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Northern Cereals – New Opportunities – A project supported by
The Nordic Atlantic Cooperation (NORA)

Status of Cereal Cultivation in the North Atlantic Region

Matis Report

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Report summary

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Titill / Title	**Status of Cereal Cultivation in the North Atlantic Region** / Staða kornræktar í löndum við norður Atlantshaf		
Höfundar / Authors	Ólafur Reykdal, Þórdís Anna Kristjánsdóttir, Jónatan Hermannsson, Peter Martin, Sigríður Dalmannsdóttir, Rólvur Djurhuus, Vanessa Kavanagh, Aqqalooraq Frederiksen		
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Ágrip á íslensku:	Í skýrslunni er gerð grein fyrir úttekt á kornrækt í löndum við Norður Atlantshaf. Skýrslan er hluti af verkefninu Norrænt korn – Ný tækifæri sem styrkt er af NORA-sjóðnum. Þátttakendur eru Matís, Landbúnaðarháskóli Íslands, Bioforsk Nord í Noregi, Landbúnaðarmiðstöðin í Færeyjum, Landbúnaðarstofnunin í Orkneyjum og Forestry & Agrifoods Agency á Nýfundnalandi. Sambandi hefur einning verið komið á við Landbúnaðarþjónustuna í Grænlandi. Svæðin sem voru til skoðunar eru mjög breytileg með tilliti til þarfa kornræktar. Breytileiki í hitastigi og úrkomu geta skapað vandamál við kornræktina. Þegar litið er á svæðin í heild, er fjöldi kornbænda um 1.100 og rækta þeir um 40.000 tonn af korni á ári á um 9.400 hekturum. Mesta kornframleiðslan var í Orkneyjum. Mögulegt er að auka kornframleiðsluna, sérstaklega á Íslandi, Nýfundnalandi og í N-Noregi.		
Lykilorð á íslensku:	*Kornframleiðsla, Ræktunarskilyrði, Kornnotkun, Framtíðarmöguleikar*		
Summary in English:	This review of Cereal Cultivation in the North Atlantic Region is a part of the project Northern Cereals – New Opportunities supported by the Nordic Atlantic Cooperation (NORA). Participants are Matis – Icelandic Food and Biotech R & D, The Agricultural University of Iceland, Bioforsk North Norway, Agricultural Centre Faroe Islands, Agronomy Institute Orkney Scotland and Forestry & Agrifoods Agency, Newfoundland and Labrador, Canada. Cooperation has also been established with The Agricultural Consulting Services in Greenland. Partner regions are very diverse with respect to conditions for cereal production. Temperature and rainfall are very variable and therefore a challenge for cereal producers. About 1,100 farmers grow cereals on 9,400 ha in the partner regions. Yearly cereal production is estimated to be about 40,000 tons. Greatest production occurs in Orkney. It is possible to increase the cereal production in most regions, particularly in Iceland, Newfoundland and N-Norway.		
English keywords:	*Cereal production, Conditions for cultivation, Utilization, Future possibilities*		

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1. Summary

A review of the status of cereal cultivation in the North Atlantic Region is presented in this report. The review is a part of the project Northern Cereals – New Opportunities supported by the Nordic Atlantic Cooperation (NORA). Participants are: (1) Matis – Icelandic Food and Biotech R & D. (2) Agricultural University of Iceland. (3) Bioforsk North, Norway. (4) Agricultural Centre, Faroe Islands. (5) Agronomy Institute, Orkney, Scotland. (6) Forestry & Agrifoods Agency, Newfoundland and Labrador, Canada. Cooperation has been established with The Agricultural Consulting Services in Greenland, which has participated in the project. Full participation is expected during the second year of the project.

Conditions for cereal cultivation

Partner regions are very diverse with respect to conditions for cereal production. In some regions cereal production is well established (Orkney, Iceland) while in others the production is being developed (Newfoundland, N-Norway) or experiments are being carried out (Faroe Islands, Greenland). Cooperation is very valuable under these circumstances.

