computational archaeology, while the second is a combination of geological and statistical analysis. Case Study One focuses on navigational methods and aims to analyse cairn distribution through roads, as well as the roads themselves. Due to the lack of data availability, a navigational cairn dataset was created through the visual analysis of aerial imagery. Likewise, a movement dataset was created from Jardabók's (Pálsson, 2018) farm interconnectedness data by undertaking the least cost path analysis, resulting in a series of possible roads. On the other hand, the second case study focuses on agriculture and the effect of clearance on the soil. A comprehensive dataset was created from Canmore's (H. E. Scotland, 2019) archaeological data, cairn locations, and The James Hutton Institute's (2019) soil and geology data. This was later examined mostly using statistical analysis. The results were then interpreted within the general literature context. In both case studies, the cairn datasets time periods are uncertain and potentially span through several centuries.

### 3.3.2 Analysis

This section will provide a brief overview of the methods of analysis used. This includes a summary of the programs used for processing the data and the production of the maps, graphics and charts, as well as an overview of the results this yielded. However, chapters 4 and 5 (sections 4.2 and 5.2 respectively) provide a more detailed explanation of the methods of analysis.

Case Study One relies on computational archaeology. To understand the way in which people move through the landscape, it is necessary to understand the landscape, the weather, the changes it experiences throughout the year, the destination, the traveller's intention and relation to the destination, etc. All of these are complex elements to represent and consider within a digital analysis. Nevertheless, the inclusion of a newly created dataset including cairn, farm networks, and LCP data, as well as the use of a variety of methodologies offers a stronger, more varied dataset, presenting a more accurate analysis. QGIS 2.18 and 3.6 were the main programs used for Case Study One. Satellite images were processed in QGIS and used to produce a vector layer with manually introduced points. The LCPs were created using the pre-set Least Cost Path function. Similarly, the viewsheds were produced using QGIS "Visibility Analysis over raster DEM" plugin.

Case Study Two is based on a combination of geological and statistical analysis. This is because agricultural processes and the relationship humans have with them cannot be understood without an awareness of the area's geology, the characteristics of the soil, and agricultural techniques. This was created with the "Merge Vector Layer" function in QGIS, in order to incorporate the geological, archaeological, and soil data to a new vector layer. As this study has observed, the changing interaction of human activity and the soil derives from the reaction soil has to how it is being exploited. A soil that has been over-exploited and no longer yields crops will not continue to be used in agriculture. Similarly, a soil that is unsuitable for cultivation due to its excessive boulder presence may be turned into a crop field once stones are cleared and piled into a cairn.

These changes in both soil characteristics and behaviour, as well as agricultural exploitation and practices, are better understood when analysed together.

Both case studies include maps, graphics, and charts. Case Study One incorporates maps which were created by the author using QGIS versions 2.18 and 3.6. The charts in this case study were created and processed using Microsoft Excel. On the other hand, the pie charts and bar charts used in Case Study Two were created using R Studio version 3.6. A copy of the code used to produce the charts displayed in Case Study Two can be found in the Appendix. This methodological difference in respects with the analysis of data is based on the amount of data and the type of analysis required. The second case study had a considerably larger dataset than the first one and relied on statistical analysis more. As for the diagram used in Case Study Two, it was created by the author with the program Canva.

## 3.4 Final Considerations

Detailed explanations regarding each case study's methodology and datasets can be found in chapters 4 and 5. These include maps and descriptions of the areas of study which have not been discussed in this general methodology. Likewise, the limitations of this project are specific to each case study and have been detailed in its respective chapters (see Sections 4.4.3 and 5.4.3). With regards to this project's generalizability, these results are specific to the study areas and, while the studies can be replicated in different geographical contexts, the results cannot be imported to other locations. Nonetheless, the interdisciplinary approach taken, and the methodologies used can be employed in other human ecodynamics and/or cairn studies.

CHAPTER 4

# Case Study One: Navigational Cairns in Iceland

This research study focuses on the use of cairns as navigational markers. Within human ecodynamics, people's movement through the landscape is one of the least studied fields due to the fact the focus is on the impact humans have had on their environment. Nevertheless, understanding the way travellers moved through their landscape can offer a great insight into human-environment relationships. It provides the possibility to acquire a greater insight into how people perceived and understood their surroundings and the landscape: which areas did they prioritise when walking from one point to another? How did they mark the routes? Are there any patterns to the way in which people moved through the landscape?

One of the few and most extensive studies to date regarding movement in Iceland is Oscar Aldred's thesis (2014a). His work defines three materialisations of movement (movement of cultural groups, that of social practices, and the movement of bodies) and the idea that the placement of navigational cairns in the Vatnsfjörður area depends on a combination of topography, and network relation (Aldred, 2014a). From these theoretical and practical frameworks, the hypothesis of this project was defined: cairns in the Westfjord area will also undertake a navigational role and will mark the roads in between farms.

Cairns are often studied from the perspective of landmarks, such as markers for *things*, or as burial and/or religious places. Likewise, most studies of movement concentrate on the start and end points rather than the routes themselves and, specifically, the role that the landscape itself plays in movement and the creation of routes and roads. For this reason, there is a need for a study which focuses on people's movement, a constant human practice through history, from the perspective of its interaction with the landscape through the analysis of cairns.

* All of the maps, tables, and charts used in this project were created by the author. Satellite images courtesy of the DigitalGlobe Foundation (www.digitalglobefoundation.org) Farm network dataset courtesy of Gísli Pálsson (www.jardabok.com).*

## 4.1 Theory: Literature Review

### 4.1.1 Movement through the landscape

Movement is a very important activity in daily life. Walking is an everyday activity that has historically connected people; in fact, the creation of roads has been a driving factor in the stimulation of network creation, trade, and the historical landscape (see Ingold, 2001, p.37-38; Fowler, 1998, p.27; Hindle, 1993, p.11). Icelandic landscape archaeology has focused mainly on the study of farms, *thingsites*, and the landscape itself, rather than the movement of people through it. One of the first people to identify this gap was Oscar Aldred (2014a), who emphasised the need to study movement and its relationship with the environment, to establish connections between the landscape areas. This section of the literature review will focus on this gap and, through the examination of the mentions of routes and journeys, or lack thereof, on the studies of markets, and saga places. Many of these studies have brief mentions related to reaching the destination, but do not provide developments on the length of the journey or the routes taken.

Travelling to markets and fairs was one of the most common reasons to move through the landscape, yet the literature fails to mention the roads and journeys to get to them, although it acknowledges their existence. Most of the literature coincides with the fact that travelling to market places by sea was often preferred because it was a cheaper, safer, and more accessible way of moving people and goods (Hunt and Murray, 1999, p.48; Miller and Hatcher, 1995, p.149; Sawyer, 1986, pp.72-3) and the studies that mention inland travelling do it briefly. For example, Hunt and Murray (1999, p.67) mention trade along the roads on the way to and from markets and fairs in Medieval Europe. The key role that movement played in defining commercial routes and marketplaces has also been highlighted by Bolender and Aldred (2013, p.144-5) and Galloway (2005, p.112). Equally, Cameron (1998, p.12) suggests that fairs in Medieval Europe helped shape the countryside by forcing the creation of more frequented and busy roads and paths. The social importance of markets in the development of cities and landscape areas is clear (Jamroziak, 2005, p.41), and these studies highlight, in one way or another, the importance of the roads themselves in the development of commerce yet fail to develop the idea further. Hence it is important to look at the roads themselves to understand both the journey and the destination.

Pilgrimage is another relevant and common reason for movement in Iceland, as it was the cause of short and long distance travel. Icelandic people and their families considered their trips to church pilgrimages and did it often (Swatos, 1984). Pilgrimage was also the source of long-distance travel and movement through the island and into other countries as, with the rise of Christianity, many went to Rome as pilgrims. Pilgrimage from Iceland to Rome was a common reason for movement between the 11th and 13th centuries and some of the routes between the island and the religious capital, and the dangers that they entailed, were recorded by pilgrims such as Nikolai of Munkathvera (Birch, 2000, pp.103-4 and 206). This was also exemplified in the sagas, with many examples of heroes who went on Pilgrimage from Iceland to Rome after converting to Christianity (e.g. p.8 in Phelpstead, 2013; Anon, 2007; Strmiska, 2000, p.131). While this study does not take into consideration religious factors and their influence on movement, it is important to acknowledge and understand that pilgrimage and churches and shrines, had a very relevant role in movement in Iceland.

Another key element in the understanding of movement through the landscape are Icelandic Sagas. These do not only offer descriptions about the topography and the landscape, which aids in the study of its change over time, but they also influenced the “cultural construction” of the landscape through the years, according to Lethbridge (2016, pp.68-70). Its influence is still tangible, since many of the farms and places they name are still in use, and many of the saga sites have been excavated for evidence of Viking remains (see p.120 in Catlin and Bolender, 2018; Cormack, 2007, pp.210-11). Sagas can be very useful in the understanding of motivations behind travel during Viking times and even 13th century, depending on the interpretation the reader decides to adopt (see Lethbridge, 2016). Nevertheless, as Bolender and Aldred (2013, p.146) highlight, the overly "saga-centric" interpretation of the landscape may lead people, especially tourists, archaeologists and saga fans to focus on sites rather than the journey and/or the routes leading to them. The public during the 19th, 20th and 21st centuries moved through Iceland visiting the locations in the Sagas and following its stories (Aldred, 2015; Powney and Mitchell, 2018, e.g.). Sagas can be very useful for understanding movement and routes, but the academic and public focus has been mostly on the farms or topographical locations they discuss.

### 4.1.2 Geographical Information Systems for the Study of the Landscape

The methods used in this study are Least Cost Path and Intervisibility Analysis. These have been used together many times in the reconstruction of movement and prediction of paths (e.g. Porcheddu, 2017; Canela Gràcia and Otero Aerraiz, 2018; Lewis, 2017; M. Llobera, 2000; Güimil-Fariña and Parcero-Oubiña, 2015; Murrieta-Flores, 2014; Leusen, 1999). Below is a brief explanation of each analysis including the main limitations to consider when using these methods.

#### 4.1.2.1 Least Cost Path

The main method used in this case study is Least Cost Path which models possible routes through the landscape. The models are based on energetic and/or time costs of the land and select the routes which will take the least time or energetic effort. These costs are calculated from a DEM or a slope model which consider the energetic cost of every tile. To calculate this, a cost surface of the entire area of study is created, then the origin and destination points are connected through the tiles with the least energetic and time cost (Conolly and Lake, 2006; Herzog, 2014). Many algorithms are used to calculate this and the choice of algorithm will affect the proposed route, but the most common algorithm is Djikstra, a version of which is the default algorithm in QGIS and ArcGIS (Gillings et al., 2019; Wheatley and Gillings, 2013; Herzog, 2014).

Regardless of the algorithm used, human movement is a complex element to represent and analyse as there are many variables and aspects which can affect it. As discussed in the General Literature Review, Chapter 2, the use of GIS in the study of movement is a highly debated topic. It can provide a great opportunity for the understanding of the space being studied but it can often lack the human or corporeal element that helps better comprehend the more nuanced element of human-landscape interactions. The landscapes that surround us are all active and embedded with meaning whether that is due to the people in it, or the elements present in it such as vegetation or monuments. These will affect humans' perception of it and, therefore, will affect how they approach it and move through it. Landscapes are alive, with the noise of human activity and movement, turning the space into busy taskscapes that humans live in and move through (Ingold 1993 and 2017). These are all difficult aspects to include in a GIS analysis.

GIS is based on a boolean model of spatial data, meaning that the results of any analysis will be true or false, which is not true for many geographical phenomena nor human choices relating to movement through the landscape (Fisher, 1999, 5-6). However, LCP can provide very useful information regarding movement patterns in the past, if its limitations are understood and acknowledged.

In this study, the use of LCP to analyse movement and travel has two main limitations that must be understood and acknowledged. The first and most important one is GIS' deterministic and functional approach to the environment (Llobera, 1996; Gillings and Goodrick, 1996; Kempf, 2019).

The fact that GIS focuses solely on environmental factors, limits the study as it does not take into consideration the influence that pilgrimage routes, churches, shrines, and/or any other socially or religiously relevant places which have been shown to influence the routes that people took in the past (Phillinps and Leckman, 2012; Kempf, 2019, p.8). Therefore, it is important to understand that an absolute statement cannot be made based on LCP analysis alone. Although this particular case study does not focus on this, future studies could incorporate socially and religiously relevant spaces within the study areas to obtain a more holistic and comprehensive result and to bypass this limitation (see Section 4.5). The second limitation to acknowledge is that these analyses are being undertaken on current landscape features, which may have changed through history (see p.2534 in Howey, 2011; Llobera, 2007; Porcheddu, 2017, p.601).

#### 4.1.2.2 Intervisibility Analysis

The other analysis that this case study uses is intervisibility. As mentioned in the General Literature Review, Chapter 2, visibility analyses are an attempt to bring a more sensory approach to GIS analysis (Witcher, 1999; Gillings and Goodrick, 1996; Wheatley and Gillings, 2000). They inform visual patterns or influences that could have affected how humans interacted with their landscape. It can aid in understanding the distribution of monuments within the landscape based on visibility either between them or from one relevant point of the landscape to them; Gillings' (2009) study on megalithic monuments' distribution. They can be very helpful in exploring datasets such as this case study's clearance cairn one.

Visibility analyses establish what parts of the landscape can be seen within any given point. According to this analysis, if an object lies within the visibility area, it will be seen by the "observer". The observer is the point in the landscape from visibility or a line of sight is calculated. The observer is often set as the starting point to indicate an area of visibility. To calculate this in GIS, a DEM is used to establish the elevation of the terrain in the study area; these elevations are then used to determine what points in the landscape can be seen by the observer because they are within its line of sight (Gillings, 2009; Bury and Svidzinska, 2015).

Visibility analyses in GIS work with a boolean data type system, meaning that the result will be binary with "true" indicating that there is visibility and "false" indicating no visibility of each raster cell in the DEM (Cuckovic and Arfon, 2020; Bruy and Svidzinska, 2015). This information is then put together, creating areas of visibility from an observer point. Intervisibility is based on these premises. This analysis puts together a series of observer points within the landscape and creates a network of visibility between them which establishes what observer points can be visible from each other when connected (Bruy and Svidzinska, 2015).

Intervisibility can provide great insight into human-landscape relationships, however, it is important to be aware that it does not provide a complete representation of past landscape perception and experience. Other senses which are more complex to study such as smell or hearing could have also influenced these experiences. Furthermore, there are a series of limitations to visibility analyses. Firstly, movement will affect how objects and the environment are perceived, affecting clarity and focus (Wheatley and Gillings, 2000; Llobera, 2007). This is very difficult to consider in GIS' boolean system as it will only consider what areas can be seen rather than whether they may or may not be out of focus for the observer, especially if it is in movement. Seasonal changes would also be difficult to add to the analysis. These would include vegetation changes which would change throughout the year, affecting visibility and changing the layout of the landscape, and seasonal weather changes which affect ambient light hindering or enhancing visibility (Wheatley and Gillings, 2000; Llobera, 2007).

### 4.1.3 Cairns

Cairns can serve multiple purposes and it is often hard to determine what function it undertakes within the landscape. Due to this, there have been many studies regarding cairns and their uses (see Section 2). The most common uses in Iceland are to mark time, routes, and properties though they can also be used as monuments and/or *things* (Heide, 2014, p.69). In most cases, and due to this versatility, cairns will often have more than one use.

One of the most common uses of cairns, which can also indicate the presence and direction of roads, are as *things*. These were places where the elites and the local people could meet for discussion and decision-making purposes, and they were marked in the shape of a bigger-sized cairn to stand out of the surrounding landscape (Sanmark, 2017, p.242). Assembly sites were in the convergence of several routes and in landlocked areas, so they had to be accessed via overland routes; as a matter of fact, many sagas mention people horse-riding to and from *things* (Sanmark, 2017, p.168). It is very plausible that cairns used as *things* also functioned as road markers.

In Iceland, cairns are also often used to mark the roads and landmarks. They have been continuously used to mark the landscape and elements within it, such as glaciers (see Eythórsson, 1949). One of the most extensive studies of the use of cairns as road markers is Oscar Aldred's (2014a and b) thesis and article which established that the placement of this type of cairn depended on a combination of topography, and relation with the roads and the site network. Cairns used for navigational purposes often had a symbolic connotation. In some cases, depositing stones on them ensured the traveller's good luck. An example of this is Lauskalavarda, where cairns were built to commemorate a farm that had been destroyed by the eruption of Katla in the 9th century, and nowadays there is a tradition that mandates travellers deposit a stone for good luck in the road (Mizin, 2013, p.320). Navigational cairns could also be used as markers in pilgrimage routes as is the case in other areas of the world (see Schmidt, 2012; Silverman, 1994), especially considering the pilgrimage tradition in Iceland. In other cases, they are a symbolic separation between the wilderness and the domesticated landscape, signifying the places of the Icelandic landscape humans reached before and thus can reach again (see pp.325-8 in Mizin, 2013; Heide, 2014, p.76).

Another very frequent use for cairns, proposed by Heide's (2014) study of cairns, is the use and distribution patterns in the Vatnsfjördur area. He discovered that cairns have a collective function when observed from afar within the landscape context, and went on to compare them to farm boundary markers, realising that these appear to coincide but are only visually active from around the farmsteads and not from the areas surrounding the farms (Heide, 2014, pp.74-5). This study brings forth the possibility of cairns being used as farm boundaries for the people within the farms and for travellers passing by rather than from those who chose to observe the area from afar.

## 4.2 Methodology

### 4.2.1 The Study Design

This case study will focus on mapping movement across the landscape in the south of the Westfjords, in the form of possible roads, through the analysis of cairns and resource networks between farms.

This research project built upon the theoretical and practical framework of modelling movement set out by Oscar Aldred (2014a, 29) in his thesis. In particular, it has developed a dataset for a different area of the Westfjords, examining the farm resource networks in Jardabók (Pálsson, 2018) and its physical connections through the establishment of roads marked by navigational cairns. It has also provided more information regarding cairn-landscape and road-landscape interactions in Iceland. This section will describe the methods and data used in this analysis and the theoretical assumptions behind these.

#### 4.2.1.1 Area of Study

This study will examine a 4,815 km2 area in the Westfjords (see Figure 1). This area of study has 167 farms located mostly in coastal and fjord areas. Unfortunately, the area has not been surveyed for cairns yet, since the surveys throughout the years have mostly focused on the southern part of Iceland (Aldred, 2014a, 84). As for the geography of the area, it is full of fjords and cliffs, while the central part of the study area is quite mountainous, making inland travel quite complex. With regards to population, the Westfjords are one of the least populated parts of the island with a density of 0.3/km2 as of 2007 (Travel, 2018).

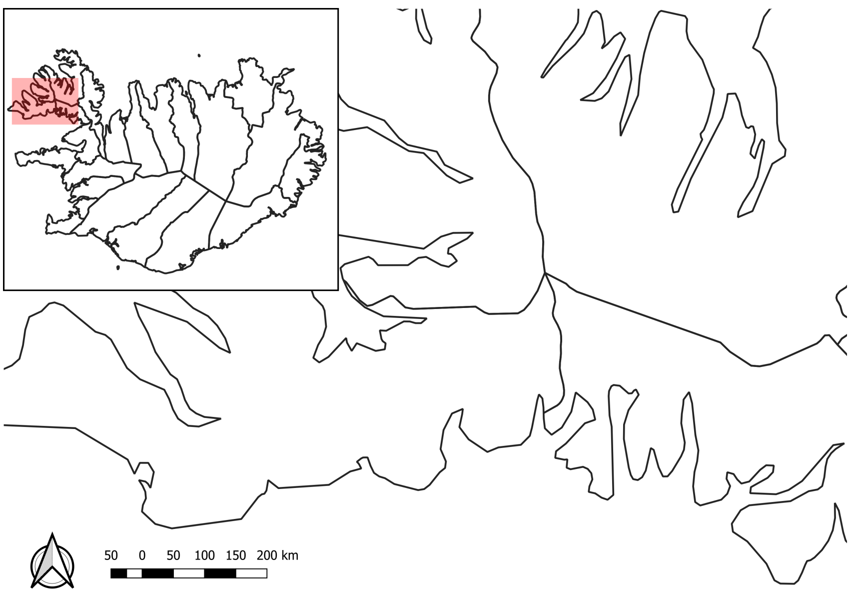


**Figure 4.1:** Map of the study area in the Westfjords of Iceland

The farms used to produce the LCP analysis were taken from Jardabókin (Pálsson, 2018). For the area of study, a total of 167 farms were registered. Unfortunately, time constraints derived from the duration of the research project and the extensive computer processing capacity required to produce LCPs of 167 (i.e. a supercomputer with enough RAM capacity) resulted in a reduction of the dataset. Three farm clusters were chosen as the final smaller study areas using Jardabókin's (Pálsson, 2018) resource exchanges. The clusters have four to five farms each which have known networks of interaction (see Figure 4.2).

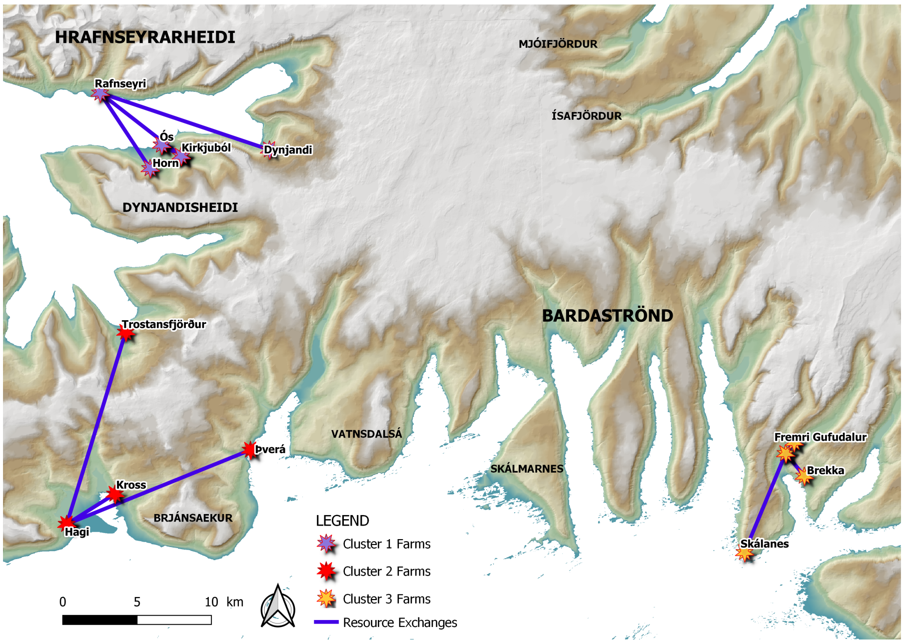


**Figure 4.2:** Map of the study area showing the three case study clusters and their interconnectedness. Cluster One (top) in green with five farms, Cluster Two (bottom left) in pink with four farms, and Cluster Three (bottom right) in purple with four farms. The most prominent fjords are also labelled.

***Cluster One*** This cluster consists of five farms: Rafnseyri, Horn, Kirkjuból, Dynjandi and Ós. The farm distribution can be seen in the map (see Figure 4.3). It is located in the northern fjord area within the delimited area of study.

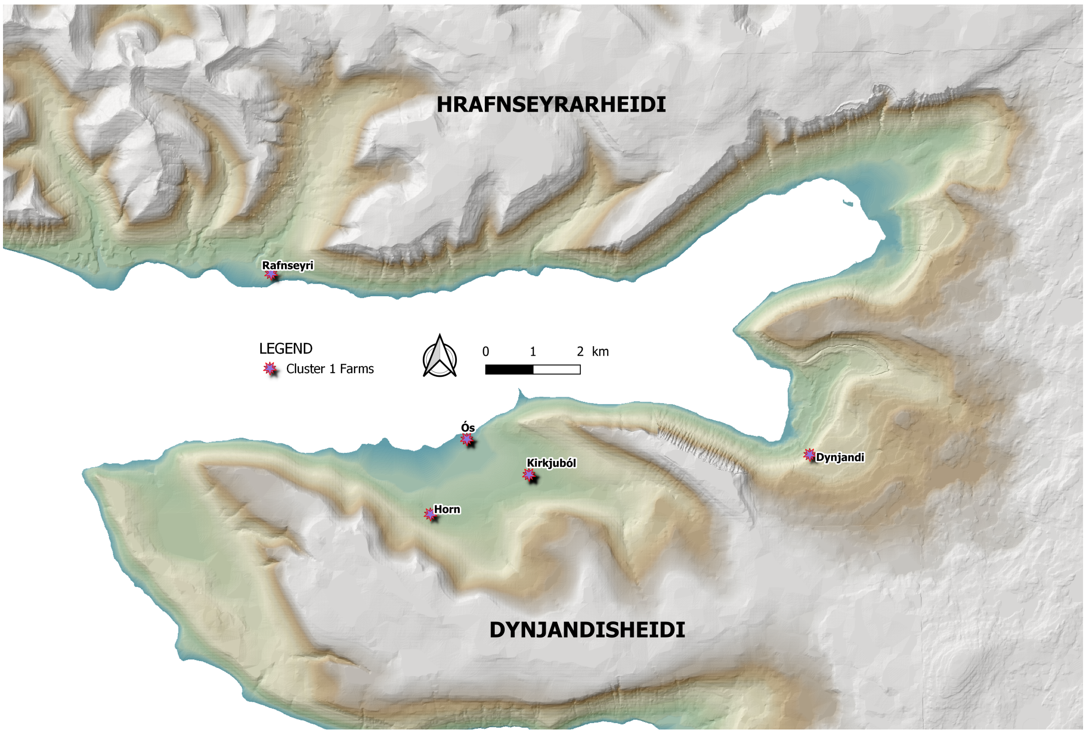


**Figure 4.3:** Map of the farms in Cluster One. It includes the names of the farms and the local most prominent fjords.

***Cluster Two*** This cluster consists of four farms: Trostansfjörður, Thverá, Kross, and Hagi. The farm distribution can be seen in the map (see Figure 4.4). This cluster is located in the southern coast of the Westfjords, and the farms are spread on both the north and south coast of a fjord which makes travelling in between the farms complex.

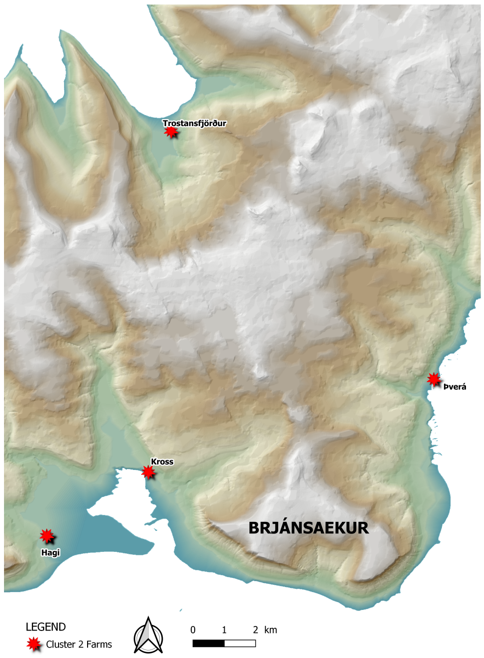


**Figure 4.4:** Map of the farms in Cluster Two. It includes the names of the farms and the local most prominent fjord.

***Cluster Three*** This cluster consists of four farms: Skálanes, Nedri Gufudalur, Fremri Gufudalur, and Brekka. The farm distribution can be seen in the map (see Figure 4.5). This cluster is located in the southern-east coast of the Westfjords. Three of the farms are concentrated in a valley area while the fourth farm is further down the coast.

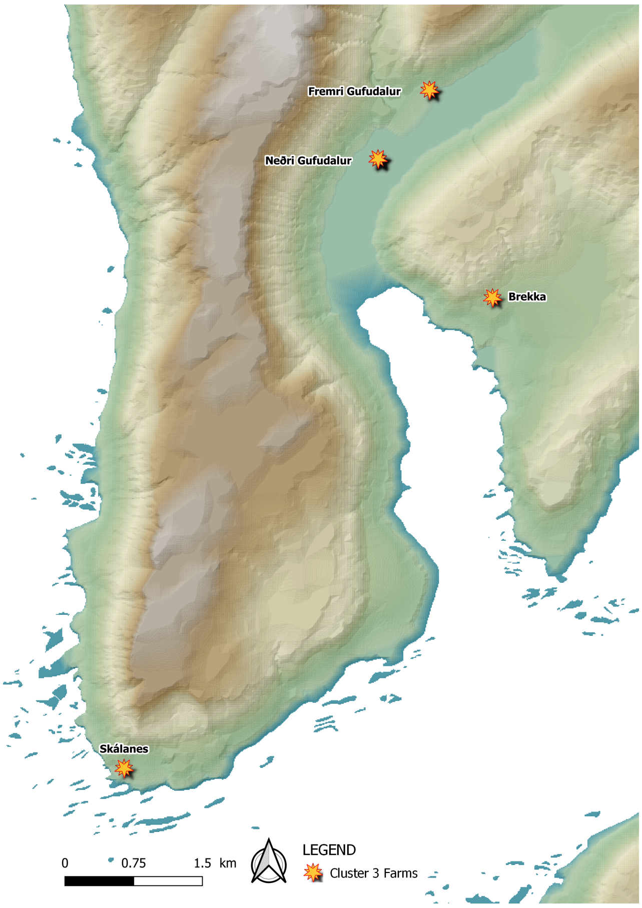


**Figure 4.5:** Map of the farms in Cluster Three with farm names

#### 4.2.1.2 Resource Networks and Movement Analysis

Resource networks and farm interrelations were analysed and used to inform movement analysis. Resource networks and farm interrelations were examined thanks to Gísli Pálsson's (2018) database, Jardabókin, and DataARC (2019). The information obtained from these resources was used to map the farms within the landscape in GIS and establish route directions and movement intentionality. Movement intentionality is understood in this context as the general route directions that people would have followed when travelling through the landscape which, for the purposes of this study, will follow the directions indicated by the farm and resource networks and connectivity. Although Pálsson (2018) specifies in his database that not all of the resource networks connections are reciprocal, for the purposes of this study it is assumed that these connections are, indeed, reciprocal and that travelling would occur in both directions. Therefore, these farms were used as starting points to undertake analysis of movement.

Once farms were identified and movement intentionality was established, possible routes within each of the designed clusters were mapped using GIS. The methodological approach used to do this was LCP analysis. LCP modelling calculates the optimal path between points with the least obstacles and energetic cost. This aspect of LCP makes it very appropriate for this study due to the topographical and natural features of inland Iceland, which make movement complex and often unattainable.

Cairn data was identified and mapped using GIS. The cairn distribution was analysed and compared to other cairn studies to determine if there are any apparent distribution patterns to assert whether the mapped cairns are indeed being used as road markers or as something else such as farm boundaries (see Aldred, 2014a and b; Heide, 2014; and Meize, 2013). Afterwards, the possible pathways and areas of movement between farms or geographical points that resulted from the clusters' LCPs analysis were compared with the final cairn map. This was done to determine the validity of this study's main hypothesis, that many Icelandic cairns have a navigational purpose and were built to mark routes to travel between farms and/or other geographical points. The comparison of cairn locations and the results of the LCP analysis allowed to demonstrate that cairns were indeed located alongside farm-to-farm routes.

### 4.2.2 Data and Data Analysis

#### 4.2.2.1 GIS Analysis of Movement

The data used to undertake the LCP was a Digital Elevation Model (DEM). The highest resolution DEM available for Iceland can be found in Polar Geospatial Centre (2018) and it is 2 metres. To undertake the LCP analysis, this study assumes that the travellers are doing these journeys frequently, know the landscape and will, thus, choose the most available and least time and energy-consuming routes when travelling from one point of the landscape to another. Due to this, the study hypothesises that the routes travellers will follow in their journeys are marked by cairns in most of their extension if not in their totality. Therefore, the study tests whether the routes were designed by frequent travellers who would mark the safest, efficient and pragmatic paths to reach their destinations. To test this, the data was analysed using primarily QGIS versions 2.18 and 3.6.

For the purposes of this study, the movement model was based on people travelling by foot rather than by horse. Considering that the Westfjord's landscape is mountainous and full of fjords and cliffs which people would try to avoid during regular travel between farms, the focus was placed on the time and energy costs. Multiple LCP analyses were undertaken for each route to offer a variety of ways of travelling through the landscape. The calculated LCP was buffered to create a potential path area.

In the initial version of the study, the LCP analysis was done with slope values. The reason for this was the wide array of studies exemplifying the accuracy of slope-based LCPs (see Alvez, 2016; Taliaferro et al., 2010, 538). Nevertheless, after analysing the results obtained from this first slope-based analysis, it became clear that this method does not provide a good representation of movement in the Westfjords. This is mainly due to the Westfjords' landscape, which has areas with high altitude but almost no slope. Due to this, the software used this slope data to create LCPs that prioritised routes alongside high altitude areas which had little to no slope. Considering that the high altitude areas in the Westfjords are covered in thick snow for most of the year, the routes proposed by the slope-based LCP prioritised areas where travel would be difficult and, in some areas, almost impossible due to the snow. Taking this into consideration as well as the viability of using DEM data in LCPs exemplified in previous studies (Lewis, 2017; M. Llobera, 2000), it was decided that the most viable data source for this study would be DEMs.

#### 4.2.2.2 Use of Cairns to Understand Movement

The scope and time framework of the project did not allow for an analysis of the cairns to observe and record their interaction within the modern landscape in person, therefore it was done via satellite images. The lack of available data regarding cairn coordinates within the area of study was the reason why satellite images were chosen as the main data source for the mapping of cairns. The imagery was provided by the DigitalGlobe Foundation and has a resolution of between 45 and 60 centimetres which allowed for the identification of cairns when zoomed in. To ensure optimal visibility, when multiple imagery was available the images with the lowest cloud percentages were chosen. The original imagery is compounded of a monochromatic set and a polychromatic set; however, the monochromatic set was the preferred one during the cairn identification process due to resolution quality.

Although the imagery available was very high resolution, cairn identification was complex due to their small size. For the purposes of this study, only the cairns that are between one and three meters in width were mapped; this is due to the project's assumption that bigger cairns are not marking the road but serving as other structures such as *things*. To better identify cairns within the satellite images, some of the satellite images were pan-sharpened to enhance the different features. The purpose of this step was to facilitate the differentiation between cairns, made of stone, and smaller round vegetation such as shrubs. These techniques have successfully been used in other studies which required the identification of geological features in satellite imagery (see Burton-Johnson et al., 2016; Won-In and Charusiri, 2003). In the pursuit of avoiding and reducing the incorrect marking of non-cairn features, all mapped cairns were given a number from one to five depending on the likelihood of them being without a doubt a cairn acting as a road marker, number five, or a doubtful cairn, number one (see Table 4.1 for a detailed breakdown of the categories).

Once cairns were identified and mapped within the landscape, they were compared with the results obtained through the movement analysis. The study set out to test whether routes connecting farms and relevant geographical points within the area of study have cairns alongside them to mark the way and/or keep the travellers safe in their journey, a hypothesis based on Alded's work (2014). Considering that the cairns would have to be visible from the roads, relationships between cairns and LCPs was established through an intervisibility analysis done from points

| Cairn Categories | Meaning |
|---|---|
| 1 | It is unlikely that this is a cairn. Could be a rock or a shrub. |
| 2 | It is possible this is a cairn but due to the high concentration of rocks and shrubs in the area, it is not certain. |
| 3 | It is very possible that this is a cairn but the landscape or quality of the picture complicate its identification. |
| 4 | It is certain that this is a cairn but the surrounding geology may have lead to misidentification. |
| 5 | It is fully certain that this is a cairn. |

**Table 4.1:** Breakdown of the cairn classification system

created alongside the road. The intervisibility analysis was projected up to 250 meters. This limit is based on the capacities of the human eye which, with perfect vision, a clear day and a flat landscape, can distinguish objects and their scale up to 3,000 meters (Wolchover, 2012, 8). The observer's height (the traveller) and the target's height (cairn) were kept with QGIS' default values, 1.60 meters.

To quantify the number of cairns that are visible within the LCP proposed routes, basic percentages were applied. A 500-meter buffer was applied to determine the number of cairns that fall within a contention area. After this, the cairns that fall within 250 meters of the proposed routes were identified by a buffer. With these two numbers, the percentage of cairns within the contention area that is within 250 metres of the proposed paths was calculated. Following these 500 and 250-metre cairn coincidence premises, two more quantification methods were employed. Firstly, the roads were divided into sections based on the geography and features along the route, if there were valleys, sharp turns, if it was along the coastline, etc. Secondly, roads were divided into 5-kilometre sections measured with QGIS measurement tool. These percentages are presented and broken down in the Results, Section 4.3.

### 4.2.3 Issues

Although most of the issues relating to the data and its processing were assessed and solved or minimised, some are worth considering. These fall within two major categories: those relating to the identification of cairns and imagery issues, and those relating to analysis and interpretation of the data.

#### 4.2.3.1 Cairn Identification

Perhaps the most important issues to consider are those relating to cairn identification within the satellite imagery. Not all of the cairns within the area may have been mapped and not all of the elements marked as cairns are actually cairns. This is due to the survey method chosen and visibility issues.

The survey method was a visual analysis of every satellite image within the study area. This involved a long process of examining two-dimensional pictures in search of small three-dimensional objects. The images were carefully observed by the author which, considering human error, is a limitation in itself and increases the potential for cairn misidentification. The element of human error involved in tasks undertaken by humans, such as this one, particularly skill-based errors in repetitive tasks (see HSE, 2020; Leadership and Engagement, 2012). It is important to highlight the author's lack of previous experience with satellite image for identification of small features such as cairns and the complexity of the survey, as it involved a large number of images of fair quality.

Visibility issues involving the satellite images themselves must also be considered. As explained in Section 4.2.2.2, measures were taken to enhance the visibility of the pictures however, some panels within the satellite images had reduced visibility. Some images had areas covered by snow or large clouds which made the identification of cairns difficult and, at times, impossible. Other elements such as cairn-sized rocks, bushes, low vegetation or the shadows of these may have interfered in the process of cairn identification.

The wide timeline of the study cairns is also a potential issue to be addressed. Cairns have been common in Iceland throughout history and still are to this day (see Section 2.3.1). The differential timelines have the potential to be misleading since not all of the cairns would be part of the original roads, especially the modern cairns. The main method to determine the construction date of the cairns would be to undertake excavations. This is not a viable option in this study. Nevertheless, while misleading, this extensive timeline shows that humans have been interacting with their environment through cairns through history, constituting the human-environment interaction that human ecodynamics seeks to understand.

Despite these issues, great care has been taken to minimise the mislabelling of cairns and the presence of patterns within their distribution around the LCP routes points towards a mostly correct identification of cairns. Nevertheless, it is advised that the reader considers the cairns within an error buffer of $\pm 10$.

#### 4.2.3.2 Interpretation and Analysis Limitations

The debates surrounding the accuracy of LCP's prediction of past movement must be assessed. Many archaeologists have argued that LCP analysis is not an accurate representation of movement in the past as it only takes environmental features into considerations (see Herzog and Posluschny, 2011, 236; Lewis, 2017; and Llobera, 2000, 81). This study understands that human movement through the landscape is related to and dependent on a variety of elements which are difficult to quantify via GIS analysis such as the influence of socially or culturally prominent spaces such as shrines, churches, or monuments. Nevertheless, for this study, it has been assumed that the travellers were aware of the landscape and had no other religious, ceremonial or personal intentions that could inform or modify their daily routes between interconnected farms and, hence, chose to follow the path with the lower energy and time costs. This limits the study and how its results can be interpreted, as the observations made from the results will be based on landscape features alone without considering cultural or religious factors. This can be addressed in future studies (see Section 4.5).

## 4.3 Results

The three clusters examined by this study are in different areas of the Westfjords and, thus, present different results to the LCP and the intervisibility analyses. Each cluster will be examined in detail below.

#### 4.3.0.1 Cluster One

The LCP has favoured coastal routes and, as for the intervisibility, it has one of the highest amounts of cairn presence within the proposed roads.

***LCP Analysis***

The terrain within this area shows steep hills and elevations right by the coast. The farms themselves are located either in coastal areas or in valleys often near river streams. The LCP analysis proposed several routes, all going along the coast, in some cases through the beach. All of the proposed routes coincide in most areas and in those in which they deviate, they often only have a difference of eight to eleven metres (see Figure 4.6).

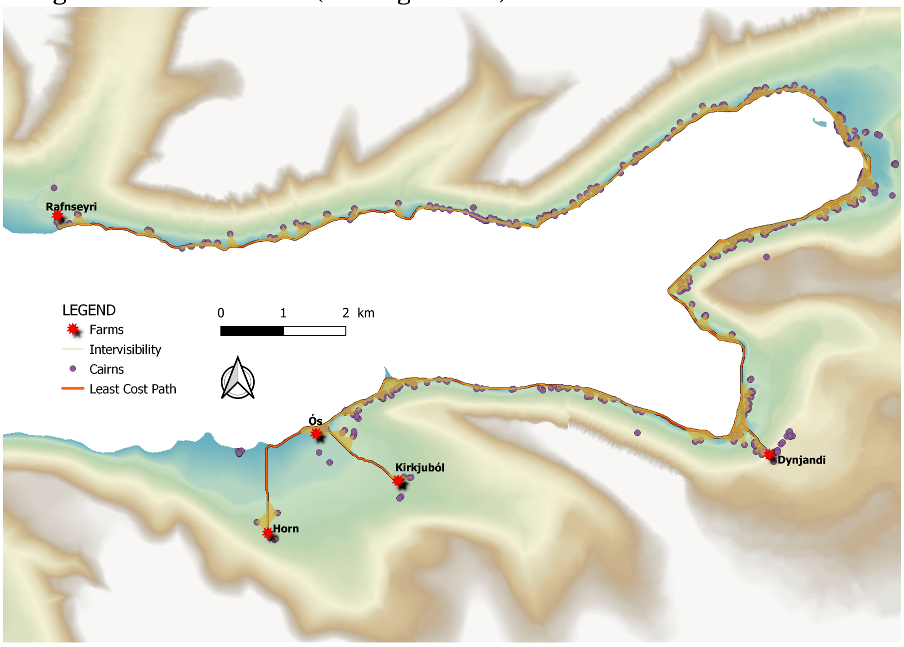


**Figure 4.6:** Map showing the intervisibility between the LCP analysis and the cairns

It is important to note that, due to the parameters set as part of the study, the LCP focused on land travel and did not include the possibility of sea travel. Considering the geographical context of this cluster and the location of the top farm, Rafnseyri, the most likely routes from this farm to the rest would have included sea travel. The time and energy spent on crossing the fjords by sea, which is a distance of four to ten kilometres depending on the farm the person is travelling to, are less than the ones spent by travelling by foot.

***Intervisibility Analysis***

Most of the LCP area is covered by the intervisibility within the surrounding cairns (see Figure 4.6). As the map shows, 91.86% of the cairns comprehended within 500 metres of the LCP routes are visible from the proposed roads.

The results of the intervisibility quantification show very high coincidence of cairns within the 250 and 500-metre areas of the LCPs. Table 4.2 shows the cairns present in each section of the road both for the feature and geology-based sectioning and the five kilometres one. As both the table and the charts (see Charts 4.7 and 4.8) indicate, the number of cairns present in both a 250 metre and 500-metre area is 81.60% and 91.59% in average.

#### 4.3.0.2 Cluster Two

The LCP favoured coastal areas as well as valley areas, only walking through the higher elevation areas during a four-kilometre area. As for the intervisibility, this cluster is the one with the least number of cairns per section of route, with large areas of the road close to having no cairns at all.

***LCP Analysis***

The terrain within this cluster's area has steep hills and elevations ranging from 440 and 540 metres at 800 metres to 1.2 kilometres distance from the coast. Towards the south coastal area, the space between the coast and the steep hills expands to 2-3 kilometres. There are also two valley

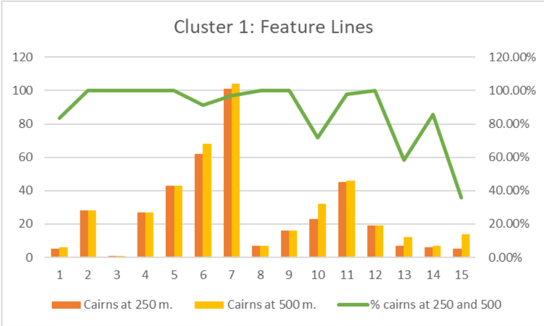


**Figure 4.7:** Feature Lines

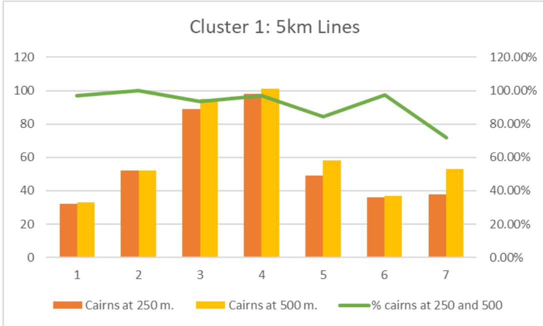


**Figure 4.8:** 5km Lines

**Figure 4.9:** Charts showing the quantity of cairns in a 250 metre (orange) and 500 metre (yellow) areas as well as the percentage of cairns that are in both areas divided in LCP road sections based on feature and geology (left) and 5 kilometre divisions (right).

**Cluster One: Features**

| Section | Cairns at 250m. | Cairns at 500m. | Cairns at 250 and 500m. | Rating | Comments |
|---|---|---|---|---|---|
| 1 | 5 | 6 | 83.33% | 1 | Small section from the farm to the coast |
| 2 | 28 | 28 | 100% | 1 | Road follows the coastline |
| 3 | 1 | 1 | 100% | 1 | Road follows the coastline - section flanked by two bays and the mouth of a river |
| 4 | 27 | 27 | 100% | 1 | Road follows the coastline |
| 5 | 43 | 43 | 100% | 1 | Road follows the coastline |
| 6 | 62 | 68 | 91.17% | 1 | Road follows the coastline |
| 7 | 101 | 104 | 97.12% | 1 | Road follows the coastline |
| 8 | 7 | 7 | 100% | 1 | LCP goes through the sea rather than the land section of the coastline |
| 9 | 16 | 16 | 100% | 1 | Road follows the coastline |
| 10 | 23 | 32 | 71.88% | 1 | Small section from the farm to the coast - follows along a river |
| 11 | 45 | 46 | 97.83% | 1 | Road follows the coastline |
| 12 | 19 | 19 | 100% | 1 | Road follows the coastline |
| 13 | 7 | 12 | 58.33% | 1 | Section from the coast to the farm - goes through a valley going along a river |
| 14 | 6 | 7 | 85.71% | 1 | Road follows the coastline |
| 15 | 5 | 14 | 35.71% | 0.5 | Section from the coast to the farm |

**Cluster One: 5km Lines**

| Section | Cairns at 250m. | Cairns at 500m. | % cairns at 250 and 500 m. | Rating | Comments |
|---|---|---|---|---|---|
| 1 | 32 | 33 | 96.97% | 1 | Road follows the coastline |
| 2 | 52 | 52 | 100% | 1 | Road follows the coastline |
| 3 | 89 | 95 | 93.68% | 1 | Road follows the coastline |
| 4 | 98 | 101 | 97.02% | 1 | Road follows the coastline |
| 5 | 49 | 58 | 84.48% | 1 | Road follows the coastline except for a 734m section which goes along a valley, following the river |
| 6 | 36 | 37 | 97.29% | 1 | Road follows the coastline |
| 7 | 38 | 53 | 71.70% | 1 | Road follows the coastline except for two sections which loosely follow along the rivers |

**Table 4.2:** Quantification of the relationship between LCP results and surrounding cairns based on a 250 and 500 metre coincidence in Cluster One.

areas around the farms; one in the southern coast going inwards to the mountain area and another in the northern area of the fjord. As for the farms themselves, they are located in coastal areas with two of them also being in valley areas, next to river streams. Therefore, the routes proposed by the LCPs were mostly going along the coast except for those leading up to Trostansfjördur which is located in the northern area of the fjord (see Figure 4.10). The route that crosses this fjord prioritises the valley areas and only has a four-kilometre-long section in which it walks in areas with 399 to 500-metre elevation. All the proposed routes coincide in most areas except for four sections in the valley areas. In these areas in which they deviate, they often have a 100 to 200-metre difference.

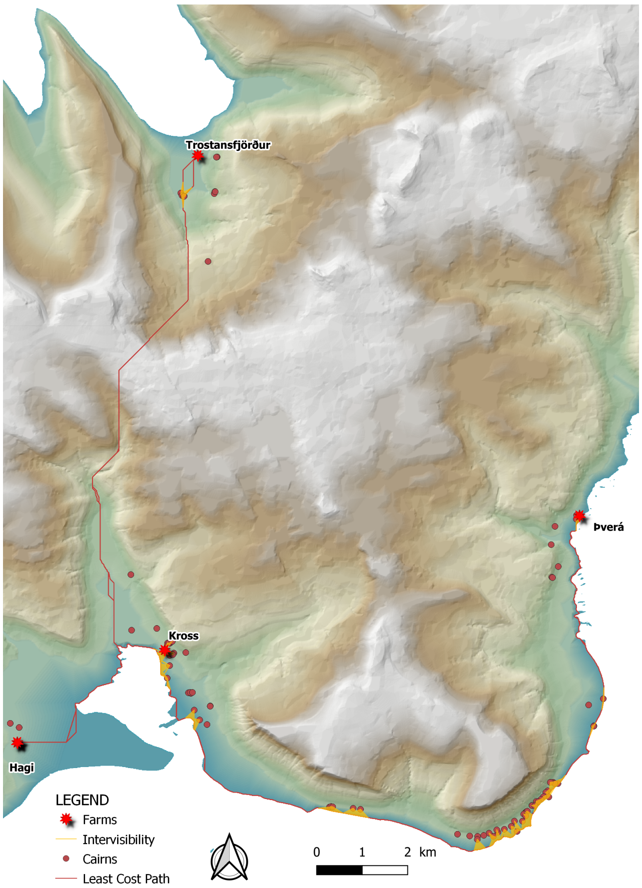


**Figure 4.10:** Map showing the intervisibility between the LCP analysis and the cairns

***Intervisibility Analysis***

Unlike Cluster One, this cluster shows a very low intervisibility percentage between cairns and the LCP proposed roads. As can be seen in the map above (Figure 4.10), only 67.02% of the cairns comprehended within 500 metres of the LCP roads are visible from the proposed routes.

The results of the intervisibility quantification show almost no coincidence of cairns within the 250 and 500-metre areas of the LCPs, with several areas having no cairns close by. Table 4.3 shows the cairns present in each section of the road both for the feature and geology-based sectioning and the five-kilometre one. As both the table and the charts (see Charts 4.11 and 4.12) indicate, the number of cairns present in both a 250 metre and 500-metre area are 27.10% and 40.17% in average.

#### 4.3.0.3 Cluster Three

Similarly to the previous two clusters, the LCP favours both coastal and valley routes. As for the intervisibility, there is a considerable ratio of cairn presence along the roads.

***LCP Analysis***

The terrain within this area is the least sharp of the area. With large and wide coastal areas expanding up to 800 metres, the slopes are gentler and the overall maximum elevations range between 300 and 400 metres. There is a large valley area as well as a smaller valley next to a bay, offering a terrain with fertile plains and ease for travel. Three of the farms are in valley areas: Brékka in the smaller valley and Nedri Gufudalur and Fremri Gufudalur are located higher up the larger valley, next to the river stream. As for the fourth farm, it is located further down the coast towards the south.

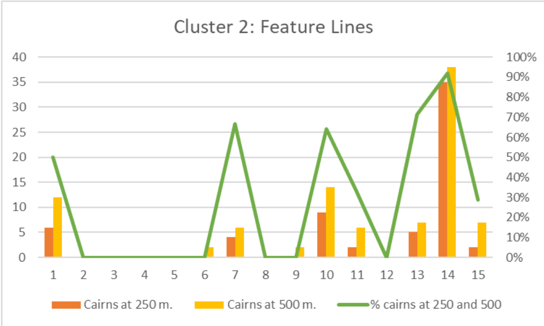


**Figure 4.11:** Feature Lines

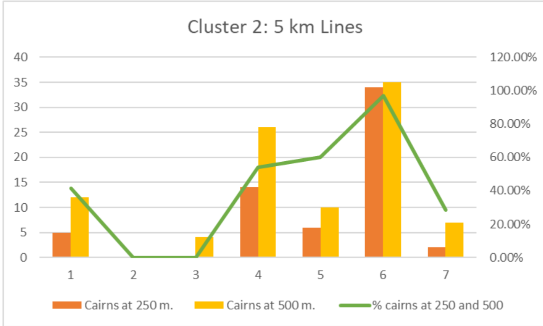


**Figure 4.12:** 5km Lines

**Figure 4.13:** Charts showing the quantity of cairns in a 250 metre (orange) and 500 metre (yellow) areas as well as the percentage of cairns that are in both areas divided in LCP road sections based on feature and geology (left) and 5 kilometre divisions (right).

Cluster Two: Features

| Section | Cairns at 250m. | Cairns at 500m. | % cairns at 250 and 500m. | Rating | Comments |
|---|---|---|---|---|---|
| 1 | 6 | 12 | 50% | 0.5 | Follows along a river stream |
| 2 | 0 | 0 | 0% | 0 | Vaguely follows along a river - goes over steep hills |
| 3 | 0 | 0 | 0% | 0 | Follows along a river stream |
| 4 | 0 | 0 | 0% | 0 | Follows along a river stream and is surrounded by steep hills |
| 5 | 0 | 0 | 0% | 0 | Follows along a river stream |
| 6 | 0 | 2 | 0% | 0 | Mostly follows along a river stream - ends in a bifurcation |
| 7 | 0 | 0 | 0% | 0 | Follows along the coastline but LCP goes into the water in fjord areas |
| 8 | 0 | 0 | 0% | 0 | Deviates from the coastline inland - follows small river |
| 9 | 0 | 2 | 0% | 0 | Deviates from the river until it reaches the farm |
| 10 | 4 | 6 | 66.66% | 1 | Deviates from the river at bifurcation - follows along the coastline |
| 11 | 9 | 14 | 64.28% | 1 | LCP goes through the sea rather that the land section of the coastline |
| 12 | 2 | 6 | 33.33% | 0.5 | Bay area - follows through the coastline |
| 13 | 0 | 0 | 0% | 0 | Follows through the coastline |
| 14 | 5 | 7 | 71.42% | 1 | Follows through the coastline |
| 15 | 35 | 38 | 92.10% | 1 | Follows through the coastline |
| 16 | 2 | 7 | 28.57% | 1 | Follows through the coastline |

Cluster Two: 5km Lines

| Section | Cairns at 250 m. | Cairns at 500 m. | % cairns at 250 and 500 | Rating | Comments |
|---|---|---|---|---|---|
| 1 | 5 | 12 | 41.66% | 0.5 | Follows along a river stream |
| 2 | 0 | 0 | 0% | 0 | Mostly follows along a river stream |
| 3 | 0 | 4 | 0% | 0 | Vaguely follows along a river stream - at the bifurcation goes into the water then turns inland and vaguely follows a river stream |
| 4 | 14 | 26 | 53.84% | 1 | At the bifurcation follows along the coastline - at times LCP goes into the water |
| 5 | 6 | 10 | 60% | 1 | Follows through the coastline |
| 6 | 34 | 35 | 97.14% | 1 | Follows through the coastline |
| 7 | 2 | 7 | 28.57% | 0.5 | Follows through the coastline |

**Table 4.3:** Quantification of the relationship between LCP results and surrounding cairns based on a 250 and 500 metre coincidence in Cluster Two.