The regions that are being studied are found from 47° north (southern part of Newfoundland) up to 71° north (northern part of N-Norway). In Greenland the southernmost part of the country is best suited for agriculture and this part of the country is south of Iceland.

The regions differ with regard to rain and temperature. Rainfall is considerable for most locations and this is unfavourable for cereal production especially during autumn. Temperature is very variable and, again, a challenge for cereal producers as low temperatures can delay both planting and grain ripening.

Growing Degree Days (GDD) are a measure of heat and time (days) over the whole growing season from sowing to harvesting. The highest GDD occurs in Orkney and the lowest in Iceland, with Norway, Faroe Islands and Newfoundland in between. Data for Greenland is not available yet. Typical sowing and harvesting times differ very much between regions. The earliest sowing time is for Orkney.

Cereal production

Iceland and Orkney have the largest areas under cereals but the greatest production occurs in Orkney (21,400 tons barley 2012). Iceland is second for production (16,800 tons barley 2012). Small

amounts are harvested in North Norway and Newfoundland. In the Faroe Islands and Greenland there is presently no cereal production.

About 1,100 farmers grow cereals on 9,400 ha in the partner regions. Yearly cereal production is estimated to be about 40,000 tons. Average grain yield is normally in the range 3-5 tons/ha. Cereal production in Iceland has increased considerably during the last 10 years. Also in N-Norway barley cultivation is increasing in some areas within the region.

It is possible to increase the cereal production in most regions. In Iceland it has been estimated that annual production of cereal (barley) could be increased from about 15,000 tons to 50,000 tons per year. Most of the cereals produced in the North Atlantic Regions are used for feed.

2. Introduction

Agriculture in the North Atlantic area is characterized by a cool and short growing season. However cereal cultivation has been successful in some areas in recent decades because of progress in breeding and increased experience and know-how among farmers. Climate change has affected the area and higher temperatures have both made the production more reliable and increased yield. Until now, the cereal production has been used mostly for feed.

Growing cereals in the cool climate of northern areas has both advantages and disadvantages. Among the advantages are the generally low levels of contaminants in the harvest and the products are therefore expected to be wholesome. Insects and other pests are relatively few and use of pesticides is limited. The relatively low temperature means that some of the mycotoxin producing moulds do not survive. Global warming is of concern as it may bring new pests and diseases to the area. Research is therefore needed to ensure food safety. Food safety should be the cornerstone of cereal production in northern areas. Also cereal production contributes to food security in the northern areas where agriculture mainly delivers animal products. It is a disadvantage that cereals in most northern areas are usually harvested before they are fully mature and consequently the grain contains too much water for storage. For food and drink uses, it is therefore necessary to dry the grain after harvest for proper storage and high quality.

Cereals are important in feed concentrates, particularly for milking cows. Cereals are also raw materials for a high proportion of foods that people consume in Europe. The bakery industry is based on cereals and barley is an important raw material for the production of alcoholic beverages.

The Nordic Joint Committee for Agricultural and Food Research (NKJ) has introduced The Nordic Bioeconomy Initiative (2013) on bio-based society in the Nordic countries. The initiative´s objective is to enhance and facilitate Nordic cooperation within research and policymaking between the primary industries and food sector in order to assist to develop the Nordic societies into sustainable bio-based economies. The Nordic Bioeconomy Initiative puts particular emphasis on the Arctic region. There are strong indications that climate change will increase the potential for food production in the Nordic countries and also increase the pressure to expand food production at higher latitudes.

Some of the growth potential and advantages that can be anticipated in partner countries from increased cereal production are demonstrated by a report from the Icelandic Ministry of Industries

and Innovation (2011). The report concludes that annual production of cereal in Iceland could be increased from about 15,000 tons to 50,000 tons per year. This increased production would result in: (1) Economic advantages because domestic production strengthens currency reserves and utilises domestic resources. (2) New and innovative ways of cultivating the land. (3) More stable business environment since fluctuations in world market prices are avoided. (4) Improved food security as Iceland is dependent on the import of many foodstuffs and feed for livestock. With increased cereal production domestic demand can be met for feed carbohydrates which will also contribute to the sustainability of meat and milk produce. (5) Innovation and job creation. More diversified agriculture will support conditions for growth around the country as well as increased numbers of jobs in rural areas.