Similarly to the previous two clusters, the routes proposed by the LCPs favour the coastal areas except for the routes leading up to Nedri Gufudalur and Fremri Gufudalur which go up the valley area, by the riverside (see Figure 4.14). All of the proposed routes coincide in most areas except for the valley area, where the analysis offered several parallel options. In these areas in which the LCP analysis offered a variety of routes, these often differ by 19 to 90 metres.

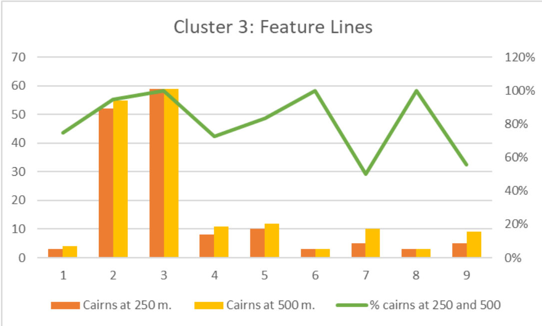


**Figure 4.15:** Feature Lines


**Figure 4.16:** 5km lines

**Figure 4.17:** Charts showing the quantity of cairns in a 250 metre (orange) and 500 metre (yellow) areas as well as the percentage of cairns that are in both areas divided in LCP road sections based on feature and geology (left) and 5 kilometre divisions (right).


**Figure 4.14:** Map showing the intervisibility between the LCP analysis and the cairns

***Intervisibility Analysis***

Cluster Three shows a high intervisibility percentage between cairns and the LCP proposed roads, as can be seen in Figure 4.14. 86.14% of the cairns comprehended within 500 metres of the LCP roads are visible from the proposed routes.

The results of the intervisibility quantification show considerable coincidence of cairns within the 250 and 500-metre areas of the LCPs. Table 4.4 shows the cairns present in each section of the road both for the feature and geology-based sectioning and the five-kilometre one. As both the table and the charts (see Charts 4.15 and 4.16) indicate, the number of cairns present in both a 250 metre and 500-metre area are 81.23% and 85.10% in average.

| Cluster Three: Features | | | | | |
|---|---|---|---|---|---|
| **Section** | **Cairns at 250 m.** | **Cairns at 500 m.** | **% cairns at 250 and 500** | **Rating** | **Comments** |
| 1 | 3 | 4 | 75% | 1 | 177 metre section from farm to the coastal area |
| 2 | 52 | 55 | 94.55% | 1 | Follows the coastline |
| 3 | 59 | 59 | 100% | 1 | Follows the coastline |
| 4 | 8 | 11 | 72.72% | 1 | Follows the coastline |
| 5 | 5 | 8 | 62.50% | 1 | Follows the coastline |
| 6 | 3 | 3 | 100% | 1 | Follows the coastline |
| 7 | 5 | 10 | 50% | 0.5 | Deviates inland from the coast to the farm |
| 8 | 5 | 9 | 50% | 0.5 | Deviates inland following the river |
| 9 | 3 | 3 | 100% | 1 | Follows along the river |
| 10 | 5 | 9 | 55.55% | 1 | Follows along the river |

| Cluster Three: 5km Lines | | | | | |
|---|---|---|---|---|---|
| **Section** | **Cairns at 250 m.** | **Cairns at 500 m.** | **% cairns at 250 and 500** | **Rating** | **Comments** |
| 1 | 21 | 22 | 95.45% | 1 | Follows the coastline |
| 2 | 95 | 105 | 90.48% | 1 | Follows the coastline |
| 3 | 27 | 39 | 69.23% | 1 | Follows the coastline - two sections deviate inland and one goes along a river |

**Table 4.4:** Quantification of the relationship between LCP results and surrounding cairns based on a 250 and 500 metre coincidence in Cluster Three.

## 4.4 Discussion

### 4.4.1 Explanation of the Results

As expected, the LCP analyses prioritised the roads in coastal areas and along rivers. Most of these proposed routes often coincide or match up with current roads. Considering that most of the farms mapped by Jardabókin (Pálsson, 2019) still exist today, it would be expected that the routes used to connect them to each other or to the rest of the island are, if not the same, quite similar.

As for intervisibility, the quantified results show different levels of engagement between the roads and the cairns depending on the landscape and the area. Nevertheless, when the results are analysed on the basis of landscape and features, a clear pattern emerges. The common cairn distribution through all clusters is that of cairns being landscape and feature-dependent. This means that, as seen in the study, the cairns tend to be in areas where road markers are needed (e.g. fork-paths, intersections, and close to farms and fields). The feature and landscape road sections with cairn percentages below 50% were often those located alongside rivers or alongside the coast next to a steep hill. In this case, the roads tend to be in areas in which the geographical conformation makes it clear what the path is since there are no other road options.

It is also worth noting that most farms were surrounded by cairns. Following the general literature trend, it can be assumed that this is a further confirmation of cairns undertaking several roles at the same time. In line with some of the cairn functions mentioned in the Literature Review (see section 5.1.1), this project shows that cairns were not only used as navigational markers but also as farm boundaries and markers. How cairns are understood within the context of this study, it can be stated that they undertake both functions in the areas surrounding farms, going beyond being simple route markers or farm boundaries but being indeed both at the same time.

### 4.4.2 Results, general background and pre-existing literature

Overall, these results fit well within the pre-existing literature which argues cairns are often used as navigational markers as well as landmark indicators (see Heide, 2014; Mizin, 2013, 326; and Aldred, 2014a). Specifically, these results are consistent with navigational marker use, landmark and feature marker, and landscape and cairn interaction.

Firstly, these results further corroborate Aldred's (2014a) findings. In his thesis, he argued that cairns are used navigational markers, even stating that routes themselves are a series of connected cairns (Aldred, 2014a, 135). The concept of cairns being used as route markers within a landscape and feature depending framework, fits well within the framework of understanding movement and farm networks Aldred created and adds further depth to the interaction between cairns and roads. Likewise, the idea of landscape-dependent interaction of cairns in their informance of roads also confirms Heide's (2014) proposed theory of cairns having a collective function within the context of the landscape. Similarly, these results fit in well with Mizin's (2013, 314) idea that cairns are not only mostly used as navigational markers but also mark specific features within the landscape such as farm boundaries or landmark markers (see section 4.4.1).

### 4.4.3 Potential limitations and weaknesses

A potential limitation to the project regarding the LCP proposed routes were rivers and sea level. It has already been mentioned that the model was not designed to consider sea travel but, when the DEM was cropped, some water was classified as land by the program. Due to this, in some areas, the analysis suggests routes that go over the sea right by the coast rather than by the land areas. In other areas, mostly relating to rivers, since the program did not identify them as such, the LCP proposed routes cross rivers in the mouth of the river which are often some of the wider areas. In these cases, there is usually a narrower area of the river a few metres above at not such high altitudes. This could have, perhaps, been avoided if a more specific model in which rivers were specified to be crossed at the narrow points, rather than the mouth, had been built using ArcGIS. As mentioned in the methods, the method used was the generic QGIS plugin for Least Cost Path calculation in which there are fewer possibilities to modify the weighting given to every option and cell, and to establish parameters such as the suggested one.

It is worth noting that, for the interpretation of the results, it was considered that the route depended on cairns acting as road markers to point the way if the percentages presented in the Results section 4.3 were equal or superior to 80%. Although this is not a limitation or a weakness *per se*, it does impose a pre-set parameter that may affect the way the results are understood and interpreted. This percentage does work for the purposes of this study, but it ought to be reconsidered for expansions. Another aspect that does affect the interpretation of the results is the cairn timeline. Since cairns were identified from satellite imagery, their dating is unclear which limits the study by not being able to establish a time period. The inclusion of time period information would be useful in different studies as it would provide a more accurate analysis.

Lastly, this study has focused on using environmental features (i.e. distance, terrain, and height) but has not taken religious or cultural locations between farms which may have influenced the decision making process when choosing what route to follow. Shrines, churches, and culturally significant areas could be added and considered in future expansions for a more comprehensive analysis.

## 4.5 Conclusion

This study's main objective was to test the utility of cairns as navigational/route markers within the Westfjords' landscape. By doing this, it intended to further the research on cairns as navigational markers as well as the understanding of movement in the Icelandic landscape, both of which have been rarely researched before with few exceptions, as mentioned in the Literature Review (see section 4.1). Considering the obtained results, it can be argued that the project has contributed to deepening the knowledge of cairn and landscape interaction in those situations in which cairns are used as navigational markers. Additionally, it has given more insight into farm network movement in the form of travelling during late medieval to early modern Iceland, roughly 1500-1860.

The datasets used were a cairn database, and farms and their networks of interaction. The first was created through the analysis of satellite imagery provided by the DigitalGlobe Foundation while the second was provided by Gísli Pálsson from his Jardabók (2018) project. From these datasets, an LCP analysis was undertaken, and a further intervisibility analysis between the resulting LCP roads and the cairns was produced. The intervisibility analysis and the cairn and road coincidence were then quantified through the creation of two buffers, a 250 metre and a 500 metre one.

Regarding the study's main findings, how the cairns interacted with the proposed roads supports the hypothesis that cairns were used as road markers to orientate people through the Icelandic landscape. It is also worth noting that the positioning of the cairns seems to be dependent on an interaction between cairns and landscape, which highlights the need for further study on cairns and their relationship with the landscape. Specifically, this analysis has shown that cairns used as road markers are often positioned in areas in which the traveller could lose the path since it is not clearly defined by the landscape. It has also highlighted their use as landmarks for features and farm boundaries.

### 4.5.1 Future Research

As for future research stemming from this study, many areas can be explored from here. Particularly, a deeper exploration of the cairn dataset which could include on-land recording of the cairns to observe their interaction with the landscape and the roads *in situ*. Likewise, expanding the research area as well as choosing a different research area would be recommended. Unfortunately, the original dataset had to be reduced from 167 to 13 farms (see Section 4.2.1.1). It would be interesting to undertake the analysis with this original dataset although this would require a supercomputer and a least cost path model designed and run in R. Likewise, exploring other areas of Iceland, such as the south, and other areas of the North Atlantic would be very interesting to establish patterns, similarities and differences within a variety of regions, islands and/or countries.

The positioning of cairns as elements which interact with their landscape and depend on it highlights the need for further study; projects that analyse the role of the landscape in the construction of cairns would be interesting. The inclusion of recorded places of worship, graves, and/or other places of cultural significance in the area of study would provide more accurate movement patterns as it could consider pilgrimage and the influence that these places have on movement. Examples of possibly culturally relevant spaces that could be included in future studies are Flókatóftir, Hrafnseyri, AuðkúlaThere, and Arnarfjörður (see p.34 in Stefánsdóttir and Hermannsdóttir, 2017, p.37 in 2018, and p.39 in 2020), however, more excavation and survey records for Icelandic archaeology can be found in *The Cultural Agency of Iceland* (M. Íslands, 2020) and *Fornleifastofnun Íslands* (2020). In conclusion, there is much to be explored and studied in the fields of movement through the landscape and regarding the use of cairns as navigational markers.

# Chapter 5

## Case Study Two: Agricultural Cairns in Scotland

This project was developed around the study of cairns and their multi-functionality. It aims to further understand the impact of agricultural practices in the landscape through the study of clearance cairns. Therefore, it assesses cairn distribution based on soil type and quality, and land use. This interdisciplinary approach brings together archaeological and geological data in an innovative way, working with soil surveys, Canmore (H. E. Scotland, 2019) data, and aerial images. Additionally, the role and presence of agriculture in human culture allows for a long-term analysis of its effects on the soil. It also facilitates the observation of the changing relationships between humans and the environment through agriculture: the adaptation to the changes in the landscape caused by the effects of human exploitation of the soil and climate change.

Although this study differs from the previous one in cairn role and geographical framework, it provides a more extended view of cairn multifunctionality as well as an opportunity to observe their landscape interactions in a different environment. It also offers an opportunity to relate with cairns in multiple ways through the use of a different methodology layout and an alternate perspective. Furthermore, it creates a more complete analysis of cairns within the North Atlantic landscape, offering more environmental and geographical variations. This combined approach that looks at two different cairn roles allows for a more complete understanding of cairns and, ultimately, of human-landscape dynamics.

To best observe the cairn-landscape interaction, the chosen study area was Scotland due to its extensive use of clearance cairns as part of traditional agricultural practices, and data abundance. In particular, The James Hutton Institute has undertaken extensive soil analysis in Scotland which provide the perfect base for this project. Additionally, due to its widespread use, other studies have looked at clearance cairns in Scotland from a more general perspective, mostly focusing on the differences between clearance cairns and other cairn types (e.g. Graham, 1959; Yates, 1984). The rest of the cairn literature in Scotland focuses mostly on the study of burial cairns. Phillips (2002) undertook a similar study to this one from the perspective of burial cairns in which he examined the cairns and their location, including geology, orientations and relationship with natural features.

* All of the maps, tables, charts, and diagrams used in this project were created by the author except for Figure 2.1 which is from BlueSky Organics (2018). *

## 5.1 Theory: Literature Review

### 5.1.1 The Study of Cairns

Cairns are structures made of stone which can take up many sizes, shapes, and functions. Generally, in Scotland, they are mostly divided into burial and agricultural cairns while in other areas of Europe they undertake different roles. In Iceland they are mostly used to mark time, routes, and properties though they can also be used as *things* (Heide, 2014, 69). In Sweden and Norway, the study of cairns focuses on clearance cairns due to their role in ancient agriculture and its study (Lageras and Bartholin, 2003, 83; Lageras et al., 1995, 224; Sageidet, 2005, 58; Sköld et al., 2010, 122). It is also worth to keep in mind that cairns in Scotland usually appear as low mounds (RCAHMS, 1978, 5). Nevertheless, since this study focuses on the role of clearance cairns in Scotland, the following section will offer a comprehensive review and summary of the state of research regarding clearance cairns and burial cairns in Scotland.

#### 5.1.1.1 Cairn Use: Burials *versus* Clearance

The study of cairns in Scotland is highly divided with most of the research focusing on burial cairns. In general, when it comes down to interpreting the use of cairns, the literature is divided and many authors discuss the use of cairns as a dichotomy between them being used for burial *versus* agricultural purposes (see Fleming, 1971, 4 and 22; Graham, 1959, 8; Johnston, 2001, 104; Phillips, 2002, 104; and Yates, 1984). This has inspired several studies with archaeologists and institutions such as RCAHMS arguing for most cairns being burial sites (The Royal Commission on the Ancient and Historical Monuments of Scotland, 1978, 8-10). Meanwhile, others argue that evidence for most Scottish cairns being used for burial purposes is not always conclusive, it is, in fact, often "incomplete and inconclusive" as a result of the acidity of Scotland's soil which makes the survival of organic remains difficult, to the use and reuse of cairns through history, and the ritual activities undertaken outside the monuments themselves which may have led to the further destruction or damaging of archaeological evidence that would support this interpretation (Phillips, 2002, 30-31; Yates, 218-219). Nevertheless, there is also the argument that cairns can or may have undertaken both tasks either at the same time or at different times through their existence.

The general study of cairns has often pointed out their polyvalent character. Heide (2014, 69) points out that in Iceland cairns undertake several functions at the same time such as route, property, and time markers amongst others. In Scotland, more often than not, clearance cairns and burial cairns coexist in the same space and appear as part of the same set of cairnfields (see Bradley, 2000, 15; Graham, 1959, 19-20; and Johnston, 2001, 104). Furthermore, some cairnfield studies have found that some cairns are likely to have undertaken sepulchral and agricultural tasks. An example of this is Graham (1959, 9-11, 12-13, 14-15, and 18-20), who proposed that the following cairnfield places he surveyed had the chance of being both: Dava Station, Burn o'Vat, Campstone Hill, Westruther Burn, Medwin Water. It is important to keep in mind that field clearance stone was potentially the main construction material in many burial cairns which means that, regardless of whether the original function of the cairn itself was to be a burial, at the end of the day, the cairns is undertaking both functions at the same time (Johnston, 2001, 108; Yates, 1984, 219). It makes sense that the fieldstones and the monuments themselves were used and reused through time by different cultures and peoples meaning that even if the original intention of the cairn was a different one, it was later used for different purposes.

***Burial Cairns***

As aforementioned, the study of cairns in Scotland is mostly focused around their sepulchral use; for this reason, it is important to highlight some of the key features of burial cairns based on the existing research. One of the most extensive burial cairn studies was undertaken by Phillips (2002), who examined them within their landscape. He concluded that have a prominent location, that 66% of burial cairns can be seen from at least another site, that they are mostly orientated to the east, and their relationship with natural features is unclear and hard to analyse due to human modification of the landscape throughout the years (Phillips, 2002, 239-253). Other burial cairn features are:

- If part of a cairnfield with a variety of cairn types, burial cairns are more carefully built to stand out among the surrounding cairns (Yates, 1984, 223).
- Unlike clearance cairns, some burial cairns have burial chambers inside, having even multiple chambers per cairn (Phillips, 2002, 7).
- They can contain more than one burial in either cremation or inhumation form and not all burials have to have been placed at the same time, with some being placed at the top during later times by different cultures (Bradley, 2000, 5; and Phillips, 2002, 20).
- Burial cairns are often located in predominant places with greater visibility and landscape control with no regard for drift geology and altitude which were key in the location of clearance cairns due to their relationship with land fertility and arability (Yates, 1984, 223).

It is also worth keeping in mind that, whether they undertook both functions or not, clearance and burial cairns stem from different needs and different social aspects. Sepulchral functions were related to the end of life and agricultural functions were related to the disposal of stones to create a space for cultivation.

#### 5.1.1.2 The Practice of Field and Fieldstone Clearance

The creation of fields through clearance started in Scotland during Neolithic times. The adoption of farming and the widespread of cereal cultivation brought along the need to create spaces for land cultivation, grazing and hunting which meant turning to the clearance of woodland (Brown, 1997, 134; Robinson, 2014, 291). As for the clearance of fieldstones, the reasons for this becoming a practice are not entirely clear. It is supposed that it could derive from a change in technique which required finer and more acidic soil, a need to keep the tools and crops from damaging, a way to reuse the fields, an improvement in the quality of the cultivated land by altering its pH through the removal of stones or to obtain a larger people-land ritual involvement (Lageras and Bartholin, 2003, 90-91; Johnston, 2001, 99 and 106; Yates, 1984, 219). It is clear that the clearance of stone from fields was widely undertaken as a way to prepare the land for cultivation and pasture (see Fleming, 1971, 20) but there could be a deeper meaning to this practice.

Johnston (2001, 107) defends that clearance cairns have a ritualistic meaning which could be linked to special events, a cumulative effort over time, and/or an expression of dominance and tenure over the land. He bases this on the presence of construction elements and deliberate deposits of charred materials and artefacts, as well as the deliberate placement of some cairns around the exterior of domestic structures and fields in places such as Green Knowe and Standrop Rigg (Johnston, 2001, 99 and 107). He also points toward other geographical areas where the clearance of plots for agriculture is often related to small-scale rituals designed to deepen the land-community relation, such as in Papua New Guinea (Johnston, 2001, 102-103). Fleming (1971, 22-23) also introduces the idea that Northern British cairnfields could be used or built as part of rituals which would explain why some have ritual pits and show were used on and off through history. This idea would point towards a mindful way of farming and relating to the land which is very plausible during Neolithic and Bronze Age times, which most of the known cairns in Scotland date to. It also establishes another parallel with burial cairns since the latter are always related to ritualistic sepulchral practices and are built mindfully. Furthermore, the idea that both types of cairns are built with a mindful and ritualistic aspect would further support the fact that they can be used as both since they would already be undertaking an important part of the social practice.

***Clearance Cairns***

The use of cairns in agriculture is often related to the clearance of stones from fields as a way to obtain a much more fertile soil that is suitable for farming and/or grazing. Cairns are constructed using reject fieldstones and the crevices are filled with soil and sometimes included domestic waste, which collaborated with rising the soil's phosphate levels (Sköld et al., 2010, 123; and Yates, 1984, 219). Many of the studies undertaken on clearance cairns in Scotland and northern Europe focus on the differences between burial and clearance cairns (e.g. Fleming, 1971; Graham, 1959; Lageras et al., 1995; Johnston, 2001; Yates, 1984). Some of the common clearance cairn characteristics distilled from these studies are the following:

- They often form part of a cairnfield which is a group of cairns. The number of cairns in a cairnfield can fluctuate from two or three to hundreds (e.g. Graham, 1959; Fleming, 1971; Johnston, 2001; Lageras et al., 1995; Sageidet, 2005).
- Clearance cairns often date back to the Bronze Age and Middle Ages (e.g. Sköld et al., 2010, 123; Johnston, 2001, 106; Yates, 1984, 225 and 228; Lageras et al., 1995, 231-232).
- They are often located in flat or gently south or south-west facing slopes, near field enclosure walls, stony banks, hollows or field plot divisions (e.g. Graham, 1959; Johnston, 2001; Fleming, 1971; Yates, 1984, 223).
- Within the fields, cairns are often located in the unusable ground areas, for example, around large boulders or extensive rock outcrops as well as on the edges of the fields themselves (Fleming, 1971, 5; and Yates, 1984, 219).
- Their size varies greatly from cairn to cairn since it depends on the amount of stone that needed to be cleared at the time. Nonetheless, Graham (1959, 8) stated that most of the cairns he surveyed measured from 1.52 to 6.10 metres in width and were no more than a metre tall.

It is worth taking into consideration that many clearance cairns may now be located in non-arable areas which would make their identification as agricultural cairns more complex. This is highlighted by Sköld et al. (2010, 121) and Yates (1984, 221-222) who discuss the impact of modern-day agricultural practices on cairns: these may now be located in woodland areas or non-agricultural areas, they may have been destroyed as part of the creation of new fields, or they may have been re-purposed as something else such as a field boundary. This is important to keep in mind during cairn identification since the location of cairns themselves (i.e. whether they were in fertile, arable lands or not) has been a key defining feature. Instead, one can focus on the location from a different perspective, rather than focusing on the fertility of the land itself, looking at the position within the landscape since burial cairns were more likely to be located in dominant areas of the landscape with a better view of the surrounding features while clearance cairns were often located in corner areas of fields which were often plains.

### 5.1.2 Study of Environmental Impact

The study of erosion and the environmental impact of farming has increased throughout the last decade, with several studies being produced to assess the impact of climate change and the levels of erosion of the land often including studies that focus on being able to stop it and prevent it. Generally, authors agree that northern European, and Scottish in particular, levels of soil erosion have reached severe stages with Scottish soils having lost water storage capacity and having augmented in compactivity (Brown et al., 2010, 514; and Fullen, 2003, 341 and 348). This is, however, not focused on the impact of ancient farming and, in particular the practice of fieldstone clearing, on the land but on a generalised urbanisation and climate change aspect.

Scottish land erosion studies from a historical point of view are not common, as opposed to other parts of northern Europe such as Iceland (see Catlin and Bolender, 2018; Greipsson, 2012; Lethbridge and Hartman, 2016, 384; and McGovern et al., 1988). There is, however, plenty of information as to how to assess changes in forestation levels, whether it be deforestation or afforestation. For example, the analysis of pollen, sediments and microfossils from sites and wetlands can provide information on landscape changes, crop harvesting, past vegetation, and land-use (e.g. Tipping, 1995a and 1995b; Campbell et al., 2002; Althea and Dixon, 2007; Whittington and Edwards, 1990 and 1993; Hirons and Edwards, 1990). Both beetles and land-snails can provide evidence for temporary Neolithic clearances in Scotland (Robinson, 2014, 292). Considering all of this alongside the fact that there are seven SEAD sites with environmental data in the area of study (see SEAD, 2019), an approximation of the environmental impact can be inferred from the study of the available data.

#### 5.1.2.1 Soils

The environmental impact that this project assessed was mostly examined via the study of soils and their current state. The characteristics of soils are key to analyse the effect of agricultural practices. They provide an understanding of the changes to compaction, erosion and overall quality of the soil. The combination of soil and cairn analysis offers a different, more complete look into the effects of agricultural exploitation, which is still important and present nowadays. In fact, according to the European Commission (2011, 3), the quality of soil is declining in many areas of Europe, mostly due to unsustainable agricultural and management practices.

Soils are composed of clay sand and silt, and they are formed from the combination of weathered rocks' mineral material and organic matter from plants and animals; they also have 50% pore space filled with air or water depending on the soil type and texture (Ashman and Puri, 2002, 2-3 and 12). Soil is organised in layers, called horizons, which form the soil profile (Fitzpatrick, 1986, 4). Not all soil profiles have the same number of horizons and not all horizons are present in all soil profiles. The characteristics of each horizon and their combination in a soil is a key factor in understanding the predisposition of the soil to erosion and/or compaction The most common horizons, which can be seen in detail in Figure 5.1, are (Ashman and Puri, 2002, 16-17):

- ***O horizon:*** it is the top layer, made of organic, peaty material; when the environmental conditions are acid, it can be separated into three smaller layers known as the Litter, Fermentation and Humus
- ***A horizon:*** layer in which organic and mineral materials interact
- ***E horizon:*** it is an area depleted of material
- ***B horizon:*** it is a mineral layer in which organic matter, minerals and inorganic chemicals accumulate
- ***C horizon:*** layer of unconsolidated soil parent material (the different materials that different soil types originated from)
- ***R horizon:*** bedrock or parent material

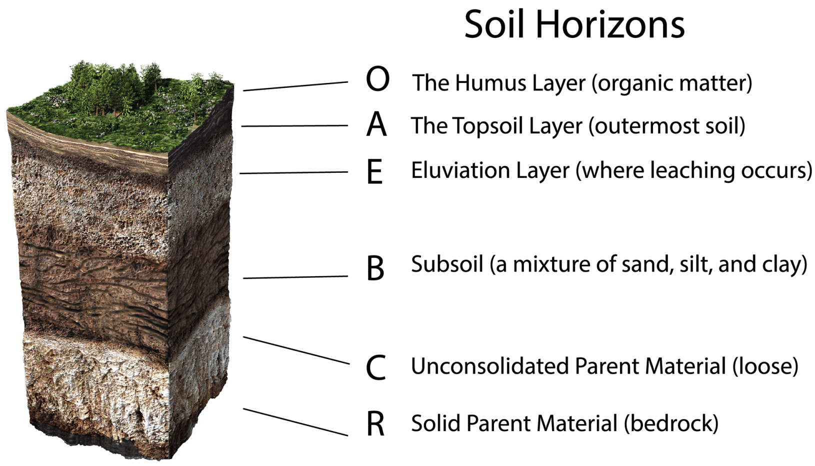


**Figure 5.1:** Breakdown of the different soil horizons and its explanations. Extracted from BlueSky Organics (2018, paragraph 19)

All of the variations and components of soil create many types of soils, in particular, Scotland is divided mostly into four types, Podzols, Brown Earths/Soils, Gleys, and Peat Soils (Institute, 2019g, paragraph 1). These and their relevant variations will be explored in the sections below.

Peat has over 60% of organic matter content because it originates from decomposed plant residues in anaerobic conditions (see pp.10-11 in Commission, 2011; Institute, 2019g, paragraph 2). Many of the peatlands are currently degrading at a fast rate due to unsustainable practices since continuous drainage and agricultural use speeds the erosion process (European Commission, 2011, 10; Scotland's Soils, 2019, paragraph 1; Institute, 2019g, paragraphs 3 and 4).

Gleys are often waterlogged or submitted to long periods of waterlogging (Ashman and Puri, 2002, 103; Fitzpatrick, 1986, 159 and 165). Due to this excessive water content, they require extensive drainage before they can be used in agriculture (Institute, 2019c, paragraph 6). Their soil profile is often formed by a mineral surface horizon with high organic matter content, a mineral subsoil with a variable texture, and an unconsolidated layer of parent material with irregular spotting (Institute, 2019c, paragraphs 3-5; and Ashman and Puri, 2002, 16). They are prone to variations that create different types of gley soil; this project will focus on Peaty and Mineral Gleys. The first is gley soil with over 5 centimetres of raw organic matter on the surface, turning the mineral A horizon into an organic O horizon made of peaty material (Glenworth et al., 2016, 33; and Institute, 2019c, paragraphs 2-3). The latter has a mineral parent material.

Brown soils are perfect for cultivation due to their free drainage and natural fertility (Ashman and Puri, 2002, 103; and Institute, 2019b, paragraph 6). They often form under broadleaf forest which promotes rapid decomposition of plant residue and recycling of plant nutrients (Institute, 2019b, paragraph 2). Therefore, it can be argued they appeared in forested areas which were later re-purposed into agricultural areas and are a testament to the agricultural exploitation of Scottish soils. Their soil profile is often formed by thin topsoil with humidified and well-decomposed organic material, a mineral subsoil that merges into a layer of loose parent material (Institute, 2019b, paragraph 3).

Podzols can be found in all elevations, and are characteristic of aerobic conditions and acidic environments, with thick accumulations of organic matter and iron and aluminium oxides (Ashman and Puri, 2002, 103; and Institute, 2019f, paragraphs 1-2). Their soil profile is often formed by a surface layer made of peaty materials which can sometimes appear as a humus horizon with a higher content of decomposed animal and plant substances which makes it more fertile, an eluviated with a weak structure, and a mineral subsoil with deposits of iron, aluminium, and organic matter (Ashman and Puri, 2002, 16-17; Encyclopaedia Britannica Editors, 2019, paragraphs 1 and 6; and Glenworth et al., 2016, 32). One of the most common variations of podzol soils are peaty podzols which have a thicker accumulation of organic matter above the E horizon, making it more exposed to waterlogging than a general Podzol soil would (SASSA, 2019a, paragraph 1; Glenworth et al., 2016, 32).

Immature soils are young, shallow soils (Institute, 2019d, paragraphs 1-2). Alluvial soils are a type of immature soils developed on water areas. They are formed on recent freshwater, estuaries, deltas, coastal areas, or alluvial deposits (Fitzpatrick, 1986, 164; and Glenworth et al., 2016, 31). They show little to no profile differentiation with only an A and an H horizon (Fitzpatrick, 1986, 164; Glenworth et al., 2016, 31; and SASSA, 2019b, paragraph 1). They have variable drainage and texture which make them good for growing a wide range of natural plants (Fitzpatrick, 1986, 164; and Institute, 2019d, paragraph 1).

#### 5.1.2.2 Cairns and Soils in the Literature

This section offers a brief review that assesses the types of soils found underneath clearance cairns. The focus lies on excavated Scottish cairns, mainly clearance cairns. The original focus of the review were the cairns which form the case study's dataset, however, according to the records in Canmore (H. E. Scotland, 2019), *Discovery and Excavation Scotland* (A. Scotland, 2010) and *Archaeology Data Service* (2020), these were only recorded as part of walkover surveys. The research then expanded to other cairns in Scotland. The review is, however, not exhaustive as many cairns are excavated as part of larger projects which are difficult to scope in a limited amount of time. Furthermore, reports tend to place more weight on describing cairns' contents, and the type of boulder or stone used to build them rather than on the layers of soil beneath them.

Many of the excavated cairns in this review were initially covered by topsoil which is often peat, heather, turf, moss, and/or lichen due to a lack of use and the passage of time. This has aided in preserving them but it has also hindered their identification for excavations or surveys. Examples of cairns laying under a thin topsoil are the Tor Cairns, Callicher cairns, Chatton Sandyford cairns, Sir William Hill cairn, Millstone Hill cairns, the cairns in the Sutherland and Strath Bora Kilbraur Wind Farms, Stoney Hill cairn, Soutra Hill cairns, and the ones in Lairg and Arran (Tilley, 2017;

Carver et al., 2012; Jobey, 1968; Willson and Barnatt, 2004; Jobey, 1981; Haston, 2007; Humble, 2007; Ballen et al., 2011; Will, 2013; McCullagh and Tipping, 1998; and Barber, 1997 respectively). These cairns will be explained in more detail below.

In general, many of the reviewed cairns are located in fields with clear signs of cultivation such as plough marks. Likewise, many are in areas which have undergone podsolisation or gleying processes, such as the cairns in Arran, Lairg, Perthshire, Sutherland Kilbraur Wind Farm, and Sir William Hill (Barber, 1997; McCullagh and Tipping, 1998; Ellis and Ritchie, 2018; Haston, 2007; Wilson and Barnatt, 2004). The soil records below some of the cairns show a stripping or damaging of the original topsoil during the building of the cairns themselves. Examples of this are the Tor Cairns, the Burnt Common Cairn, Cairn 10/3 in Arran, and the cairns in Lairg (Tilley, 2017; Barber, 1997; McCullagh and Tipping, 1998).

***Cairn Excavations***

This section includes a summary of the soil profiles found below the cairns in this review:

- **Tor Cairns:** These are Early Bronze Age cairns. The larger cairn has three soil layers below: a basal subsoil with pebbles, an inverted turf base, and a truncated subsoil (Tilley, 2017). Charcoal samples were found underneath it; these show that before the cairn's construction, there was an open oak woodland with ferns, hazel, and grasses which may have been cleared to use the lands for cultivation (Tilley, 2017). Another smaller cairn in the area lays on two main sections of soil: a soft sandy orange-brown matrix with a small patch of yellow clay, and the old ground surface, formed by an organic horizon, a partially removed turf (possibly removed to build the cairn) and a mineral horizon (Tilley, 2017).

- **Burnt Common Cairn:** This cairn is in East Devon and lies on the remains of a stripped topsoil and signs of burned areas (Tilley, 2017). This could indicate that, similarly to the previous cairns, the original topsoil was damaged during the construction of the cairn, perhaps by small controlled fires, whether these belong to a cremation or land clearance.

- **Pitcarmick Cairns:** These lay on top of ploughed soil, followed by a layer of gritty yellow natural subsoil which had not been altered by cultivation (Carver et al., 2012; Carver et al., 2013). This ploughed soil coincided with the rest of the plough marks found along the area of study (Carver et al., 2012; Carver et al., 2013). One of the cairns in the area was part of a stone wall and in addition to these two soil layers, they also had remains of soils which had been washed down the hill and rested by the cairn (Carver et al., 2012; Carver et al., 2013).

- **Callichar Burn Cairns:** One of the cairns in this area was built on a rocky outcrop, in the non-cultivatable area of what appeared to be a field in the past (Dalland, 2012). The other was built on a yellow sandy silt horizon (Tuffin, 2012).

- **Chatton Sandyford Cairns:** There were four cairns in this area. Cairns A and B lay on an irregular iron pan followed by a grey surface with carbon specs (Jobey, 1968). Similarly, Cairns C and E lay on grey subsoil (Jobey, 1968). The stratigraphy of Cairn D was not specified.

- **Sir William Hill Cairn:** This is a prehistoric cairn located in Derbyshire. It lay on heavily podsolised soil, causing the soil layers to loose their original interfaces, therefore, the subsoil is now formed by a grey-brown sandy loam overlaying a thin iron pan, followed by orange loamy sand below (Wilson and Barnatt, 2004).

- **Millstone Hill Cairns:** These were located in Northumberland. The subsoil below shows no signs of cultivation although it is quite deteriorated and impoverished (Jobey, 1981).
- **Sutherland and Strath Bora Kilbraur Wind Farms:** The cairn in the Sutherland Kilbraur Wind Farm lays on a gleyed mineral horizon with no plough marks, below this layer there is a thin iron pan, followed by an orange-brown silt layer (Haston, 2007). The cairn on the Strath Bora Kilbraur Wind Farm lays on an iron pan over the area's natural sand (Humble, 2007).
- **Stoney Hill Cairn:** This clearance cairn is on a farm in Aberdeenshire. It lays on a humified peat formation followed by an iron pan horizon (Ballin et al., 2011).
- **Strontoiller Cairn:** This cairn is in Argyle. It lays on the original natural soil gravel (Ritchie, 1971).
- **Perthshire Cairn:** The first cairn in the area is laid over a podsolized fine grey silt, followed by brown silt (Ellis and Ritchie, 2018). The other cairn was in an area of cultivated brown soil, the cairn itself lays on orange-brown sandy soil with oak charcoal remains (Stevenson et al., 1996).
- **Lairg Cairns:** In general, the area of study has brown podzol and stagnopodzol soils, and there are marks of continued ploughing which indicate cultivation (McCullagh and Tipping, 1998). The excavation concluded that, between the 2nd and 3rd millennium BC, the soils had suffered considerable erosion and loss of 0.3-0.5 m. of the topsoil likely caused by a combination of ploughing, the use of manure, cultivation, roots, and invertebrates all of which accelerated natural soil truncation processes (McCullagh and Tipping, 1998). Cairn 1 in the area lays on shallow tilled A horizon soil and a B horizon with plough marks; overall, McCullagh and Tipping (1998) highlight that the soil profile shows disturbance during the period of construction of the cairn. Cairn 2 lays on anthropic soil and glacial till, both of which showing vestiges of human activity prior and after the construction of the cairn. Cairns 3 and 4 stand near shallow soil formed into parallel rigs and with stones, the cairns themselves lay over poorly preserved coarse mineral gravel which could indicate a ground disturbance before their construction (McCullagh and Tipping, 1998).
- **Arran Cairns:** Several cairns were excavated as part of this project. Similarly to Lairg, the soils in this area of study have suffered considerable damage, having all undergone podsolisation and gleying processes, changing from fertile forest brown soils to less cultivatable lands (Barber, 1997). These changes are due to natural soil profile development accelerated by cultivation techniques such as the use of manure, ploughing techniques, and the creation of clearance cairns which may have intensified the leaching and gleying of the soils immediate to them (Barber, 1997).
  - Cairn 10/3 - it is on the slope of a hill and there is a single furrow running alongside the cairn. It lays on a predominantly B horizon with small remains of a disturbed A horizon which was a water gley with an iron pan base (Barber, 1997).
  - The cairn and cist - it lays on charcoal silty sand. Below the cairn, there is a horizon of brown soil indicating that podsolisation had not happened in the area at the time of the construction of the cairn (Barber, 1997).

- Cairns 24/7 A and B- they are small cairns that lay on a podzolic soil profile, which displays problems caused by surface gleying and excessive iron pan formation after the construction of the cairns (Barber, 1997).
- Cairn 24/7C - it lays on a grey-black mineral soil (Barber, 1997).
- Cairn 24/01 - it lays on a grey gritty podzolic layer, followed by red-brown soil. The original ground topsoil was damaged during the period in which the cairn was constructed (Barber, 1997).

The general podzolisation and gleying seen in these excavated examples are also present in this case study's cairns. Many of the study's cairns are located on types of podzolised or gleyed soils (see Figure 5.3 and Section 5.3.2). Understanding the types of soils below cairns and the state of the layers is particularly important to frame the results of this study within the wider context of Scotland.

## 5.2 Methodology

### 5.2.1 The Study Design

This case study analyses the interaction of clearance cairns and the Scottish landscape by assessing their impact on it. In order to understand this, the project will examine a variety of landscape data and archaeological data ranging from soil type and drainage, and erosion risk to current land use. This approach is innovative and there are no studies that incorporate this data to the study of clearance cairns in Scotland.

#### 5.2.1.1 Area of Study

The area of Study is in the east and south-east of Scotland (see Figure 5.2).

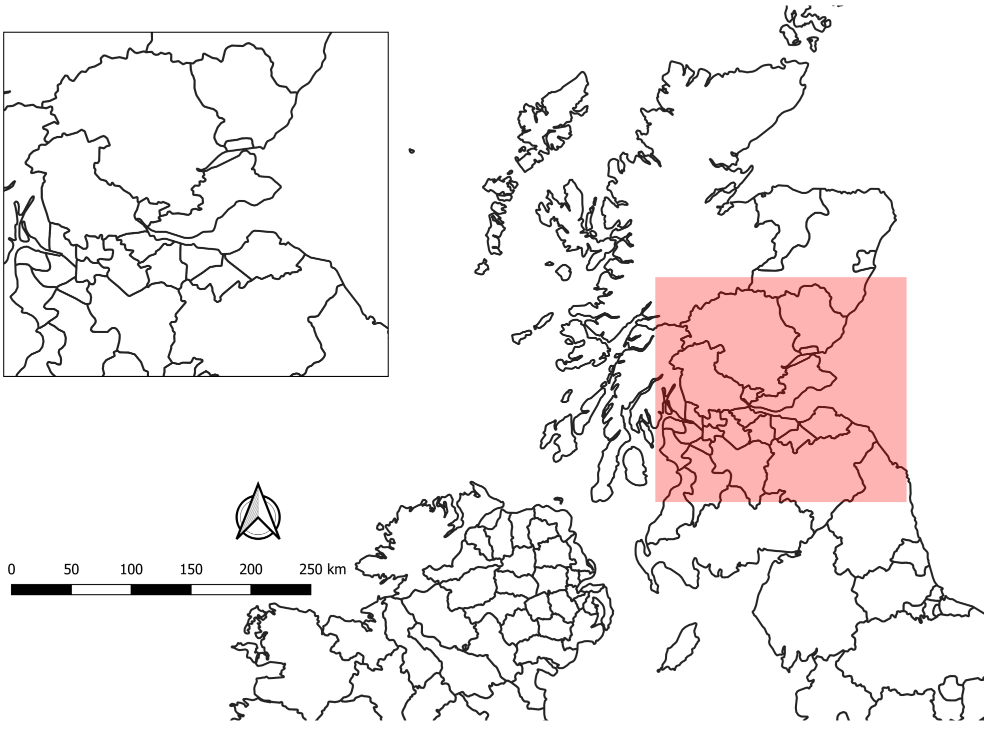


**Figure 5.2:** Map of the Study Area

### 5.2.2 Data and Data Analysis

The data for this project was gathered from a variety of sources depending on the analysed variable. It examined two main variables, clearance cairns and landscape data, which includes a variety of soil characteristics, risks and land use data.

#### 5.2.2.1 Cairn Data

Cairns were mapped through a variety of sources. The bulk of cairn data was obtained from Canmore (H. E. Scotland, 2019) which has a series of recorded cairns such as clearance and burial cairns, as well as cairnfields. To ensure that clearance cairns which may have disappeared or are no longer visible were also included, the historical OS maps for the area were also be examined. These were acquired through Digimap (2019). In his study of cairnfields in Scotlalnd, Graham (1959, 7) stated that in many occasions, cairnfields are marked as "tumuli" in historical OS maps. Therefore, the maps were examined in search of the labels "tumuli", "cairnfield", and "mounds". Unfortunately, these yielded no results.

#### 5.2.2.2 Landscape Data

The landscape was analysed through maps such as soil type and erosion, compaction risk, and runoff risk. In order to assess the land and the soil's quality the following maps were downloaded from The James Hutton Institute (2019):

- **Soil map of Scotland partial cover:** This map covers most of Scotland's cultivated agricultural soils at a scale of 1:25,000 (Soil Survey of Scotland Staff, 1970).
- **Land Capability for Agriculture partial cover:** This map shows the different land classes across Scotland's cultivated agricultural land at a scale of 1:50,000; with classes ranging from Class 1 for those lands that can produce a wide range of crops to Class 7 which have very little agricultural value, it also includes an Urban category (Soil Survey of Scotland Staff, 1984).
- **Map of topsoil compaction risk:** This map is based on natural soil drainage, soil texture and organic matter content, and it is organised within 5 categories: low, moderate and high risk of compaction, organic topsoils with an unassessed compaction risk, and areas of no data (Lilly and Baggaley, 2018a).
- **Map of subsoil compaction risk:** This map shows compaction risk in the subsoil based on the soil's texture, bulk density and the number of days in a year that the soil is at its field capacity for water (Lilly and Baggaley, 2018b). There are six categories: areas which are not particularly vulnerable to subsoil compaction, those that are moderately vulnerable, those that are very vulnerable and those that are extremely vulnerable, shallow soils which have no subsoil, and areas where there is no data available (Lilly and Baggaley, 2018b).
- **Map of runoff risk:** This map shows how easily can water drain away from the soil surface, as well as the soil's water storage capacity which depend on porosity and flow pathways through the soil (Lilly and Baggaley, 2018c). The data is divided in three classes: low, moderate, and high percentage of runoff (Lilly and Baggaley, 2018c).

- **Map of soil erosion risk:** This map shows soil erosion risk depending on the soil texture and its capacity to absorb rainfall as well as the slope of the land; this risk potential is divided in mineral and organic (peaty) soils, each type of soil is then classified into those with a low erosion risk, those with a moderate one, and those with a high erosion one. (Lilly and Baggaley, 2018d).

#### 5.2.2.3 Data Analysis

Similarly to Phillips' (2002) analysis of burial cairns, the clearance cairns data was examined within the larger context of the surrounding landscape, provided by the landscape data gathered from maps. They were analysed with respects to the following aspects:

- **Geology and soil quality:** This is to establish whether there is a relationship between the presence of clearance cairns and a particular type of soil or risk of compaction both in the topsoil and subsoil levels. It was determined by analysing the cairn and soil data together in QGIS.

- **Position and relationship within the landscape:** This is to determine the current and past locations of clearance cairns. Did the cairns appear in the historical maps? What is the land where they are used as now - is it still arable land? If so, are the cairns still in use as clearance cairns? This was informed by examining historical OS maps of the area and aerial imagery retrieved from Google Maps.

- **Pertinence to a cairnfield:** To establish if they were single cairns or part of a larger system, a cairnfield. This was presented in the form of a categories in the cairn dataset; single cairns were labelled with a "no" while cairnfields were marked as "yes".

In order to undertake these analyses, the data was merged in QGIS. This resulted in the creation of a shapefile containing the cairns, multiple soil description categories, erosion risk, topsoil compaction risk, subsoil compaction risk, current land use, pertinence to a cairnfield, geology, leaching risk, soil drainage, and cairn appearance in historical maps was created. This was then turned into a table of attributes and the most relevant categories were chosen: Cairn, Soil Type, Topsoil Compaction Risk, Subsoil Compaction Risk, Erosion Risk, Soil Drainage, Pertinence to a Cainfield, and Current Land Use. These categories have the following variables:

- **Soil Type:**
  - Alluvial soils
  - Brown soils
  - Immature soils
  - Organic peat
  - Peaty gleys
  - Peaty podzols
  - Mineral gleys
  - Mineral podzols
  - Lochs

- **Topsoil and Subsoil Compaction Risks:**
  - Organic topsoil and extremely vulnerable subsoil
  - Organic topsoil and very vulnerable subsoil
  - Organic topsoil and moderately vulnerable subsoil
  - High risk topsoil and extremely vulnerable subsoil
  - High risk topsoil and very vulnerable subsoil
  - High risk topsoil and moderately vulnerable subsoil
  - High risk topsoil and not particularly vulnerable subsoil
  - Moderate risk topsoil and shallow subsoil soils
  - Medium risk topsoil and extremely vulnerable subsoil
  - Medium risk topsoil and very vulnerable subsoil
  - Medium risk topsoil and moderately vulnerable subsoil
  - Low risk topsoil and shallow subsoil soils
  - Low risk topsoil and extremely vulnerable soils
  - Low risk topsoil and very vulnerable subsoil
- **Erosion Risk:**
  - Low erosion risk
  - Medium erosion risk
  - High erosion risk
- **Soil Drainage:**
  - Very poorly drained
  - Poorly drained
  - Imperfectly drained
  - Freely/imperfectly drained
  - Freely drained below iron pan
  - Freely drained
  - Undifferentiated drainage levels
- **Current Land Use:**
  - Uncultivated area
  - Field
  - Roadside
  - Forested area

These variables were classified by soil type, then by topsoil and subsoil compaction risk, then erosion risk, followed by soil drainage, and finishing by pertinence to a cairnfield. The classified data was turned into an interactive table in an Excel Workbook that has been attached as a digital appendix for the reader to interact with the data. Another unclassified version of the data was analysed in R Studio and turned into bar charts, pie charts and a scatterplot to facilitate data visualisation and comprehension.

## 5.3 Results

The clearance cairn dataset was created by joining several soil quality maps as well as aerial imagery and information from geological maps. After examining the data obtained both as a whole and individually, a few elements were chosen to undertake a more detailed analysis. This was done through the creation of charts and tables to have a clearer understanding of the results. In this section, the results will be separated into categories to facilitate interpretation: cairn distribution and cairn-landscape interaction based on soil.

### 5.3.1 Cairn Distribution

Overall, the studied clearance cairns are in areas with a considerable risk of erosion, they are often located in mineral gleys and brown soil areas, and the areas they are in are predominantly uncultivated areas. A factor that may influence this distribution is cairn preservation which shows only those that have not been removed. Most cairns in this case study's dataset are those located in soils that are no longer in use where cairns will have been left untouched and will have often been covered in peat, further preserving them from being removed. Meanwhile, cairns in areas with good cultivatable land that is still in use tend to be removed as part of the cultivation process.

As seen in chart 5.3, a majority of the cairns are located in Mineral Podzols and Brown Soils with 33% and 29% of the studied clearance cairns respectively, while the remaining are in other types of soils. As for the risk of soil erosion, most of the studied cairns are located in areas of Medium and High risk with 62% and 32% of the cairns fitting in these categories respectively, while low-risk areas are almost non-existent (see Figure 5.4). Regarding the soil's drainage levels, Figure 5.5 shows that 48% of the soils with cairns in them are Freely Drained; this dataset has the most gaps with "No Data", being the second biggest category with 19%. There is not a clear pattern of single cairns *versus* those in cairnfields with 55% and 45% respectively. Lastly, the current land use shows most cairns are either in Uncultivated areas, 39% or in Fields, 32%, which may or may not be currently cultivated (see Figure 5.7).

The relevance of their grouping in cairnfields is hard to determine without context since it is often better interpreted when seen in correlation with other soil variables; this will be explored further in section 5.3.2.

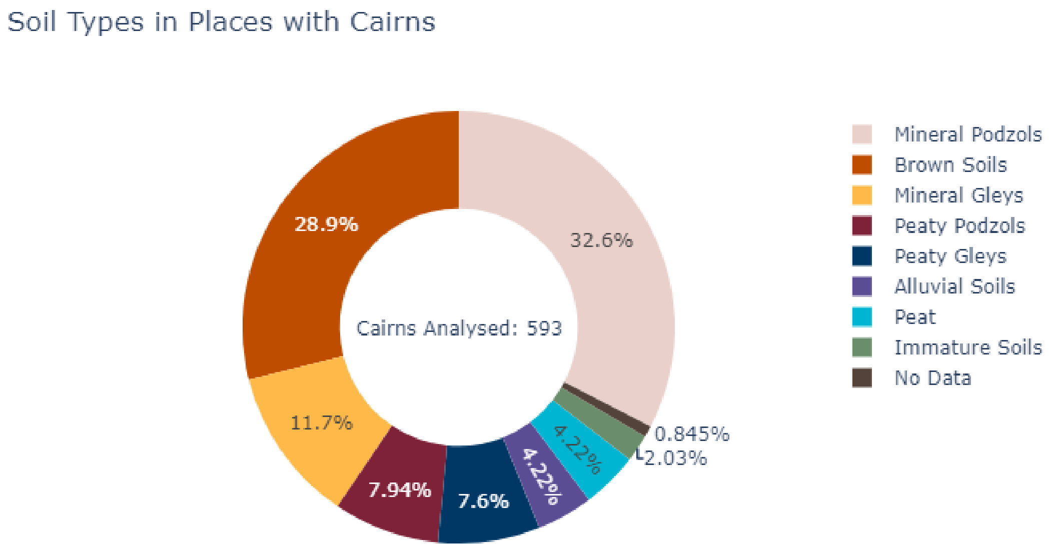


**Figure 5.3:** Chart showing the percentages of cairns in each soil type. Most of the cairns are in Mineral Podzols, 32.6%, and Brown Soils, 28.9%.

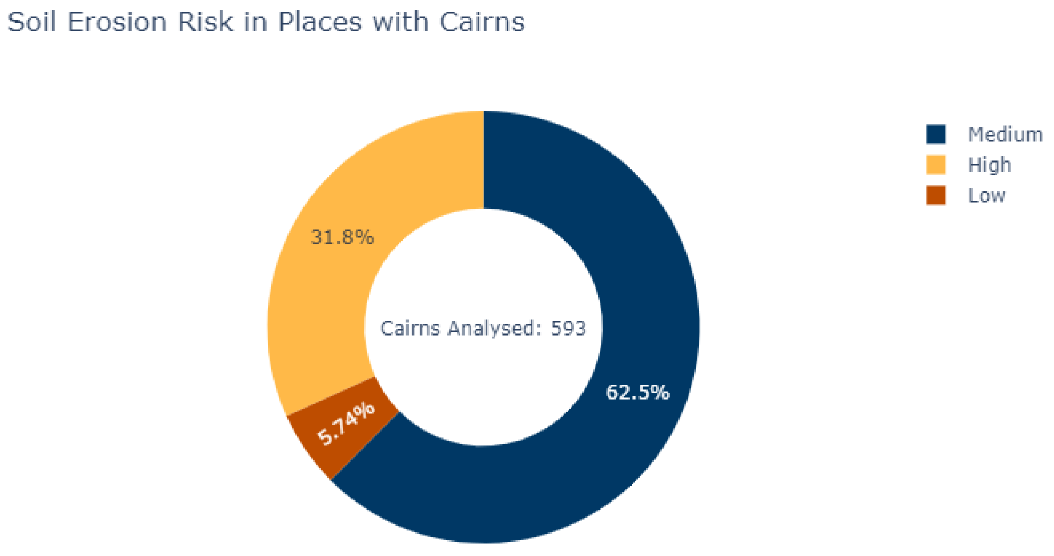


**Figure 5.4:** Chart showing the percentages of cairns according to the erosion risk of the soil they are in. Most of the areas with cairns have Medium, 62.5%, and High, 31.8%, erosion risk.

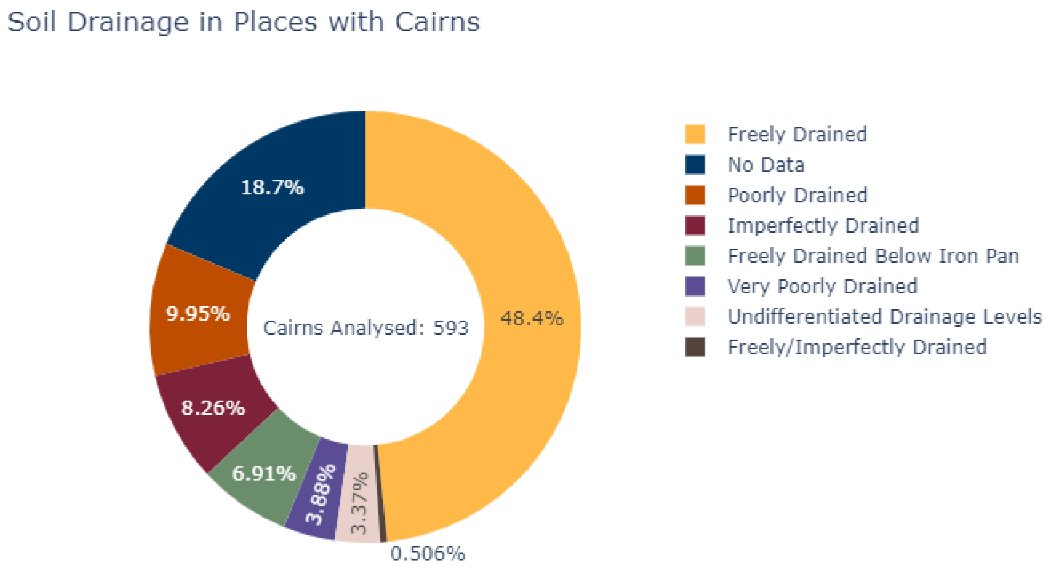


**Figure 5.5:** Chart showing the percentage of cairns according to the drainage levels of the soil they are in. Most of the areas have freely drained soils: freely drained (48.4%) and freely drained below pan (6.91%).