Cereal cultivation in the North Atlantic region

Cereal cultivation differs between the countries in the North Atlantic region. In Orkney, Iceland and Newfoundland cereal cultivation is well established while Faroe Islands and N-Norway are restarting cultivation. Cereal cultivation in Greenland is in an experimental phase. Barley is the most important cereal, particularly in the northernmost regions. The following paragraphs summarize the situation in Iceland, Faroe Islands, N-Norway, Orkney and Newfoundland.

Iceland. Barley was grown in Iceland from the time of settlement but was discontinued through the middle ages. Barley has now been grown uninterrupted in Iceland for about 50 years. Barley cultivation has increased considerably during the last 20 years and the harvest was 12 – 16 thousand tons per year in the period 2009-2012. In the year 2009 the number of farmers growing barley was 470 and barley fields were about 4,800 hectares. Some farmers have been successful in growing wheat and even using wheat for small scale bread baking. Oats and rye have also been grown successfully on a small scale.

The special climatic conditions mean that the grain needs to be dried after harvest to make it a viable commercial commodity. A few small scale drying facilities are available for farmers, most of which are located on farms. Farmers have also the possibility to process silage (wet feed) for cows.

Most of the barley production is used as concentrates for cows and for pigs to a limited extent. In recent years the interest in barley as food has increased but still only a very small proportion of the production is used for food. Three farmers are marketing cereals on the consumer and food industry markets. Eymundur Magnússon, a farmer at Vallanes, East-Iceland, has for about 25 years sold barley products in supermarkets (Mother Earth, http://www.vallanes.net). Ólafur Eggertsson, a farmer at Þorvaldseyri, in close vicinity to the Eyjafjallajökull glacier South-Iceland, has for a few years sold

barley flour to the baking industry and breakfast cereal industry (http://www.thorvaldseyri.is). Haraldur Magnússon, a farmer at Belgsholt West-Iceland has supplied barley to the brewery Ölgerðin Egill Skallagrímsson, which has used it unmalted through enzyme technology.

North-Norway. Barley was grown in North-Norway in the old days but most of the old barley varieties used at that time have apparently been lost. Barley cultivation is now limited in Northern Norway and the skill to cultivate barley has been lost in some areas. However, a few farmers in Alta and South Varanger in Finnmark, in Inner-Troms and parts of Lofoten cultivate barley for animal feed production. At the Helgeland coast in Nordland County, there are farmers growing barley for full maturity and some of those farmers are experimenting with their own breweries. Most of these farmers are localized in the municipality of Sømna. A few breweries are operated in North-Norway, Mack in Troms being the largest company. There is an increasing interest in N-Norway in microbreweries. The farmers growing barley in N-Norway are both organic and conventional farmers. The short growing season is a limiting factor for barley cultivation. Therefore, an extended growing season as an effect of climate change, may create new opportunities for annual crop production in N-Norway. Likewise, use of new varieties with early maturation could improve the cultivation and increase yields.

Faroe Islands. Cereals have not been grown in the Faroe Islands for more than 50 years, and all cereals for feed and food are now imported. However, farmers grew barley for centuries and baked their own bread. Normally the barley did not fully ripen outdoors but was harvested and then stored indoors for drying, and subsequently threshed indoors. All the work was carried out by hand. As the labour and money moved from agriculture towards fisheries and fish industries in the first half of the 20th century, barley production in Faroe Islands gradually decreased and finally came to an end about 50 years ago. The end of barley cultivation was also a result of competition from cheaper imports from areas with a more suitable climate and more efficient production due to modern machinery for cultivation and harvesting.

In the Faroe Islands it will be important to restart cereal cultivation, especially barley. In addition to brewing and baking it is important to introduce Faroese barley as feed on dairy farms similar to what Icelandic farmers have done in recent years. Farmers growing barley in the Faroe Islands will face many challenges and one of them will be how to cope with the high precipitation at the end of the growing season.