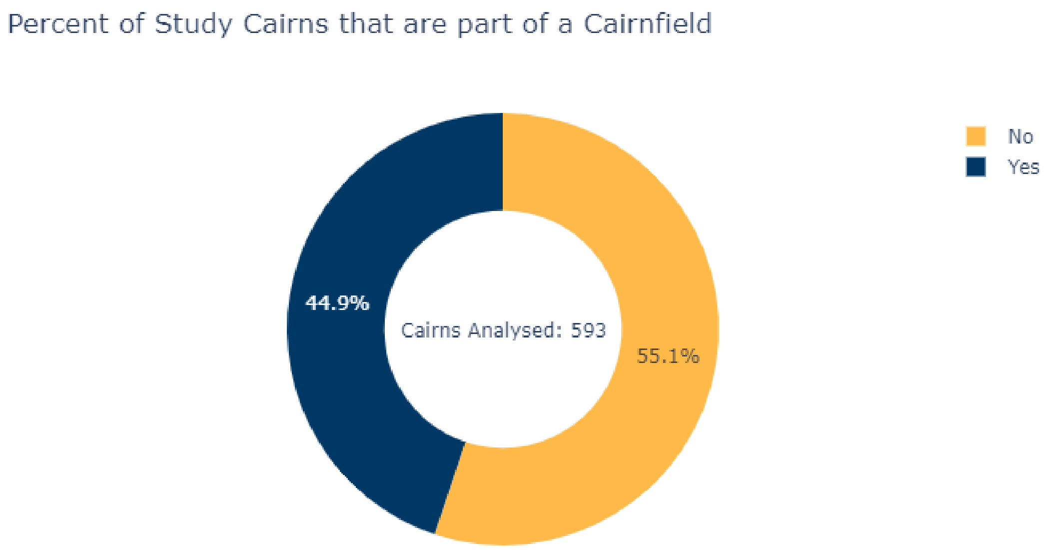


**Figure 5.6:** Chart showing the percentage of cairns that are part of a cairnfield. The chart shows an even distribution of cairnfields and single cairns, 55.1% and 44.9% respectively.

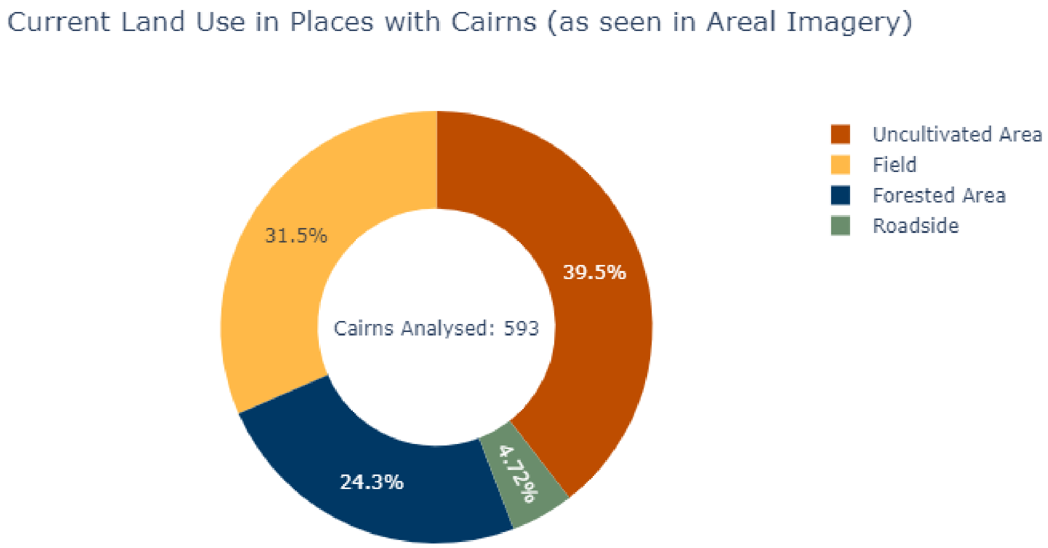


**Figure 5.7:** Chart showing the percentage of cairns according to the current use of the soil they are in. Most cairns are currently no longer in field areas: uncultivated areas (39.5%), forested area (24.3%), and roadside (4.72%).

### 5.3.2 Cairn-Landscape Interaction based on Soil

In order to better understand and analyse the data, cairns were classified depending on their soil type. They were then sorted depending on compaction risk, erosion risk, soil drainage levels, whether it has a single cairn or a cairnfield, and the current land use. There are nine soil types: Brown Soils, Alluvial Soils, Immature Soils, Peat, Mineral Podzols, Peaty Podzols, Mineral Gleys, Peaty Gleys, Lochs. It is important to mention that five cairns were in areas with no soil data. Below is a detailed breakdown of the cairns in each category. In those instances in which there is no data available for one of the data categories, the category has been omitted; this is most common with drainage data. A digital Excel Workbook has been attached for the reader to explore this dataset and its categories more freely. The results are accompanied by diagrams which exemplify the detailed breakdown of the most numerous cairns in each category. Below (Figure 5.8) is the key to better understand the diagrams:

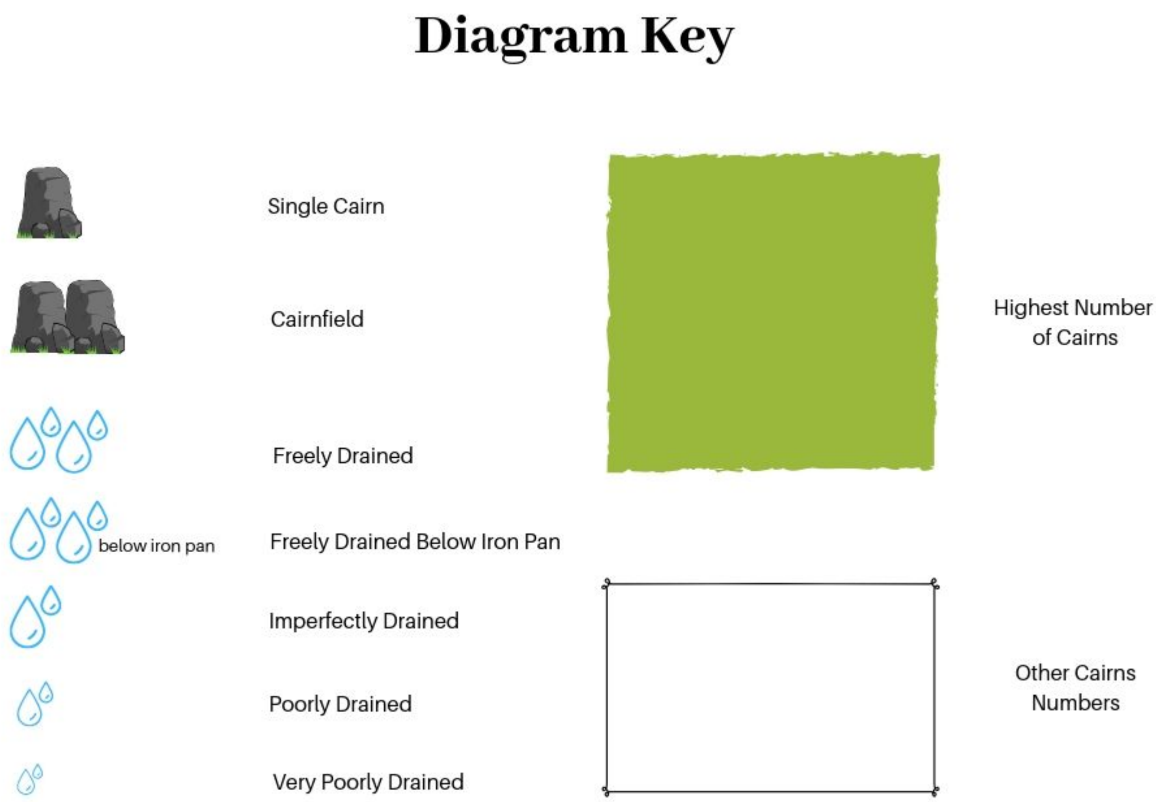


**Figure 5.8:** Key to the diagrams displaying the cairn results.

#### 5.3.2.1 Brown Soils

171 cairns are in brown soils. A majority of them, 129 cairns, are located in areas with low topsoil and very vulnerable subsoil compaction risks, with 133 cairns in medium erosion risk areas, and an abundance of single cairns, 112 cairns. Most of the cairns, 132, are in freely drained soils. These results can be seen more clearly in the bar charts in section 5.3.3. The complete breakdown of the cairn classification is as follows:

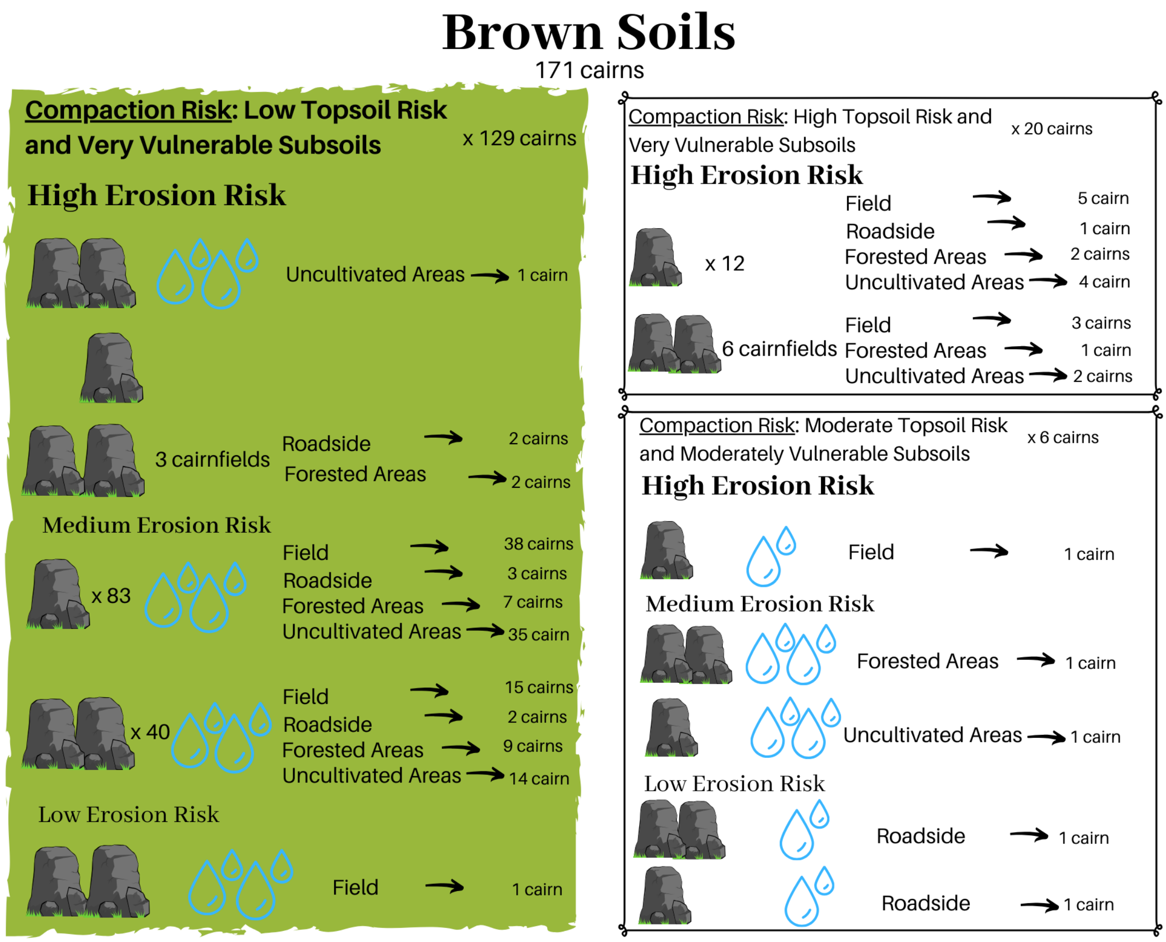


**Figure 5.9:** Diagram displaying the most numerous cairns in Brown Soils. The cairns are first classified by compaction risk, followed by erosion, drainage (if any data available), and current use. 129 cairns are in areas with low topsoil compaction risk and very vulnerable subsoils, mostly in areas with medium erosion risk, with 83 single cairns in freely drained areas and 40 cairnfields in freely drained areas.

#### 5.3.2.2 Alluvial Soils

25 cairns are located in alluvial soils. Most of them, 19 cairns, are located in areas with moderate topsoil and extremely vulnerable subsoil compaction risks, with 19 cairns in medium erosion risk areas, 20 cairns are in undifferentiated soil drainage levels. Alluvial soils have a predominance of single cairns (18 cairns). These results can be seen more clearly in the bar charts in section 5.3.3. The complete breakdown of the cairn classification is as follows:

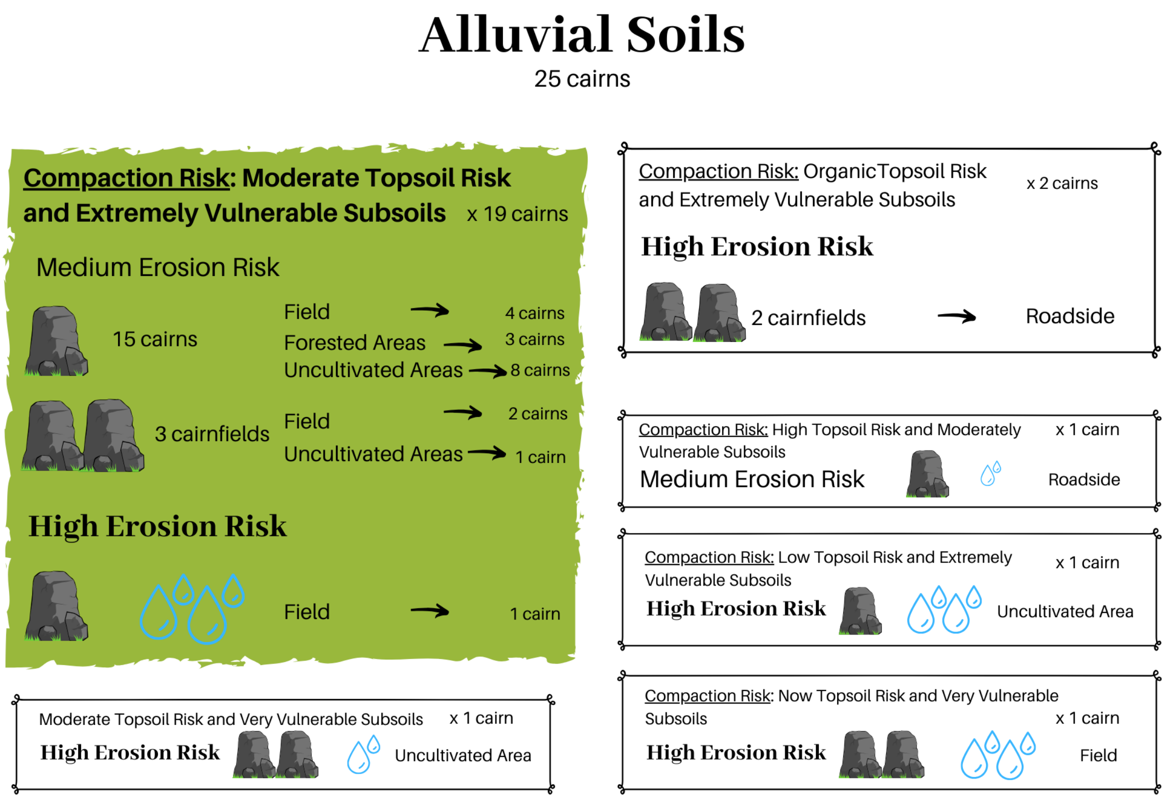


**Figure 5.10:** Diagram displaying the cairns present in Alluvial Soils. The cairns are first classified by compaction risk, followed by erosion, drainage (if any data available), and current use. The most numerous cairns are in a green square. Most cairns are in areas with moderate compaction risk topsoil and extremely vulnerable subsoils with most cairns in medium erosion risk areas, 15 of these are single cairns and 3 are part of cairnfields.

#### 5.3.2.3 Immature Soils

12 cairns are located in immature soils. 5 of these are located in areas with a low topsoil compaction risks and shallow subsoil, 11 cairns are in medium and high soil erosion risk areas, and there is an even number of single cairns and cairnfields (6 each). There is only data for three cairns in a freely drained soil area, therefore, a drainage significance patter cannot be determined. These results can be seen more clearly in the bar charts in section 5.3.3. The cairn classification is as follows:

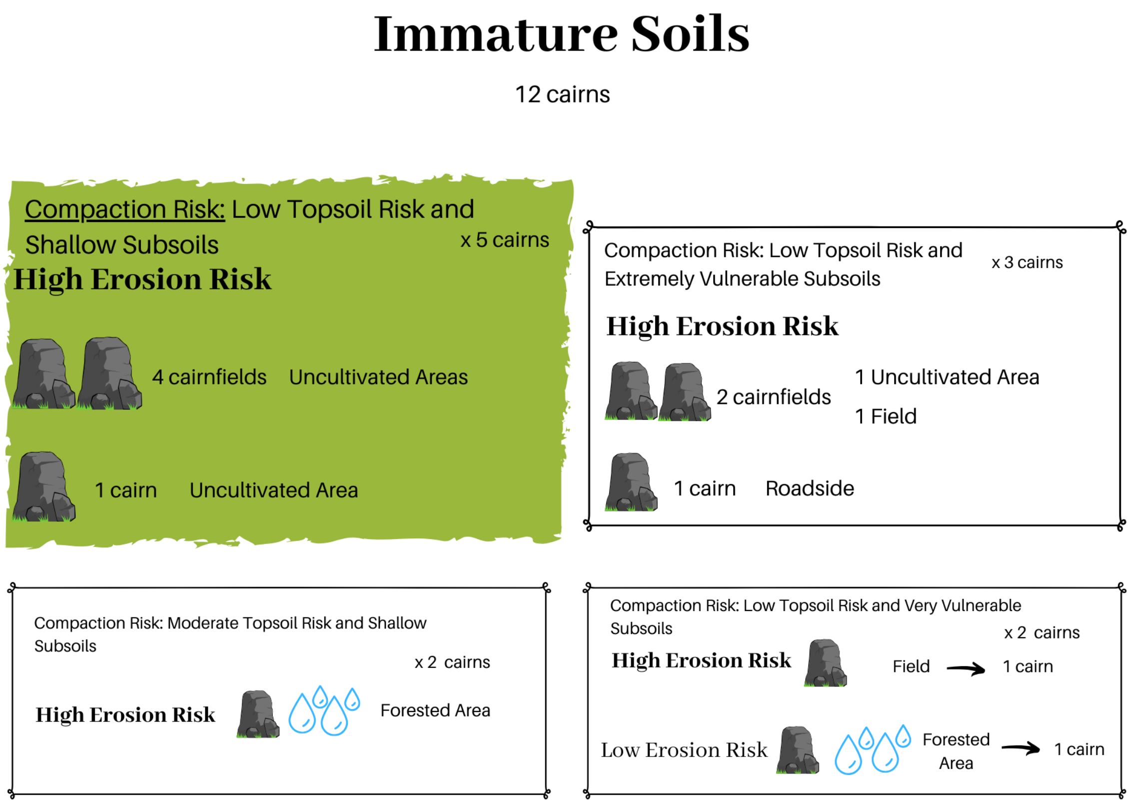


**Figure 5.11:** Diagram displaying the cairns in Immature Soils. The cairns are first classified by compaction risk, followed by erosion, drainage (if any data available), and current use. 5 cairns are in areas with low compaction risk in the topsoil and shallow subsoils, they are in areas with high erosion risk. 4 of those are cairnfields and 1 is a single cairn.

#### 5.3.2.4 Peat

25 cairns are located in peat soils. All of them are located within areas with organic topsoil and extremely vulnerable subsoil compaction risk, with high erosion risks, and an abundance of single cairns, 16. Unfortunately, there is no drainage data for peat soils. These results can be seen more clearly in the bar charts in section 5.3.3. The complete breakdown of the cairn classification is as follows:

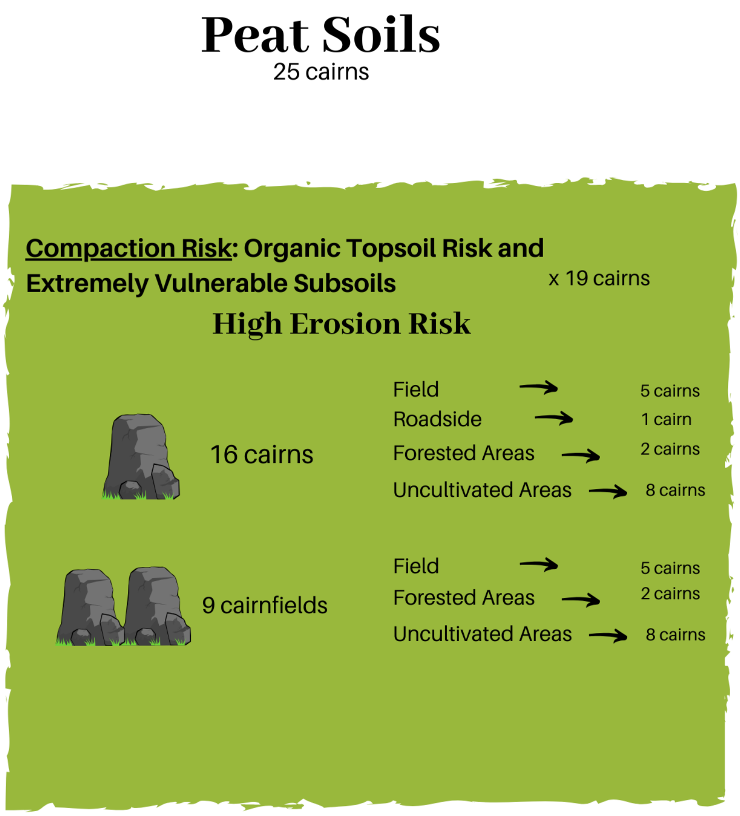


**Figure 5.12:** Diagram displaying the most numerous cairns in Peat Soils. The cairns are first classified by compaction risk, followed by erosion, drainage (if any data available), and current use. 16 of these are single cairns located mostly in uncultivated areas (8 cairns).

#### 5.3.2.5 Mineral Podzols

193 cairns are located in this soil type. 85 of them are located in areas with organic topsoil and extremely vulnerable subsoil compaction risks, with mostly medium erosion risks (132), and an abundance of cairnfields (111 cairns). Most of these soils are freely drained, 151. These results can be seen more clearly in the bar charts in section 5.3.3. The complete breakdown of the cairn classification is as follows:

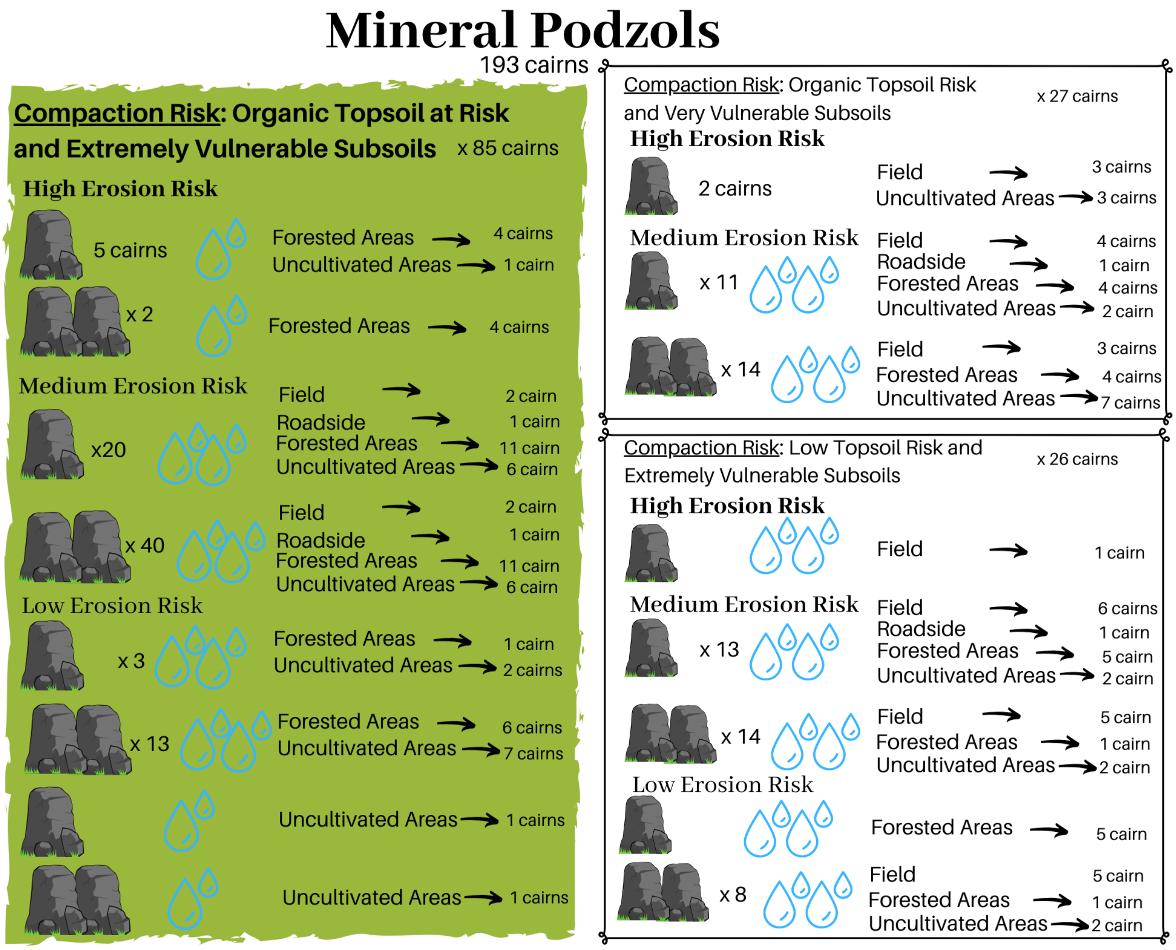


**Figure 5.13:** Diagram displaying the most numerous cairns in Mineral Podzols. The cairns are first classified by compaction risk, followed by erosion, drainage (if any data available), and current use.

### 5.3.2.6 Peaty Podzols

47 cairns are located in this soil type. Most of them, 40 cairns, are located in areas with organic topsoil and extremely vulnerable subsoil compaction risks, with exclusively high erosion risk, and an abundance of cairnfields (31 cairns). Most of these soils are freely drained below the iron pan (41 cairns). These results can be seen more clearly in the bar charts in section 5.3.3. The complete breakdown of the cairn classification is as follows:

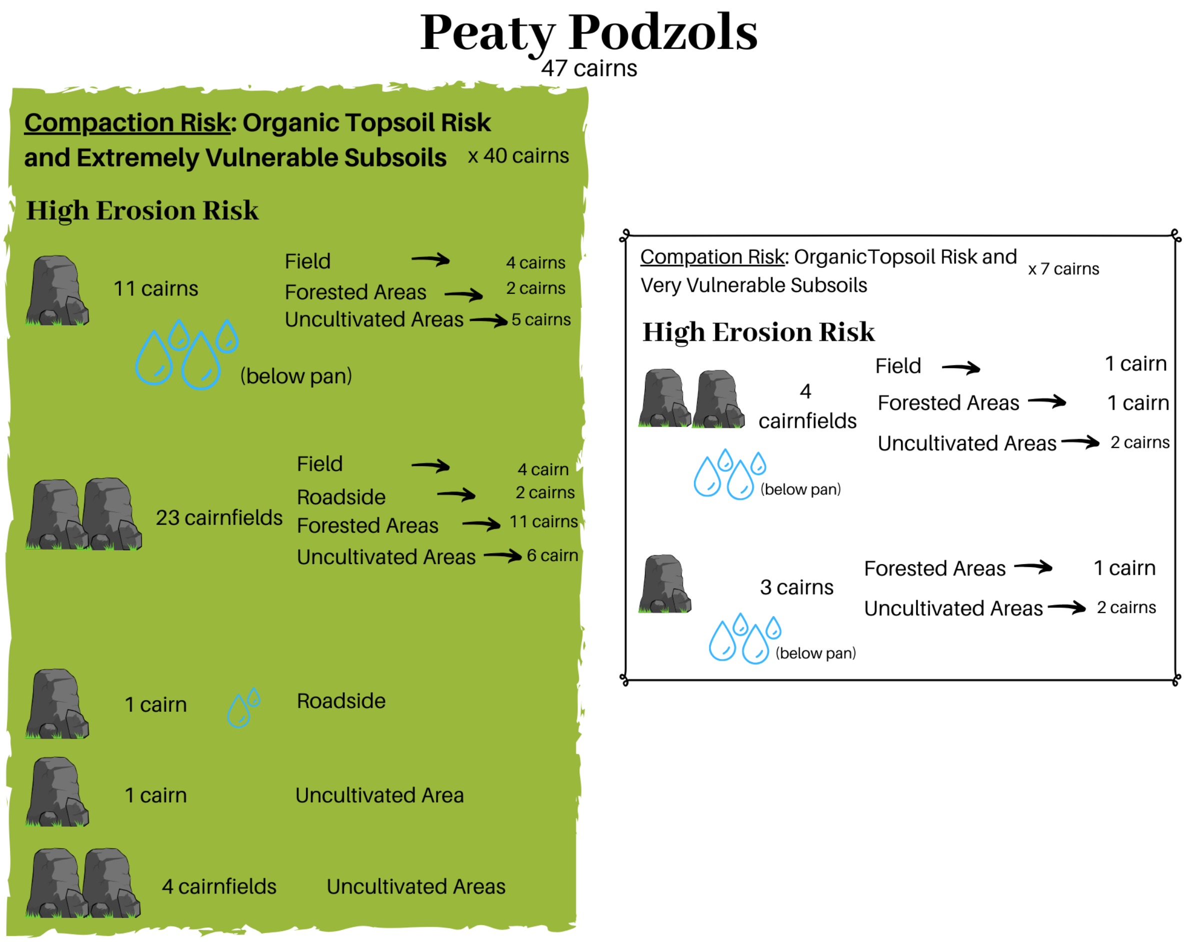


**Figure 5.14:** Diagram displaying the cairns in Peaty Podzols. The cairns are first classified by compaction risk, followed by erosion, drainage (if any data available), and current use. 40 cairns are in areas with organic topsoils and subsoils that are extremely vulnerable to compaction. 23 of these are cairnfields while 11 are single cairns in areas freely drained below the pan.

#### 5.3.2.7 Mineral Gleys

69 cairns are in this soil type. Most of them, 41 cairns, are located in areas with high topsoil and very vulnerable subsoil compaction risks, with mostly medium erosion risk (68 cairns), and an abundance of single cairns, 47. Most of these soils are poorly drained, 47. These results can be seen more clearly in the bar charts in section 5.3.3. The complete breakdown of the cairn classification is as follows:

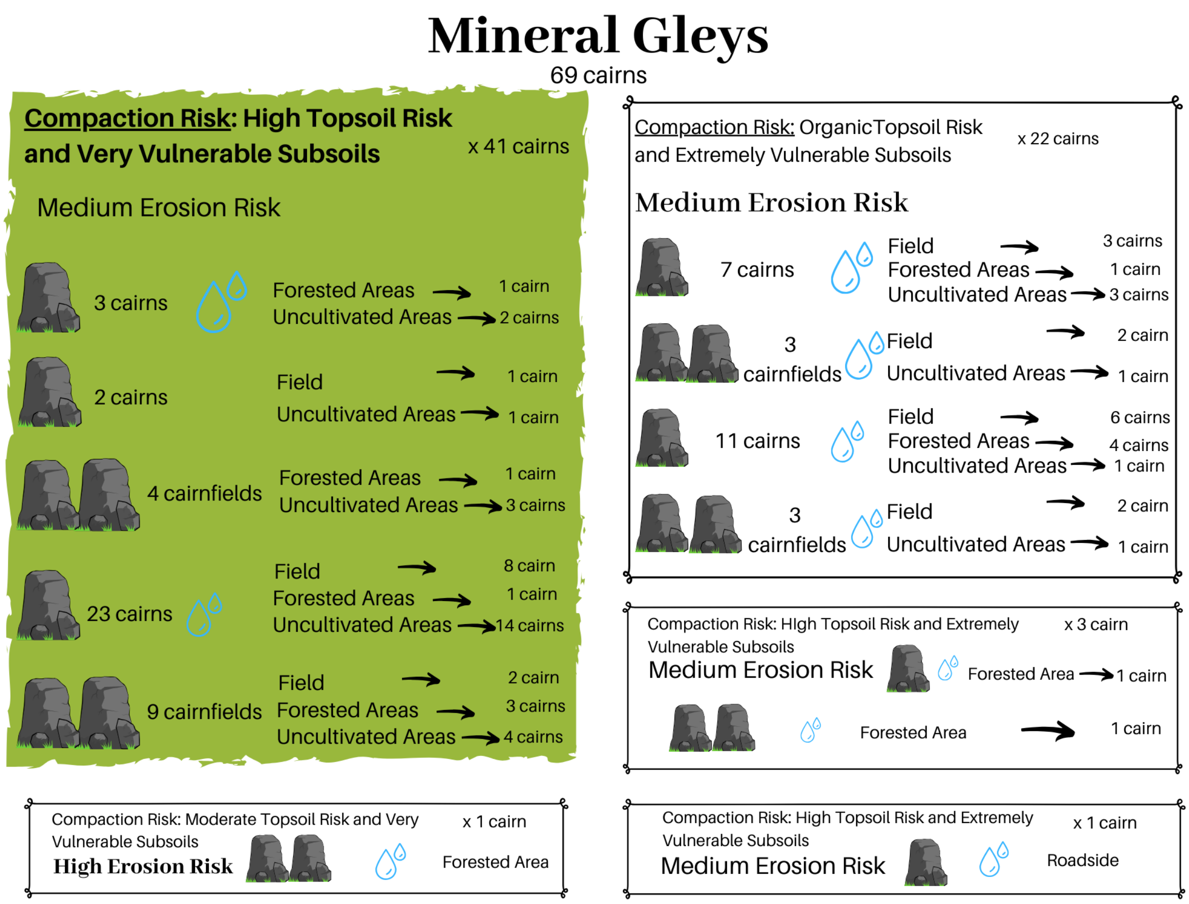


**Figure 5.15:** Diagram displaying the most numerous cairns in Mineral Gleys. The cairns are first classified by compaction risk, followed by erosion, drainage (if any data available), and current use. 41 of these cairns. 23 of these are single cairns in poorly drained soils.

#### 5.3.2.8 Peaty Gleys

45 cairns are located in this soil type. Most are in both areas with an organic topsoil and extremely vulnerable and very vulnerable subsoil compaction risks (both 16 cairns), with mostly high erosion risk (30 cairns), and an abundance of single cairns, 27. Most of these soils are very poorly drained (25 cairns). These results can be seen more clearly in the bar charts in section 5.3.3. The complete breakdown of the cairn classification is as follows:

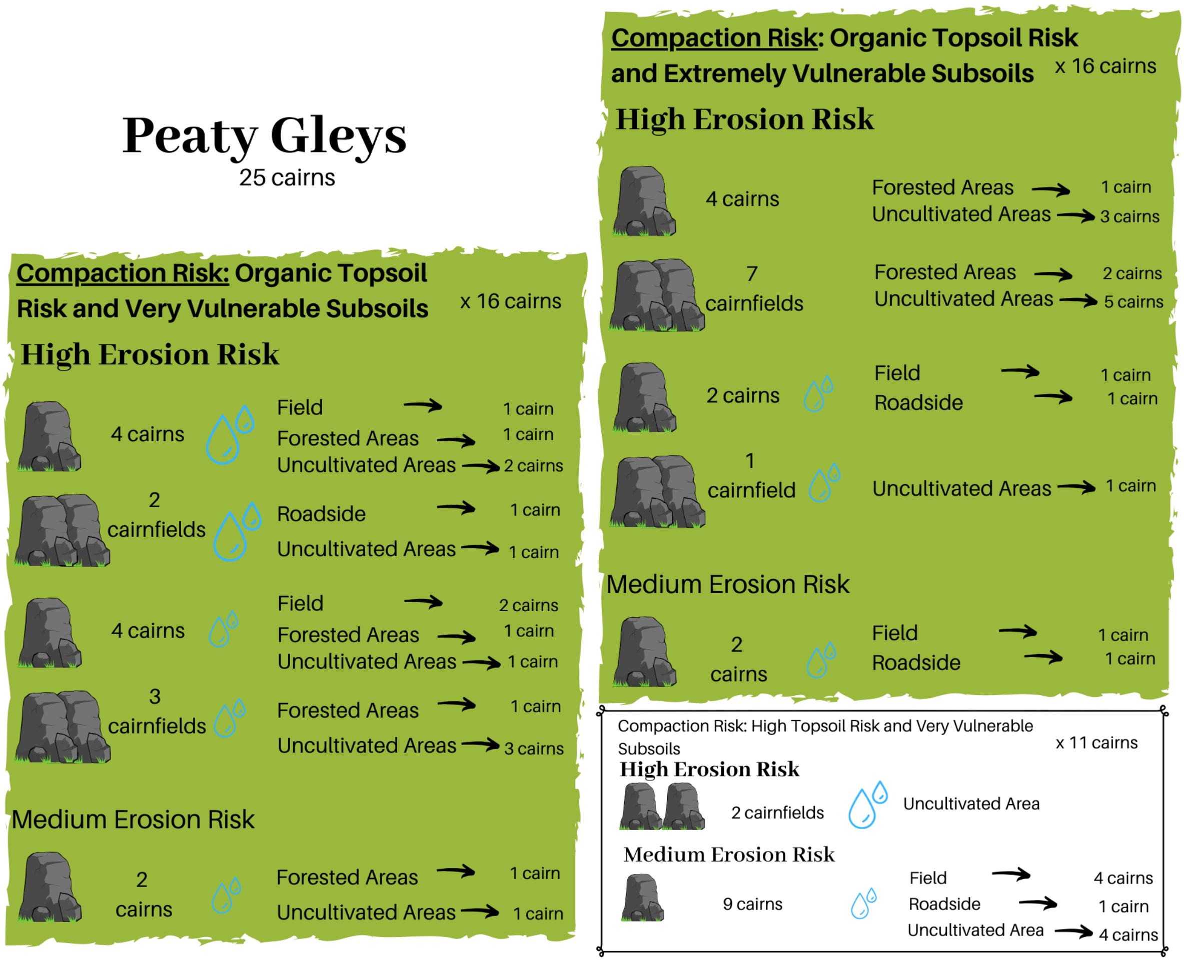


**Figure 5.16:** Diagram displaying three of the most numerous cairns in Peaty Gleys. The cairns are first classified by compaction risk, followed by erosion, drainage (if any data available), and current use. 32 of these cairns are in areas with organic topsoil and subsoils that are very and extremely vulnerable to compaction risk. Many of these are in freely drained areas (4 of which are single cairns and 2 are caifields).

#### 5.3.2.9 Lochs

This category had one cairn with no data for any other data categories since it is in the middle of a loch.

### 5.3.3 General Charts

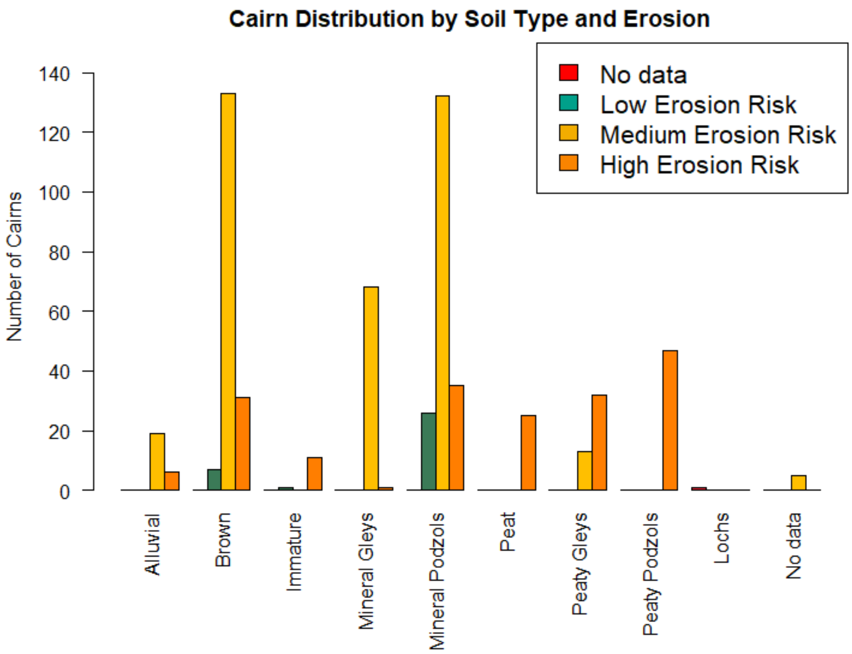


**Figure 5.17:** Bar chart showing the distribution of cairns depending on soil type (x axis) and erosion risk (classified by colour).

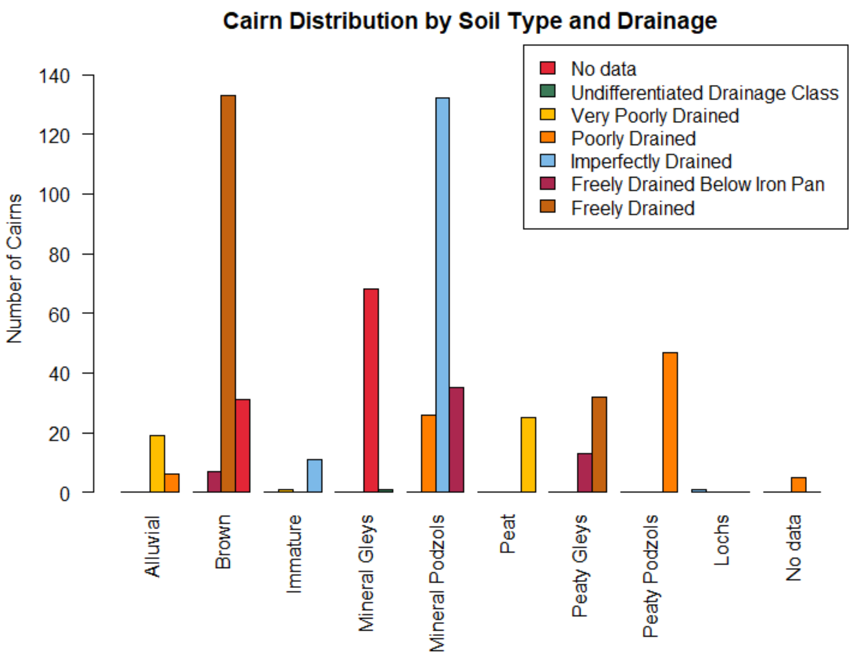


**Figure 5.18:** Bar chart showing the distribution of cairns depending on soil type (x axis) and drainage (classified by colour).

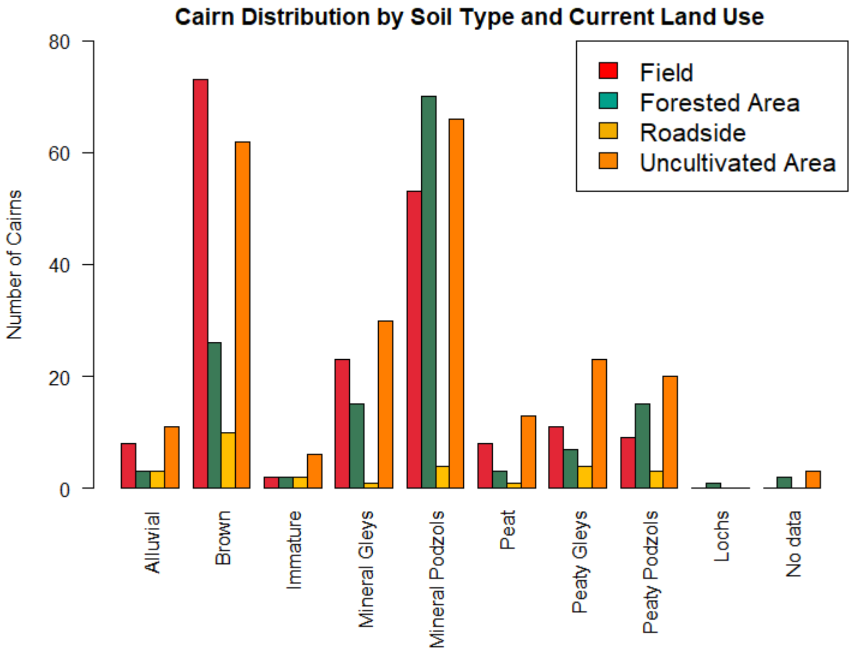


**Figure 5.19:** Bar chart showing the distribution of cairns depending on soil type (x axis) and current land use (classified by colour).

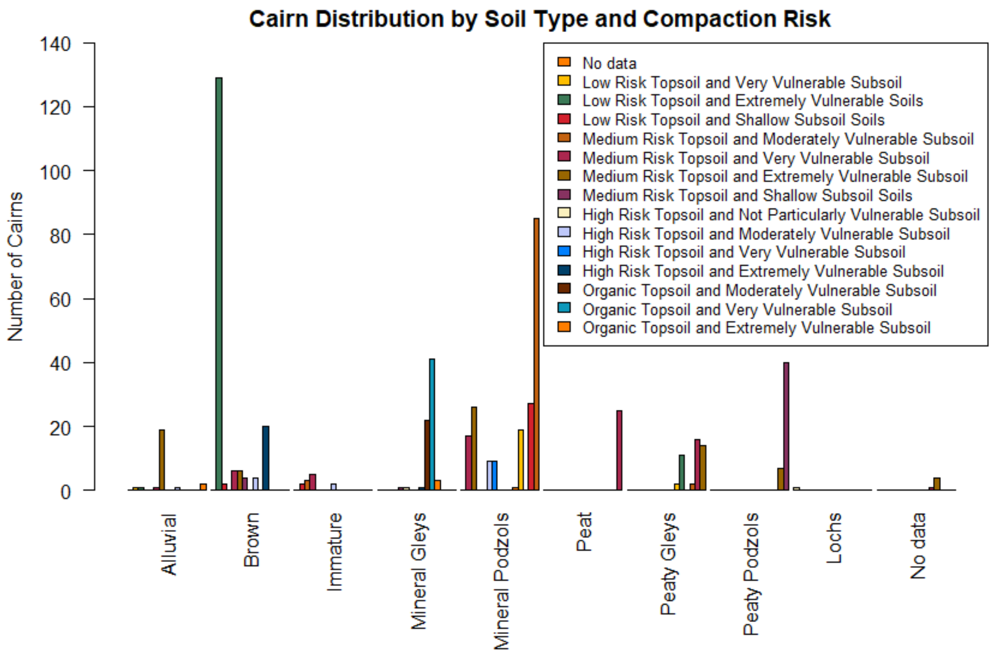


**Figure 5.20:** Bar chart showing the distribution of cairns depending on soil type (x axis) and topsoil and subsoil compaction risk (classified by colour).

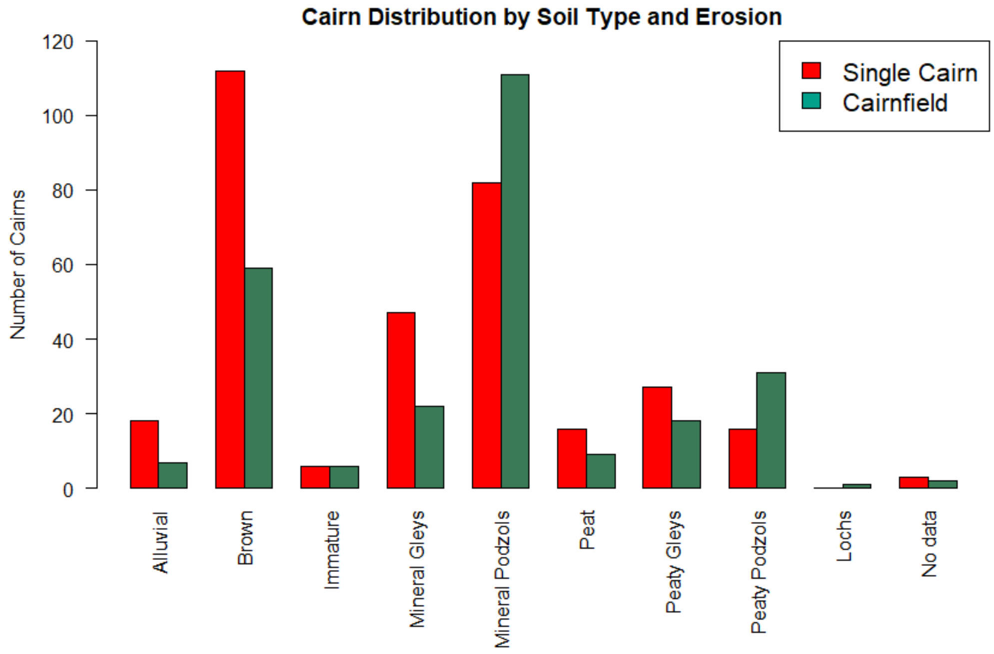


**Figure 5.21:** Bar chart showing the distribution of cairns depending on soil type (x axis) and cairnfield pertinence (classified by colour).

## 5.4 Discussion

### 5.4.1 Explanation of the Results

In order to better understand the results that were obtained from the data analysis, these will be separated into categories depending on the soil type the cairns are in. The effects they had on said soils will be assessed by referring to the soil's characteristics seen in section 5.1.2.1 of the Literature Review.

#### 5.4.1.1 Brown Soils

As seen in the results section, Brown Soils were the most common type of soil, which is not surprising since this type of soils is one of the most common in Scotland. Most of the cairns located in these soils were in areas with low topsoil compaction risk and subsoils, which are very vulnerable to compaction, were freely drained; this becomes relevant when considering that brown soils are naturally looser and well-drained. This data supports the theory that cairn exploitation, which was mostly done by single cairns instead of the more exhausting and intensive cairnfield, did not elevate the erosion or compaction risks too much. Hence, it can be argued that their constant and sustainable land exploitation has preserved the topsoil and favoured a preservation of the land, even though the lower levels of these soils are very susceptible to compacting.

As for whether they are currently still used for cultivation, as seen in the aerial imagery, there is a mix of areas used as fields and others with shrubs and trees (i.e. uncultivated and forested areas). When considering that brown soils were derived from forested areas, one can hypothesise that in those areas where the cultivation has decreased and/or stopped, forests and shrubs have reappeared, which can be symptomatic of a healthy brown soil. This soil is the best example of the effect that a sustainable use and agricultural exploitation can have on the land, maintaining it healthy and cultivable.

#### 5.4.1.2 Alluvial Soils

Alluvial soils are very shallow and have varying levels of drainage. As happened with Brown Soils, it is likely that the effect that clearance cairns and cultivation have had on these soils is very mild. This could be since the soil was allowed to rest or because the removal stones and the crop cultivation was not aggressive or intensive. This is another example of sustainable agricultural practices.

#### 5.4.1.3 Immature Soils

Immature Soils are, like alluvial soils, very shallow and have no profile definition. The result section shows how these have an equally distributed presence of single cairns and cairnfields, as well as the fact that now they are mostly forested and uncultivated areas. This could be because they have a high erosion risk and, due to their shallow nature, they have either eroded too much to be cultivatable, or they are close to. This is an example of the effect of an overly aggressive agricultural approach that does not respect the needs of the soil.

#### 5.4.1.4 Peat

Despite how common peats are in Scotland, covering 1.8 million ha or 20% of its land (see Marsden and Ebmeier, 2012, pg.9), they are uncommon in the study area, as reflected in the dataset. They are very vulnerable to compaction and erosion, which has most likely been aggravated in these areas by the presence of clearance cairns and the agricultural exploitation that can be inferred from it. Peat's waterlogged nature required the creation of clearance cairns to allow proper cultivation, but it can be argued that its excessive creation was the probable cause behind their current highly eroded and uncultivatable state in the area of study.

#### 5.4.1.5 Mineral Podzols

These are very fertile soils and have a high oxygen content. Nevertheless, cairns are abundant in these soils, with a very high presence of cairnfields. One can speculate that this intense cultivation and abuse of the land is what caused it to be uncultivated now. Despite good soil drainage and a medium erosion risk, this study's dataset shows they are mostly forested and uncultivated areas now, and that both the topsoil and subsoil compaction risks are too elevated to cultivate these areas safely, despite their traditional high fertility levels (see 5.3.2). This is the best example of the effect that excessive land exploitation for agricultural processes has on the land: it can turn a perfectly cultivatable land into an area that is no longer valid for cultivation.

#### 5.4.1.6 Peaty Podzols

Unlike Mineral Podzols, these soils are more susceptible to waterlogging and need to be aerated and drained more frequently. It can be argued that the use of clearance cairns was to remedy this, explaining the abundance of cairnfields in these soils, which increased the erosion risk and yielded the soil uncultivatable. In fact, this can be seen in the results, which show these soils are mostly uncultivated now (see Section 5.3.2).

#### 5.4.1.7 Mineral Gleys

These soils are difficult to cultivate *per se* due to their disposition to water-logging and inherent poor drainage. In fact, The James Hutton Institute (2019b, paragraph 6) states they are very dense and need to be thoroughly drained, and aerated prior to successful cultivation. Nevertheless, due to the higher mineral content in these soils, they are less prone to erosion. As seen in the results, cairns are more present in mineral gleys with high compaction risks, both at a topsoil and subsoil level, complicating drainage and increasing soil density. Mineral gleys are predisposed to these but the agricultural exploitation they experienced, particularly the removal of stones and creation of clearance cairns, is likely to have increased them and rendered these soils uncultivatable. This is also reflected in the data gathered, since most of these are uncultivated areas now (see Section 5.3.2).

#### 5.4.1.8 Peaty Gleys

Similarly to Mineral Gleys, these soils are prone to water saturation and poor drainage, requiring frequent drainage for successful cultivation. Therefore, it is not surprising that the data shows an abundance of cairnfields in the areas that are more waterlogged (see Section 5.3.2). Most of these areas are, however, no longer cultivable due to their high erosion risk and very poor drainage (see Section 5.3.2). It can be argued that the agricultural exploitation of these soils made them more susceptible to erosion and, in the long run, aggravated their drainage issues.

#### 5.4.1.9 Lack of Data and Loch Areas

The dataset contained five cairns located in areas with no soil data. These corresponded to areas with very high compaction risks, both in the topsoil and subsoil levels, and medium erosion risk. Unfortunately, the effect of these cairns on the soil they are in cannot be measured. Likewise, one of the cairns is in an area that has, with time, turned into a loch.

### 5.4.2 General Results Discussion and Theorising

As expected, the presence of cairns influences the landscape, namely on the soil and its state. Clearance cairns were a very important part of the agricultural process and, as this study has shown, their presence is higher in more eroded soils and has possibly had an effect of them. Although this is not proof of causation, it does establish a strong correlation. The results suggest that agricultural practices in Scotland have different sustainability effects on soil:

- *Areas cultivated in the past that are no longer cultivatable.* Those now have an organic or high topsoil and an extremely/very vulnerable subsoil. In Figure 5.22, one of the clusters in the top right shows that this type of soil compaction risk was correlated with High and Medium levels of erosion and has quite a high cairn count. This could be explained by theorising that the exhaustive working of the land via cultivation and the stone removal that lead to clearance cairns strained the land to the point where it is no longer sustainable, and it is highly erodible, thus no longer cultivatable. In addition to this, factors such as the use of manure, use of tools to work the soil which can break it apart and increase erosion risk. The effects of cairns on Mineral Podzols, Immature soils, Peaty Gleys, Peaty Podzols, and Mineral Gleys are the best example of this theory.

- *Areas cultivated in the past that can still be cultivated but are under risk of erosion.* Those are classified as having medium to low compaction risks with medium to high risk of erosion (bottom right cluster in Figure 5.22). This could be explained by theorising that the work of the land, although straining a delicate land, was not as exhaustive and has not worn out and compacted the soil as much; perhaps the removal of stones within it was more moderate and/or that the soil was allowed to rest more and so the cairns were reused over longer periods of time or taken down and rebuilt with the newly removed stones. The effects of cairns on Alluvial and some Brown Soils are a good example of this.

- *Areas cultivated in the past in mostly non-exhaustive ways and can still be cultivated.* This areas have low to medium compaction and erosion risks with a low cairn count (see bottom left cluster in Figure 5.22). Although their subsoil is very vulnerable to compaction, due to their medium and low compaction levels of the topsoil, and the gentle stone removal with lower cairn production as part of the agricultural practices, the land is still able to be cultivated. The effect of cairns on most Brown Soils is the perfect example of this.

These three categories focus on the role that clearance cairns could potentially have had on the soils; however, they must be understood within the wider context of cultivation practices. Another element to consider is the fact that some soils may no longer be cultivated due to factors unrelated to soil quality. An example of this would be the cultural shift to a bigger part of the population working and living in cities rather than fields.

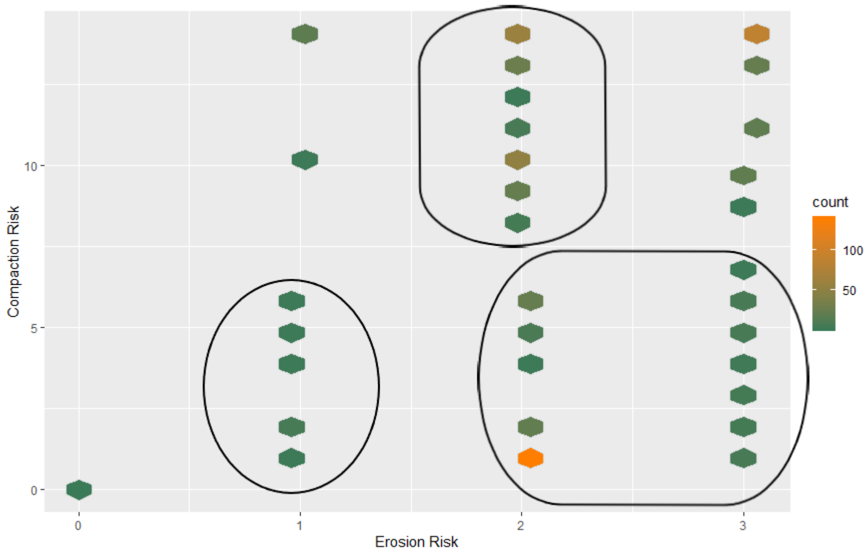


**Figure 5.22:** Correlation between Erosion and Compaction Risks coloured according to cairn amount; orange tones indicate higher amount of cairns and green tones indicate a very low amount of cairns. The distribution is very even but there are three main clusters: the lower left has low erosion and compaction risks, the bottom right one has high erosion risks and low compaction risks, and the top right one has high erosion and compaction risks.

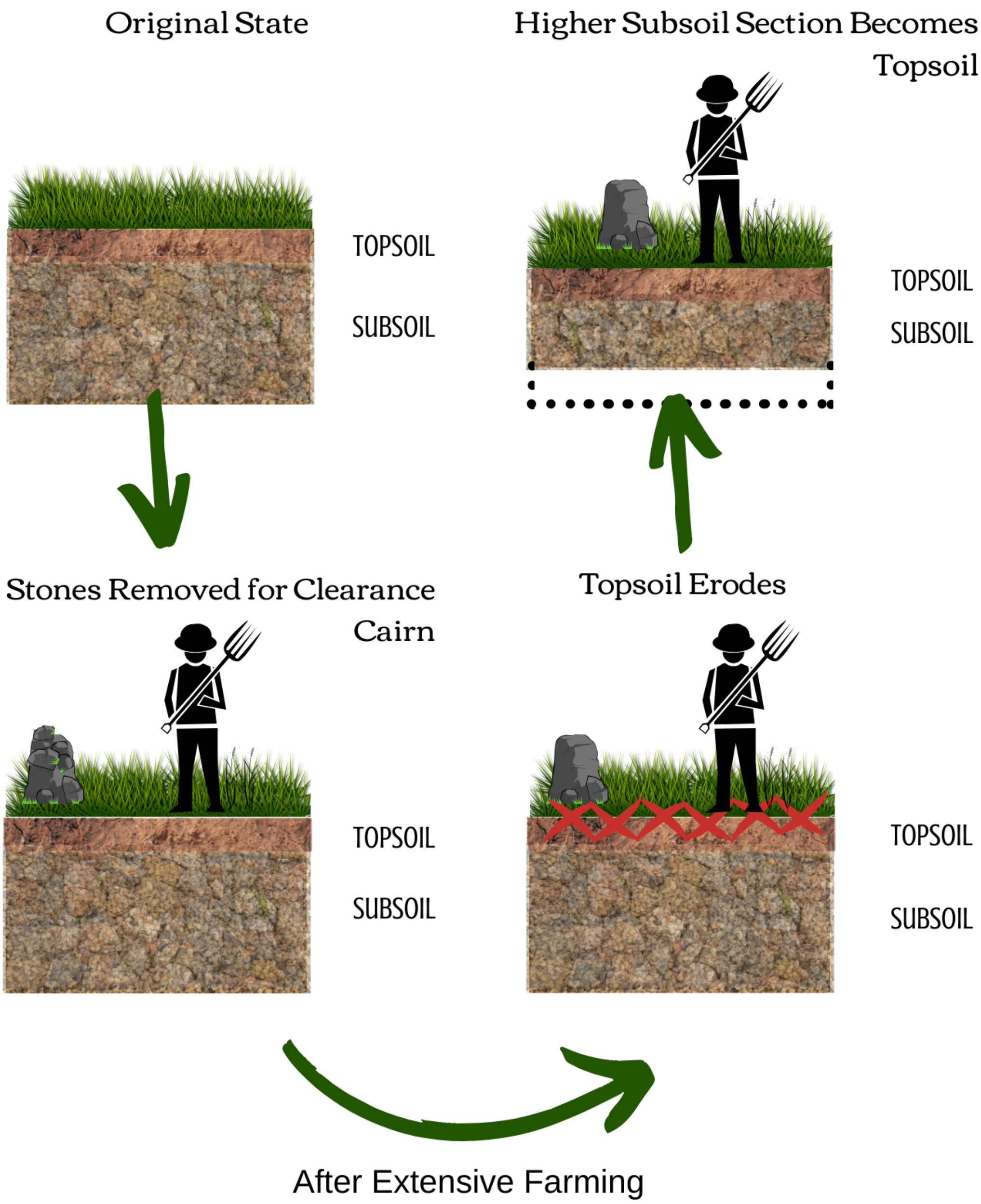


**Figure 5.23:** Diagram representing the exhaustive use of clearance cairns and its impact on soil quality

### 5.4.3 Potential Limitations and Weaknesses

One of the main limitations of the project is the data availability. As stated in the Methodology, the soil data has been obtained from The James Hutton Institute and is limited to the east and south-east areas of Scotland which reduces both the study area and its depth. In addition to this, some of the datasets cover different areas within that general east and south-east location. This caused gaps in the data which were reflected in this case study with "no data" sections in all categories, it was more evident in the drainage dataset with a 19% of the data falling within the "no data" category.

The case study's time period is limited by the cairn timeline. The cairns used in the study have a wide timeline, spanning from prehistoric to modern. Furthermore, many of them were labelled by Canmore (2019) as "period unknown" which further complicated the establishment of a general case study time period. Including time period as an analysis variable in future studies may provide more information on the impact of clearance cairns on the soil through time.

Another weakness relates to the display of the data. Due to the size and complexity of the dataset and its multiple variables, it was difficult to decide on a means to display the data clearly and concisely. This study presented the data via a combination of an interactive table, bar charts, pie charts, and a scatterplot. These data displays are in themselves a limitation of the way in which the reader will explore the data and, if revised or recreated, the data display must be kept in mind.

Likewise, the interdisciplinary character of this project is one of its greatest strengths but also a weakness. The researcher's knowledge of Scottish soils and geology is more limited than that of an expert and, although the utmost care, detail and research were put into the description of soils and their behaviours, the author's knowledge may have limited the depth the study was able to reach. An expansion of the study done in conjunction with a geologist or a soil expert may offer a deeper understanding of the theories and hypothesis put forward in this project.

## 5.5 Conclusion

This project's main aim was to study the clearance cairn and landscape interaction in the east and south-east of Scotland. It intended to analyse the impact of clearance cairns, as a representation of agricultural practices, in the environment, in particular, soils. Through this, the project aimed to further develop the knowledge of clearance cairns and their roles, impact and relationship within the landscape; a topic that is often neglected in the literature. Considering the obtained results, it can be argued that it has deepened the knowledge into clearance cairn and landscape interaction as well as its effect on soils as an agricultural practice.

The datasets used were a series of soil, drainage, erosion, geology, and compaction maps obtained from The James Hutton Institute. Likewise, information regarding the current land use was obtained via the analysis of aerial imagery. From these data, a large shapefile was created. This was shortened to six relevant categories that were processed with R Studio and Excel, and turned into a series of tables, charts and plots. These categories were soil erosion, topsoil and subsoil compaction, soil drainage, cairnfield pertinence, and current land use.

The study's main findings are that there is a correlation between the presence of cairns and higher erosion risks in soils. The study has also observed three patterns of sustainability effects that the use of clearance cairns have on the soils: an exhaustive use that makes it no longer cultivable, an intense use that puts the soil in risk of erosion, and a non-exhaustive use that allows the soil to still be cultivated. These have affected our current landscape's appearance and the way that it has changed along the years. Being aware of these changes (i.e. soil erosion and degradation) and the practices that caused them can allow current farmers and users to make more informed choices that allow us to preserve the landscape and environment.

These results could be expanded onto similar studies focused on a more modern period, to observe if these practices are still in place and how they can be modified and/or adapted based on the findings stemming from the study of the past landscape. Other recommended future research is the expansion of the study to different European countries to compare and contrast the regional differences in agricultural practices and their effects on the landscape; this would allow the establishment of overarching patterns as well as key differences. In a deeper, more local sense, obtaining a full dataset of Scotland would be ideal. In this respect, a study of all of Scotland would deepen the knowledge of clearance cairns' impact on the landscape and would highlight any differences between the East and West and/or North and South parts of the country. Generally, there is still much to be studied regarding clearance cairns and their use and landscape impact, in particular in Scotland.

# Chapter 6

## Discussion

This discussion will re-examine the project's aims and offer some observations based on the results obtained. These considerations will cover the results of each case study as well as a general level to contextualise the results within the general literature. This chapter also assesses the success of the methodology used and its limitations, as well as the issues encountered and how these could be overcome. Finally, the discussion assesses the project's role within DataARC. It reflects on the integration of the project and its datasets within the CI's framework while reviewing DataARC's user experience.

### 6.1 Research Aims and Considerations

Within the context of DataARC, discussed later in this chapter, this master's thesis aimed to study human-environment interactions through the analysis of cairns. The project adopted an interdisciplinary approach to further develop the understanding of these human-landscape relationships in the wider framework of human ecodynamics. The research was conducted in the form of two separate case studies which produced several observations based on the results. The main consideration is the relevance of the role of cairns within the landscape. The case studies show cairns as a physical representation of human-landscape relationships in many instances. Although a full demonstration has not been provided in this project, with the case studies only providing information on movement and agricultural practices, the combination of its results with the large pre-existing general literature argues for the development of cairn study as a means to better understanding the human-landscape relationships within the field of human ecodynamics.

As the human ecodynamics literature often mentions (see Section 2 for a revision of this), the relationships between people and their landscape are "constantly negotiated and renegotiated", prompting constant changes and re-assessments of how they interact (McGlade, 1995, 114). This project defends and demonstrates that cairns are a perfect way to examine these changes due to their versatility and their continued use through history in a variety of geographical areas. This is supported by the extensive research on the use of cairns, focusing on different geographical locations, functions, and significance in many rituals, cultures, and/or beliefs (see Vejby, 2016; Goldhahn, 2009; Bortolini et al, 2019; and Abu-Azizeh et al., 2014 for funerary cairns; Overland and Hjelle, 2012; Tilley, 2017, 123; Graham, 1959; and McCullagh and Tipping, 1998 for clearance cairns; and Aldred, 2014a; and Heide, 2014 for navigational cairns). A thorough analysis of this pre-existing research already offers a sound basis for this argument; however, this project and its results further support it. Case Study One and Two emphasise the role of cairns within different aspects of human-landscape relationships. In these, cairns are very good physical representations of these interactions, providing evidence of the engagement between people and their environment, as well as a way to study them in-depth.

Cairn versatility and use through history ensures and demonstrates the constant presence in human cultures for a variety of roles. There are many studies which focus on the diverse aspects of cairns, highlighting their role as burials, route markers, agricultural elements, and disposal systems, amongst others (see Section 5.1.1 for a detailed explanation). Cairn reuse and the extensive information this can provide to archaeologists have been discussed by Graham (1959), Heide (2014, 69), and Johnston (2001, 108). Based on the study of the general literature, it can be argued that cairns undertake the functions of burials, navigational markers, agricultural elements and overall markers in the North Atlantic, as proven by the many existing studies such as Aldred (2014a and b), Graham (1959), Goldhahn (2009), and Sanhueza Tohá (2004) amongst others (see Section 5.1.1). These exemplify a variety of human tasks and how they materialise and interact with the landscape in the form of stone structures. Despite the evidence for cairn versatility, the scale of this master's thesis only allowed for the assessment of two cairn roles: navigational and agricultural. This limitation emphasises the need to contextualise, this project's statement that cairns are a physical representation of people's interactions with their landscape. This conclusion, while supported by the results of these case studies, is complemented by the general context that takes into consideration other studies analysing different cairn functionalities to offer a more complete analysis.

## 6.2 Cairns in the Study of Human-Landscape Dynamics

As mentioned above and in Section 5.1.1, cairns have been thoroughly studied for a variety of reasons. Some studies, such as Bortolini et al (2019), have focused on the study of cairns in general and the information that these can give archaeologists about a culture and its history. Cairns are nuanced and have many variations, however, this masters' thesis only discussed the navigational and the agricultural aspects. The main aims of the project in regards with these two aspects were to further develop the understanding of these cairn uses while providing an analysis of the human-landscape engagement in two geographical areas of the North Atlantic, Scotland and Iceland. These aims were achieved and provided a series of case-specific observations. The first deepened the understanding of movement in Iceland, as well as the role of cairns as route markers, and as a representation of people's active engagement with the landscape. This people-landscape engagement is emphasised by the landscape's active role within human activity rather than a passive one. The second offered a unique analysis of how agriculture has affected the landscape and proved the usefulness of cairns in studying these changes. The change in clearance cairn use can be understood as a physical representation of the changes in people's relationships with the land in agriculture. More detailed and case-specific discussions are provided in each case study (see Sections 4.4 and 5.4) although this general discussion will provide a broader look at their fit within the pre-existing literature and their relevance when examined together.

### 6.2.1 Cairns and Landscape's Active Role

Case Study One's approach to movement is based on farm networks and the role of navigational cairns in marking the roads. Although the conclusions fit well within the phenomenological trend that highlights the landscape's active role, this study did not engage with the data in a traditionally post-processualistic methodology. Instead of an experimental approach to movement, it was analysed through the perspective of cairns because they are one of the movement's physical remains, the most common route marker in Iceland, as seen by their abundant presence. This study favoured a GIS approach based on human experience, LCP and visibility analysis as opposed to the more physical approaches to movement, such as personally tracing the roads and taking a first-person account of the experience and the perception of the navigational cairns from the proposed roads (see Witcher, 1999 for an in-depth discussion on empirical versus physical methodology). This allowed for a more comprehensive and physical analysis than the examination of maps, but it does not have the physical component, and excludes the effects of weather changes in visibility and mobility. The study concluded that humans interact with their landscape in general but in particular when establishing roads. The distribution of navigational cairns was deemed feature-dependent within the landscape (see Section 4.4). This landscape agency and relevance in human selection of the location of relevant constructions, such as burials or *thingsites*, has also been observed in other studies (e.g. Maher and Harrison, 2014; Maher, 2014; Amundsen, 2014), and, as explained below, has thoroughly been defended in a theoretical framework.

Movement has not been studied as deeply as it could have, with more emphasis being placed on the destinations rather than the routes taken or the journeys themselves (good examples of movement study can be found in Hindle, 1993 and Aldred, 2014a as opposed to other studies that concentrate more on the destinations rather than the journey itself such as Whitmore, 2013 and Galloway, 2005). Although this project did not provide an in-depth study of the routes and the rituals or elements which informed the feelings and decisions involved in and derived from travelling, it analysed the materialisations of routes through the study of cairns. From a different angle to that of Oscar Aldred's (2014a), this project observed the validity of the navigational role of cairns which offered excellent insight into people's interaction with their landscape. The distribution of cairns throughout the roads, as well as their acknowledgement of the traits of the landscape, shows an awareness of the environment and how humans can use it in their favour. This also shows a deeper human interaction with the landscape, and how they both play an active role in this interaction.

This fits well with phenomenological trends of landscape archaeology. Authors such as Tilley (1994, 10, 13 and 23) and Fleming (1998, 61) have highlighted the active role that the landscape has in human activities, being constituted by them and changing as a response to the changes in the activities themselves. This landscape involvement and interaction can be seen through Case Studies One and Two. The first emphasised the landscape's key role in the distribution of navigational cairns when marking places of travel and frequent routes. It showed people's awareness of their surroundings and their incorporation of them into their daily activities such as movement. The navigational cairns work alongside the landscape to guide the traveller, not in spite of it. Tilley's (1994, 13) statement "the kinetic activities of human beings orientate apprehension of the landscape and create it as human" remarked the relevance of human movement and landscape interactions, being a key part of the development of the landscape while showing the relevance that this plays in the relationship, actively engaged. Furthermore, the second case study highlighted people's awareness of the landscape as an agent that does not remain static but responds to human interaction and experiences changes. This can be seen in the ever-changing nature of the landscape which responds to human changes whether they be political, social, religious, etc. and is reflected in the construction and destruction of monuments, landscaping and gardening, farming patterns, etc. (this is further discussed by Aston, 1985, 19, 106, and 151; Tilley, 1994, 24-25; Williamson, 1998, 1-6; Everson and Williamson, 1998, 145-149; and Fleming, 1998, 61). As such, how humans interact with it must be constantly reassessed to adapt to these changes.

### 6.2.2 Cairns and Changing Human-Environment Interactions

Case Study Two aimed to further the study of clearance cairns in Scotland and did so by providing information on the effect they had on the landscape. Studies of human effect in the landscape are common in the North Atlantic (e.g. Dockrill and Bond, 2014; Finlayson and Carrión, 2007; Dugmore et al, 2014; Amundsen, 2014; Sköld, Lageras, and Berglund, 2010). However, this case study's analysis of a combination of soil characteristics, erosion, compaction, and current uses with clearance cairn data is an innovative approach. As such, it helped further the knowledge of the effect certain agricultural practices have had on the soil in Scotland, which can be seen in the case study's conclusion that there are three sustainability outcomes (see 5.4.2). It also helped understand certain aspects of human-landscape relationships, in particular, how the consequences of land exploitation force people to change how they use the land. This can be observed in Case Study Two's data, indicating that 68% of clearance cairns that were in cultivated fields are now in uncultivated areas, roadside, or in forested areas; it is important to consider that the remaining 32% of fields may not be used for cultivation despite appearing so. This study shows a change in people's interaction with and cultivation of the land.

Changes in people's interaction with their surroundings can be seen in the fact that many of the studied clearance cairns are no longer in cultivated fields (see Section 5.3.2). This relates to the consequences of the agricultural exploitation of the soil, part of which included the creation of clearance cairns. Agricultural changes to the landscape are one of the most common sources of physical landscape change, often entailing the conversion of forested areas into pasture or cultivated areas and vice versa once the land is no longer fertile (Williamson, 1998, 6). Case Study Two's Brown Soils are a good example of these landscape changes brought upon by agriculture; the need for fertile lands driving people to use fertile forested areas which have a high resistance to agricultural exploitation and very good drainage (see Section 5.1.2.1). These changes demonstrate a renegotiation of the interactions humans have with their landscape.

The role of agriculture in the reorganisation of the landscape argued by this project has been thoroughly defended by Aston (1985, 11), and Williamson (1998, 6). They emphasise the effect that agriculture has had on the current state of the landscape and how this has modified how humans engage with it. The relationship re-negotiations mentioned in Case Study Two take place due to a change in the landscape itself which forces humans to re-evaluate and modify the way they interact with it as well as consider the introduction of modern techniques and/or technology. The first is exemplified by Case Study Two which, based on the results obtained, theorised that agricultural practices in Scotland have three main sustainability effects (see Section 5.4). These effects have put some of the soils under risk of erosion and rendered others uncultivatable, forcing humans in the area to reconsider how they engage with those soils and reconsider the practices used, thus turning those areas into something other than a field to allow them to rest or, simply, because they are no longer fertile or profitable.

It can be argued that cairns represent these changes very well. Alongside the changes in the interaction with the landscape, seen in the agricultural changes (i.e. fields no longer being cultivated), the role that cairns undertake in that space changes. The changing role of the clearance structures was not examined in depth in this study and would have been better understood if it had been combined with an in-person exploration of the current landscape to see how the cairns interact with their new surroundings. However, the change in landscape use prompts a questioning of the changes in the roles of cairns. Have those that have stayed in fields remained as clearance structures? Have the ones that are now in uncultivated areas turned into historical monuments or have they become an unnoticed part of the landscape? Whatever their current role, it can be argued that they have become an intrinsic part of the history that the landscape tells as well as a part of their identity. Similarly, many of the navigational cairns in Iceland which are still in use as route markers, however, they have now acquired a symbolic role. They not only mark the roads but also act as a reminder of the history of the country's navigational systems and, in some cases, they are seen as a ritual for good luck (see Atlas Obscura, 2019, paragraph 2). Cairns are the physical representation of this historical human-environment interaction and, as highlighted by Tilley (1994, 24-25 and 59), Miller and Davidson-Hunt (2010, 402) and Witcher (1999, 13), the landscape is, after all, the product of all of this human history and the constant changes in interactions.

## 6.3 Relevance of the Project's Design and Methodology

As detailed in Section 3, this project examined human-environment dynamics with an interdisciplinary approach in both case studies. The design was based on a general analysis of the state of cairn literature and two specific case studies that examined navigational and agricultural cairn roles. The chosen methods of study were a combination of interdisciplinary methodologies and datasets intended to provide a complete study of human-environment interactions. This combined approach helped accomplish the project's, and the individual studies', aims: it furthered the understanding of cairns as navigational and agricultural structures and offered an analysis of the human-landscape engagement in two different areas of the landscape. It has also shown the relevance of landscape in human movement, as well as the effects and changes of human-landscape dynamics through time. This was done through the analysis of specific aspects of human life, movement/travelling and agriculture, which still takes place in today's world.

The dual case study layout with differing geographical contexts is an unorthodox design but it proved helpful in understanding two different cairn uses in varying landscapes. Each geographical context provided a different study opportunity due to the differences in overall use. While the argument and data analysis of this project may have proceeded in two parts, they should not be understood as separate entities. The comparison of these two cairn roles in both areas of the North Atlantic shows the diversity in human-landscape relations and requirements. The geographical and environmental differences in Scotland and Iceland affect how people exploit the landscape. This can be seen better in the lack of use of clearance cairns in Iceland as opposed to their extended use in Scotland; a difference explained by the contrasting soil types, with Icelandic soils not requiring clearance. It can be argued that Iceland's soils do not require the use of clearance cairns in agriculture while it is a common agricultural practice for Scottish soils. The opposing navigational cairn distribution can also be observed thanks to this double geographical study area. This type of cairn is often found in Scottish mountainous areas rather than field ones. The use of cairns in Scottish agriculture, as well as their positioning in the fields, are possible reasons why navigational cairns are mostly located in the Scottish mountains, mainly to avoid misleading travellers. Likewise, changes in the role of cairns through time can also be appreciated. As mentioned in the Literature Review, navigational cairns are still in use in Iceland and Scotland and official organisations build them and maintain them regularly (e.g. The John Muir Trust, 2016; Ástvaldsson, 2019, paragraphs 1-3).

The main criticism of this geographical layout of the project can be based on the fact that the areas cannot be studied in-depth and the design does not allow for in-area contrast. However, it can be argued that although this approach did not allow to go into one geographical area in-depth, it provided an opportunity to observe different cairn behaviours through the North Atlantic depending on the landscape they are placed in. Studies which offer a comparison of cairn roles within the same area already exist (e.g. Graham, 1959; Heide, 2014), however, as of now, there seem to be no prior studies involving taking this dual use and geographical approach thus making a methodological contribution to the study of cairns. Additionally, the approach has allowed the case studies to show the changes in cairn usage in different areas of the North Atlantic through time, as well as deepening the particular cairn functionality they focused on.

Regarding the interdisciplinary character of the study, this was a very useful approach for a human ecodynamics study. Interdisciplinary approaches are common when studying the environment and reconstructing people's interactions with it, due to the complexity of these relations (see Amundsen, 2014; McGovern et al, 2014; Dallai et al, 2018, 136). It can be concluded that, overall, this was the correct approach since it provided a deeper analysis than one based exclusively on archaeological data would have. It also allowed adopting different approaches that have not been taken before, as is the case of Case Study Two, which presents an extensive and unique dataset combining geological, archaeological, and soil data.

The project could be improved in later iterations. In particular, having a more precise time framework to delimit the project would be a very good improvement. This project did not have a specific time span and examined the cairns overall, through time, without considering their dating. The reason for this was mainly the lack of dating data for most of the cairns datasets (particularly in Iceland where this dataset was created from the analysis of satellite imagery). There is also a lack of physical experimentation of the cairns within their landscape. For example, Case Study One does not take into consideration weather and seasonal changes that impact visibility and that can block off the roads at times. An acknowledgement of these changes and their effect on the role of cairns and the movement through the landscape would provide further insight. Likewise, an in-person study of the cairns in Case Study Two would have allowed for a better understanding of the role they undertake in the current landscape and how people's perception of them in that specific space has changed through time, as opposed to the satellite image engagement. These could not be applied in the current project due to time and physical constraints.

## 6.4 Integration within DataARC and CI Feedback

This project was framed within DataARC's framework which provided it with a wide interdisciplinary context. This section will provide a detailed explanation of DataARC's influence on the project as well as feedback on the use and functionality of the CI.

The inspiration drawn from the CI during the development of the project reinforced its interdisciplinary character because it facilitated access to a wide variety of data and resources from many disciplines. It also provided the opportunity to contextualise the newly created datasets within a wider North Atlantic data framework through the creation of combinators to connect it to the CI's concept map (see Section 3.2.1 for an in-depth explanation of this process). This enhanced the creation and development and of the project since it urged the creation of a general ontology as well as individual ones for the case studies. It also involved the assistance to meetings in which the structure of the CI, as well as the development and expansion of its concept map, were discussed. This aspect allowed for a better understanding of how the CI integrates datasets and links them in the concept map. It was helpful in the understanding of DataARC's operation, as well as the configuration of an international interdisciplinary collaboration project. Understanding these two was useful during the use of the CI and the creation of combinators. This was used in a later part of the project, to inform the incorporation of new datasets and concepts to DataARC's ontology.

The creation of combinators as a part of the introduction of this project's dataset into DataARC constituted a thought exercise that aided in the analysis process. Creating these required an analysis of the connections, if any, between cairns and the rest of the data available in the CI. It also established the extent of the relationships through the creation of a 'description' and a 'combinator query' further aiding in the understanding of the connection (see Section 3.2.1). This preliminary thought exercise, alongside the framework provided by the project's concept map, was a helpful way to contextualise the results within a wider array of concepts, theory and pre-existing literature. It also allowed for collaboration with an interdisciplinary project in the form of data linking within a CI.

Regarding the concept map, the project's one was created as a part of the ontological design. It was the central part of the connection of theory and data in the form of concepts. Furthermore, it was particularly helpful in connecting the studies to the overall DataARC research and data availability. In particular, DataARC's Concept Map was key in the creation of the project's map as well as in the general analysis of the results since they displayed a wider array of connections to the overall social and environmental framework of the North Atlantic. This became one of the most useful tools of the CI during the creation of the project as well as the analysis process. The extensive concept connections that can be explored through the search tool in DataARC, as well as the project's concept map, sparked the observation of the results from a series of different aspects to see how cairns and their role fit within the landscape, its changes, movement, burials, exchange, farms, rituals, and family units amongst others.

In general, the project benefited from being involved in DataARC. This involved not only included the creation of this master's thesis but also the integration of the datasets created for the project into the CI. The data was linked to the CI through this creation of combinators (see Section 3.2.1). This linking process, as well as the creation of the combinators themselves, required further analysis of the data obtained and its relationship with other data available in the CI. These steps were crucial to ensure the correct integration of the newly created navigational cairn and agricultural cairn datasets. In order to ensure the project fit correctly within its DataARC framework, the CI's concept map was analysed and consulted thoroughly during the developmental phase of the project. Initially, this project's ontology was based around DataARC's. Following an exploration of the CI's Concept Map, a navigational cairn concept map was developed, adding connections and concepts that were not present in DataARC's; the same process was repeated with agricultural cairns (see Section 3.2.1). Finally, these two were re-examined and combined in a more developed Concept Map that exemplified the final ontology of this project (Figure 3.2). Although these thought exercises are not a central part of the masters' thesis, they were very important for the correct development of the project and its later integration within a wider collaborative project such as DataARC, which can be challenging.

### 6.4.1 Feedback on DataARC's use and functionality

As stated in Section 3.1.1, DataARC seeks to facilitate access to a wide array of data within the North Atlantic in order to encourage an interdisciplinary approach to the study and understanding of human-environment dynamics in this area. Although the CI is still in a developmental stage and does not have much of the data available, it has still proven to be a very useful tool both in the development of this project and in the access to data. More detailed feedback on the use of the tool can be found in this subsection.

The creation of this project as well as the methodology was challenging due to the scope of the project and the vast amount of archaeological data in the North Atlantic which is not always easily available to researchers. The exploration of DataARC and the interaction with the experts involved in its development were key for the correct development of this project. The CI allowed for the interaction with a variety of North Atlantic datasets such as tephra and insect SEAD data. Although these were not incorporated into the project, they are available in DataARC and are connected to this project's datasets through the CI's concept map.

Regarding feedback of the CI, DataARC is clear to use and allows its users to develop their knowledge on the North Atlantic's environmental, historical, and archaeological data amongst others. The CI is easy to use with a clear search layout: the searches are based on a time period, a location within the North Atlantic, and/or a concept and its related ideas. As for the results it provides, they are classified into three groups depending on whether they are archaeological, environmental or textual data. Despite a few glitches, which can be attributed to the natural process of the CI's development, the results are always accurate and useful. The results have a brief explanation of their meaning which facilitates their understanding; they also offer links to their original databases which, in some cases, have more detailed explanations.

DataARC can also undertake searches based on only one of the three filters which facilitates its use and allows for broader searches. The ability to undertake searches solely based on one of these characteristics allows the user to obtain more information targeted to expand on the knowledge of one concept, time period, or geographical area. In particular, the most useful ones to this masters thesis were the search by concept and geographical area. These were mostly used during the design and development phases of the project. This type of search allowed for a wider array of results within a delimited area (e.g. Scotland or Iceland) which helped determine data availability. It also helped in the understanding of the CI concepts engagement with each other as well as the data available may interact during the analysis. DataARC also offers the possibility of adding other filters after this preliminary one or two-concept search. This enhances the user experience since it allows them to refine their search without the need to clear the filters and/or re-select them.

On the other hand, the project encountered a few issues with DataARC that could be further developed. In particular, an expansion of the geography of the data offered. Currently, most of the data linked to the CI relates to Iceland: 58,363 results are related to this area of the North Atlantic as opposed to the 2,505 that relate to the rest of the North Atlantic (roughly 6 in North America, 577 in Greenland, 572 in Scotland, 78 in Germany, 542 in Sweden, and 414 in Norway). This is understandable when considering that Iceland is one of the most studied areas in the North Atlantic, in particular by the main contributors to the CI. For example, Jardabók and the

Icelandic Saga Database, are orientated mainly towards Iceland, with the Saga Database having a few textual sources linked to other areas of the North Atlantic. However, other areas of the North Atlantic, such as Scotland, have also been studied thoroughly both in an archaeological and environmental level, and can currently be accessed through online catalogues such as Canmore (H. E. Scotland, 2019) and Scotland's Environment (2019). This type of data can be very useful in the study of North Atlantic human ecodynamics and can be related to much of the data and the concepts present in DataARC. If the CI were to provide a connection to these, it would expand the concept map and present DataARC's with a wider array of environmental, archaeological, and historical data from the North Atlantic, further aiding in human ecodynamic studies. Nevertheless, it is necessary to keep in mind that many of DataARC's data is still being uploaded and that, as it is now, the CI does include almost 600 results, mostly environmental, in Scotland. While the extent of what DataARC can tell us about Iceland is very much, it is still good to keep an eye on other areas of the North Atlantic, especially Scotland which has a lot of information available.

Another issue this project encounter was related to DataARC's Concept Map which lacked certain ideas surrounding cairns. The concept "cairn" itself was not present in the CI's map. This and other sub-concepts of pre-existing ideas in the map were introduced as part of the project (see Section 3.2.2). Considering the vast information cairns can provide about human-landscape interactions, expanding their connections to other data in DataARC through the creation of more combinators would be helpful to researchers looking to approach cairn analysis in the North Atlantic. Other research areas may be missing as well but these can only be discovered, improved, and expanded on through use and user feedback. Overall, the expansion and further development of the Concept Map would be helpful to the CI's users since it enables them to understand the connections between the data results obtained as part of the searches themselves. However, it is important to keep in mind that DataARC is still in a developmental stage, with the constant upload of data and creation of combinators on a regular basis.

To conclude, DataARC was a helpful tool in the creation of this project, in particular when considering that it is still under development. The access to a variety of data was, overall, easy and aided in the creation of the datasets. Nevertheless, the CI would benefit from including more data outside from Iceland, particularly in the Scotland and Greenland regions, and in constantly developing and updating the concept map. The aspects that helped the project the most were the Concept Map and the creation of combinators. This is an advisable and useful tool regardless of whether access to data is required. The CI's Concept Map can be easily explored by users and offers the possibility of interacting with a variety of concepts and their related ideas, more so once it is fully updated and expanded. This becomes a very useful thought exercise which can be key for any researcher; it can help further develop their ideas or observe their data from a different disciplinary perspective which they would not have considered before. Although this is not DataARC's primary use, it is one that should be considered as a way to stimulate conceptual and ontological thought exercises which are key to researchers.

# Chapter 7

## Conclusion

This masters thesis sought to further the study of human ecodynamics in the North Atlantic. In particular, it focused on the analysis of cairns as a way to understand the relationship between people and their surroundings. The project studied two different cairn functionalities and roles, navigational and agricultural, in two different North Atlantic geographical areas, Iceland and Scotland. As such, it was divided into two case studies, each analysing a cairn function with different methodologies and approaches. The case studies included a combination of interdisciplinary methodologies and resources such as the use of computational archaeology and statistical analysis. The multidisciplinary character of the project allowed for the incorporation of different types of data and methodologies to the study. This enabled the creation of new datasets which were analysed using computational archaeology and statistical analysis.

The data used in the project was obtained from a variety of sources, in particular, aerial imagery, and historical, archaeological and geological data. This integration of a diversity of data allowed for the production of two original datasets corresponding to each case study. Case Study One resulted in the creation of a navigational cairn dataset for the southern area of the Westfjords which was later integrated to DataARC. On the other hand, Case Study Two's analysis allowed the development of an interdisciplinary dataset focusing on the relationship between clearance cairns in the south-east of Scotland and the characteristics of the soil they are in. This incorporated geological, geographical, historical, and archaeological data. These datasets are one of the project's main contributions to general knowledge.

The methodology used for the project depended on the case study. The first case study relied on computational archaeology to better analyse the movement of people, mostly through the landscape through the use of LCP. The analysis of aerial imagery combined with the use of GIS tools (LCP, Viewshed, Intervisibility, and distance buffers) proved effective and allowed for the correct analysis and interpretation of the dataset. The change in data availability, quantity and theoretical approach required a different methodology for Case Study Two. It was a combination of geological and statistical analysis to better understand human interactions with the agricultural landscape through the use of clearance cairns. Overall, the methodology used for this case study was also successful in the analysis of the dataset and obtainment of results. Despite this, the project's methodology could have been improved with the refinement of the computational tools used in the first case study, in particular an LCP tailored to the study rather than the standard version. Likewise, a physical exploration of the cairns in their current environment to better understand the changes in their role and in the way they are perceived in the modern landscape. Another aspect that could have improved the analysis of the data is the establishment of a time framework.

The project's general results reinforce the concepts of cairn multifunctionality and emphasise the utility of cairns in the study of human-landscape relations. The first main point of the discussion focuses on cairns' physical representation of the agency of the landscape, highlighting an active and ever-changing interaction between humans and their environment. This is based on the general observation of the two case studies. Firstly, how navigational cairns were positioned in Case Study One supports the theory that they were feature-dependent, they were located in areas where the traveller could no longer be guided by the landscape and required external guidance in the form of a road marker, thus indicating that the roads were not only indicated by route markers but also by the landscape. Case Study Two showed that the landscape reacts to human action instead of remaining static, engaging and reacting to people's interaction with it. The landscape undertaking an active and important role in human tasks such as movement fits well with phenomenological trends of landscape study. The second main point focuses on the reassessment of human-landscape relationships as represented by cairns and the changes in land use. Case Study Two shows how, as a reaction to the effect that excessive agricultural practices (e.g. clearance cairns) fields that were cultivated in the past no longer being cultivated due to erosion risk or infertility. These denote a reassessment in the way humans react to changes in the soil and its composition; changes that their agricultural exploitation and their initial interactions with their landscapes brought along. They are greatly represented by the changing role that these clearance cairns have had in the landscape, where, regardless of their current use, they constitute a formative part of the landscape, representing a type of people-environment interaction in history.

Regarding the specific findings, these are better detailed in the case studies (see Sections 4.5 and 5.5). Case Study One's hypothesis that cairns were used as road markers in Iceland was supported by the interaction between roads and cairns shown in the dataset (see 4.3). Furthermore, as highlighted above, these navigational cairns were positioned in a way that denoted an interaction with the landscape features, acting as a complement to guide people in the areas in which the traveller could lose his or her path (e.g. in turns or areas where visibility through the landscape was poor). One the other hand, Case Study Two aimed to undertake an analysis of the impact of clearance cairns in the Scottish soils as a representation of agricultural practices in the environment. The study observed a correlation between the presence of clearance cairns and high erosion risks in soils while proposing three patterns of sustainability effects based on the dataset's observations. These include an exhaustive exploitation of the landscape leading to non-cultivable soils, an intense use that puts soils in risk of erosion, and more sustainable exploitation that does not seem to have a negative effect on the quality of the soil.

It is equally important to highlight the role of DataARC in this masters thesis. The project's design was highly inspired and informed by DataARC's Concept Map and Ontology. Likewise, the experience of creating combinators to unite the newly created datasets with other data available in the CI provided an opportunity to analyse the data from different angles. This is due to the fact that the creation of combinators encouraged the consideration of alternative relationships between cairns and other theoretical concepts present in the CI's Concept Map. As for the use of the tool itself, it is still under development, but it provides a great link to a wide variety of interdisciplinary data that can be very useful in the study of human ecodynamics in the North Atlantic.

## 7.1 Final Remarks

This project's main conclusion is the relevance of cairns in the study of human ecodynamics. This master's thesis has argued for the use of cairns in the study of human-landscape relationships both through the results obtained and through their contextualisation within the general literature. This is due to their versatility and continued use throughout history in many geographical areas. In fact, one of this project's observations is that cairns also constitute a physical representation of a variety of human-landscape interactions. In this master's thesis, cairns acted as the materialisation of movement and agriculture's engagement with the landscape. Both case studies were able to analyse the interactions between people and their landscape and observe some of the changes in these, thanks to the use of cairns and the information they can provide as sources of data and also when contextualised within the extensive general literature.

Finally, this master's thesis is an example of interdisciplinarity in the study of human ecodynamics and the use of open data. The case studies were based on data from a variety of disciplines, primarily, archaeological, historical, and geological. This interdisciplinary aspect is what has allowed for the creation of complete datasets that yielded a more informed analysis and interpretation. Interdisciplinary approaches are very helpful in the understanding of the human past. This is particularly relevant for the study of human-landscape relationships, due to their nuanced character which makes them complex to understand and investigate. Another aspect that the project has benefited from and contributed to is Open Data which can be a powerful tool in interdisciplinary studies. In line with DataARC's quest to make data accessible to all, this project has mostly used Open Data as sources in the creation of its datasets; examples of this are the geological and soil maps obtained from The James Hutton Institute (Lilly and Baggaley, 2018a-d) and the Macaulay Institute for Soil Research (Soil Survey of Scotland Staff, 1970 and 1984), archaeological data obtained from Canmore (H. E. Scotland, 2019), and Icelandic farm data obtained from Jardabók (Pálsson, 2018). Furthermore, this project has also uploaded its data to Zenodo, an open-access repository (see Roigé Oliver, 2019).

## 7.2 Future Research

Many of this project's areas can be developed into further research to expand both the knowledge of cairns and human ecodynamics in the North Atlantic. Although both case studies can be expanded and further research can stem from the specific cairn types, such as navigational and agricultural cairns (see Sections 4.5 and 5.5), this project has shown that the analysis and comparison of different cairn functionalities can be very beneficial to their understanding and use. Cairns can offer much information regarding the different ways in which humans interacted with the landscape since they have many purposes. Therefore, a study comparing the different roles of cairns in the North Atlantic would provide very useful information regarding how these constructions are used and how this varies in function of the geographical area and/or country. The study could be contained to a specific area while focusing on many of the functionalities of cairns such as agriculture, navigation, ritualistic, burial, marker, or it could expand to other territories and add a spatial contrast.

Another of the aspects that this project has emphasised is the multiphase and multiuse of cairns. It would also be interesting to further develop this by assessing the compatibility of certain functions and their multiuse. For example, this project suggested some navigational cairns in Iceland may be also acting as farm boundary markers, it also acknowledged the possibility of clearance cairns acting as burials. A study further developing the multiple uses of cairns, assessing if cairns are used jointly for specific combinations such as route and boundary marker or agricultural and burial purposes, or if this is a coincidence.

Regarding the replication and expansion of this particular study, there is much room for expansion. The study could be broadened to include all the cairns in Scotland and/or Iceland depending on data availability. The study could also be expanded to other areas outside of the North Atlantic to compare the human-environment relationships through cairns in different regions and continents. This would allow to determine patterns of use and observe wider trends. One of the most important aspects of this study is its interdisciplinary approach which could be incorporated into other aspects of cairn study when expanding these case studies. An example of this would be to consider the visibility changes in the Icelandic changes through time and how this may affect the visibility of route markers, which could be assessed adding meteorological data and field surveys at different times of the year. Overall, it is clear that there is much to be explored in human ecodynamics and, in particular, in all of the information that cairns can provide on this topic.

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# Appendix

All of the data produced during this project is stored in the attached hard drive. This includes the following:

- **"InteractiveCairnDataset":** This is an interactive table produced for Case Study Two. It allows its users to explore the cairns located in each type of soil according to a variety of features, such as compaction risk, erosion risk, current land usage, etc. The user can interact with the table by expanding the fields they are interested in and mininmising the ones they are not, to ease the exploration and understanding of data and avoid the "data overload" that presenting this in a traditional table would represent.
- **"CombinatorsForDataARC":** This file includes the list of combinators created to link the project's dataset to the DataARC's concept map.
- **Metadata:** Both datasets include metadata in PDF format. These can be found in the folder labelled "Metadata".
- **Datasets:** This folder includes the datasets for Case Study One, "NavigationalCairnDataset", and Case Study Two, "ClearanceCairnDataset".
- **Charts R Script:** This folder includes to Open Source documents with a copy of the R script used to process Case Study Two's data.

All of this files can also be accessed through Zenodo, an open-access repository (see Roigé Oliver, 2019).

## Code

The statistical analysis of Case Study Two was done using Colaboratory Python 3 and R Studio Version 1.2.1335. This was used to produce donut charts, bar charts, and a chart to show correlation (Figure 5.23). Below is the code used to produce these broken down with explanations for each command.

### Donut Charts

Done in Google Colaboratory using Plotly.

```
#Imports
import plotly.graph_objects as go

#Erosion Risk
labels = ['Low','Medium','High'] #add label names for each section
values = [34, 370, 188] #number of cairns in each section
```

```
colors = ['#BE4D00', '#003865', '#FFB948'] #establish palette
#create chart and use "hole" to create a donut chart
fig = go.Figure(data=[go.Pie(labels=labels, values=values, hole=.55)])
fig.update_traces(marker=dict(colors=colors)) #create a key with the colours and the section labels
fig.update_layout(title_text="Soil Erosion Risk in Places with Cairns", #create title for the chart
annotations=[dict(text='Cairns Analysed: 593', x=0.5, y=0.5, font_size=12, showarrow=False)])
fig.show() #show the chart


#Soil Types
labels = ['Alluvial Soils', 'Brown Soils', 'Immature Soils', 'Mineral Gleys', 'Mineral Podzols',
'No Data', 'Peat', 'Peaty Gleys', 'Peaty Podzols'] #add label names for each section
values = [25, 171, 12, 69, 193, 5, 25, 45, 47] #number of cairns in each section
colors = ['#5B4D94', '#BE4D00', '#6A8D6C', '#FFB948', '#E9D0CA', '#54433A', '#00B5D1', '#003865',
'#7D2239'] #establish palette
#create chart and use "hole" to create a donut chart
fig = go.Figure(data=[go.Pie(labels=labels, values=values, hole=.55)])
fig.update_traces(marker=dict(colors=colors)) #create a key with the colours and the section labels
fig.update_layout(title_text="Soil Types in Places with Cairns", #title for the chart
                  annotations=[dict(text='Cairns Analysed: 593', x=0.5,
                  y=0.5, font_size=12, showarrow=False)])  #add number of analysed cairns in the centre
fig.show() #show the chart


#Soil Drainage
labels = ['Freely/Imperfectly Drained', 'Freely Drained', 'Freely Drained Below Iron Pan',
'Imperfectly Drained', 'No Data', 'Poorly Drained', 'Very Poorly Drained',
'Undifferentiated Drainage Levels'] #add labels for each section
values = [3, 287, 41, 49, 111, 59, 23, 20] #number of cairns in each section
colors = ['#54433A', '#FFB948', '#6A8D6C',  '#7D2239', '#003865', '#BE4D00', '#5B4D94', '#E9D0CA'] #palette
#create chart and use "hole" to create a donut chart
fig = go.Figure(data=[go.Pie(labels=labels, values=values, hole=.55)])
fig.update_traces(marker=dict(colors=colors)) #create a key with the colours and the section labels
fig.update_layout(title_text="Soil Drainage in Places with Cairns", #title for the chart
                  annotations=[dict(text='Cairns Analysed: 593', x=0.5,
                  y=0.5, font_size=12, showarrow=False)]) #add number of analysed cairns in the centre
fig.show() #show the chart


#Current Land
labels = ['Field', 'Forested Area', 'Roadside', 'Uncultivated Area'] #add label names for each section
values = [187, 144, 28, 234] #number of cairns in each section
colors = ['#FFB948', '#003865', '#6A8D6C', '#BE4D00'] #establish palette
#create chart and use "hole" to create a donut chart
fig = go.Figure(data=[go.Pie(labels=labels, values=values, hole=.55)])
fig.update_traces(marker=dict(colors=colors)) #create a key with the colours and the section labels
fig.update_layout(title_text="Current Land Use in Places with Cairns (as seen in Areal Imagery)",
                  annotations=[dict(text='Cairns Analysed: 593', x=0.5,
                  y=0.5, font_size=12, showarrow=False)]) #add number of analysed cairns in the centre
fig.show() #show the chart


#Cairnfield Pertinance
labels = ['No', 'Yes'] #add label names for each section
values = [327, 266] #number of cairns in each section
```

```
colors = ['#FFB948', '#003865'] #establish palette
#create chart and use "hole" to create a donut chart
fig = go.Figure(data=[go.Pie(labels=labels, values=values, hole=.55)])
fig.update_traces(marker=dict(colors=colors)) #create a key with the colours and the section labels
fig.update_layout(title_text="Percent of Study Cairns that are part of a Cairnfield", #add chart title
                  annotations=[dict(text='Cairns Analysed: 593', x=0.5,
                  y=0.5, font_size=12, showarrow=False)]) #add number of analysed cairns in the centre
fig.show() #show the chart
```

## Bar Charts

Done in R Studio using ggplot2.

```
install.packages("ggplot2")
library(ggplot2)
library(wesanderson)

#Erosion Risk
Soil <- c("Alluvial","Brown","Immature","Mineral Gleys","Mineral Podzols","Peat","Peaty Gleys",
"Peaty Podzols", "Lochs", "No data") #Labels for X axis
erosion <- c("No data","Low Erosion Risk","Medium Erosion Risk", "High Erosion Risk") #Colour labels
palette2 <- c("#E32636", "#3B7A57", "#FFBF00", "#FF7E00") #Establish palette
par(mar = c(7, 4, 2, 2) + 0.2)
counts <- table(dataset$EROSION, dataset$SOIL) # create table to extract data from
#Set data, establish palette, axis labels, position of bars and labels, and sizes of chart
barplot(counts, main="Cairn Distribution by Soil Type and Erosion", names.arg = Soil,
las = 2, col = palette2, ylab = "Number of Cairns", beside=TRUE, ylim = c (0, 150))
legend("topright", erosion, cex = 1.3, fill = colors) #Create and position legend for colours

#Land Use
Soil <- c("Alluvial","Brown","Immature","Mineral Gleys","Mineral Podzols","Peat","Peaty Gleys",
"Peaty Podzols", "Lochs", "No data") # Labels for X axis
erosion <- c("Field","Forested Area","Roadside", "Uncultivated Area") # Labels for colours
palette1 <- c("#E32636", "#3B7A57", "#FFBF00", "#FF7E00") # Establish palette
par(mar = c(7, 4, 2, 2) + 0.2)
counts <- table(dataset$LAND, dataset$SOIL) # create table to extract data from
#Set data, establish palette, axis labels, position of bars and labels, and sizes of chart
barplot(counts, main="Cairn Distribution by Soil Type and Current Land Use", names.arg = Soil,
las = 2, col = palette1, ylab = "Number of Cairns", beside=TRUE, ylim = c (0, 80))
legend("topright", erosion, cex = 1.3, fill = colors) #Create and position legend for colours

#Cairnfield Pertinence
Soil <- c("Alluvial","Brown","Immature","Mineral Gleys","Mineral Podzols","Peat","Peaty Gleys",
"Peaty Podzols", "Lochs", "No data") # Labels for X axis
erosion <- c("Single Cairn","Cairnfield") #Labels for colours
par(mar = c(7, 4, 2, 2) + 0.2)
counts <- table(dataset$CAIRNFIELD, dataset$SOIL) # create table to extract data from
#Set data, establish palette, axis labels, position of bars and labels, and sizes of chart
barplot(counts, main="Cairn Distribution by Soil Type and Erosion", names.arg = Soil,
las = 2, col = c("red", "#3B7A57"), ylab = "Number of Cairns", beside=TRUE, ylim = c (0, 120))
legend("topright", erosion, cex = 1.3, fill = colors) #Create and position legend for colours

#Soil Drainage
Soil <- c("Alluvial","Brown","Immature","Mineral Gleys","Mineral Podzols","Peat","Peaty Gleys",
"Peaty Podzols", "Lochs", "No data") #Labels for X axis
```

```
erosion <- c("No data","Undifferentiated Drainage Class","Very Poorly Drained", "Poorly Drained",
"Imperfectly Drained", "Freely Drained Below Iron Pan", "Freely Drained") #Labels for colours
palette3 <- c("#E32636", "#3B7A57", "#FFBF00", "#FF7E00", "#7CB9E8", "#AB274F", "#C46210") #Palette
par(mar = c(7, 4, 2, 2) + 0.2)
counts <- table(dataset$EROSION, dataset$SOIL) # create table to extract data from
#Set data, establish palette, axis labels, position of bars and labels, and sizes of chart
barplot(counts, main="Cairn Distribution by Soil Type and Drainage", names.arg = Soil,
las = 2, col = palette3, ylab = "Number of Cairns", beside=TRUE, ylim = c (0, 150))
legend("topright", erosion, cex = 1.0, fill = palette3) #Create and position legend for colours


#Soil Compaction
Soil <- c("Alluvial","Brown","Immature","Mineral Gleys","Mineral Podzols","Peat","Peaty Gleys",
"Peaty Podzols", "Lochs", "No data") #Labels for X axis
erosion <- c("No data", "Low Risk Topsoil and Very Vulnerable Subsoil", "Low Risk Topsoil
and Extremely Vulnerable Soils", "Low Risk Topsoil and Shallow Subsoil Soils", "Medium Risk
Topsoil and Moderately Vulnerable Subsoil", "Medium Risk Topsoil and Very Vulnerable Subsoil",
"Medium Risk Topsoil and Extremely Vulnerable Subsoil", "Medium Risk Topsoil and Shallow
Subsoil Soils", "High Risk Topsoil and Not Particularly Vulnerable Subsoil", "High Risk Topsoil
and Moderately Vulnerable Subsoil", "High Risk Topsoil and Very Vulnerable Subsoil", "High Risk
Topsoil and Extremely Vulnerable Subsoil", "Organic Topsoil and Moderately Vulnerable Subsoil",
"Organic Topsoil and Very Vulnerable Subsoil", "Organic Topsoil and Extremely Vulnerable Subsoil")
palette <- c("#FF7E00", "#FFBF00", "#3B7A57", "#D3212D", "#C46210", "#AB274F","#996600", "#873260",
"#FAF0BE", "#BEC8FA", "#0080FF", "#00416A", "#6B2900", "#0D98BA") # Establish palette
par(mar = c(7, 4, 2, 2) + 0.2)
counts <- table(dataset$COMPACTION, dataset$SOIL) # create table to extract data from
#Set data, establish palette, axis labels, position of bars and labels, and sizes of chart
barplot(counts, main="Cairn Distribution by Soil Type and Compaction Risk", names.arg = Soil,
las = 2, col = palette, ylab = "Number of Cairns", beside=TRUE, ylim = c (0, 140))
legend("topright", erosion, cex = 0.82, fill = palette) #Create and position legend for colours
```