Orkney, Scotland. For hundreds of years, Bere, a barley landrace was grown for milling, malting and as animal feed on Orkney. During the 20th century Bere was almost completely displaced by modern barley varieties (about 4000 ha are now grown annually) which are harvested at a high moisture

content, treated with a preservative and used for animal feed. Oats were commonly grown as an animal feed and for human consumption on Orkney from the Iron Age but there has been a dramatic decline in the area grown since the 1940's (when tractors replaced horses on the farm) and now only about 100 ha are grown, almost entirely for animal feed. Very little wheat has ever been grown in Orkney. The Agronomy Institute (AI) is developing several new higher value markets for Orkney-grown cereals and has also tested a number of different varieties. Amongst these, North European varieties have often been very suitable. Some of the AI's most successful cereal projects have included collaborations with distilleries (malting barley and Bere), a brewery (Bere) and a local water mill (oats and wheat) which produces stone ground flour. The main challenges restricting progress are a lack of suitable varieties, grain quality for some end uses and the high cost of small-scale grain drying.

Shetland, Scotland. As in Orkney, cereal cultivation in Shetland started in the Neolithic and expanded considerably during the Iron Age and Norse settlement, especially in coastal areas. In Shetland, however, the harsher climate and poorer soils create greater challenges for cereal cultivation so that the islands have seldom been self-sufficient in cereals, even for animal feed. During the 20th century there was a gradual decline in the area of cereals grown – from about 3400 ha in 1912 to about 70 ha in 2000. The reasons for this decline are complex but include an expansion of sheep farming and decline in cattle rearing. This has partly been driven by a need for easier farm management systems as many small farmers (crofters) have taken on jobs away from their crofts. Cereal cultivation in Shetland is still important, however, in the south of the mainland where farms and fields are largest and the soils and climate are more conducive for earlier planting and harvesting. These are also the areas where it is easiest to use larger farm machinery. Although there are a number of potential higher value outlets for locally grown cereals (bakeries, breweries and plans for a distillery), the majority of the cereal crop is used for animal feed. The main cereals currently grown are barley (c. 60 ha) and oats (c. 25 ha).

Newfoundland, Canada. The agriculture/agrifoods sector of Newfoundland and Labrador provides direct and indirect employment for 4000 persons on farms and in the food and beverage manufacturing sectors. Value of farm production has grown in 27 of the last 30 years with sales of $111 million in 2008, while Agrifood processing reached $501 million. The dairy industry has led this growth with expansion on farms and in dairy processing of value-added milk products such as cheese and novelty ice creams. Higher energy costs are having an effect on agriculture operations, with significant impacts on livestock production. These impacts are direct, such as equipment operations, and indirect, such as higher feed costs due to the demand on grain for ethanol.

Historically barley had been grown on the island, however over time Newfoundland became dependent on the rest of Canada for its grain requirements. In today's economy, increasing fuel prices and biofuel diversions has meant that the cost of importing grain has climbed to where it is no longer economical to import substantial quantities. Unfortunately, there are no commercial cereal operations in Newfoundland to supply its livestock industries. The province's short season ends with a rainy period that makes harvesting dry grain problematic. A high moisture grain system appears promising to accommodate these challenges allowing earlier harvest at higher moisture contents. Newfoundland is in the beginning stages of a cereal program which will be assessed for animal feed production.

A NORA project on northern cereals

In the autumn 2013 NORA funded a project on new opportunities for northern cereals. Partners come from Iceland, Faroe Islands, N-Norway, Orkney and Newfoundland (Canada). Connections have also been established with Greenland. The purpose of the project was to support economic growth and sustainable communities in rural northern regions by developing cereal production and utilization. The project provides a unique opportunity to obtain a range of varieties well-suited to north Atlantic conditions and for these to be tested locally for growth and quality characteristics. The project has established cooperation in the field of cereal research, production and utilization in the NORA region. In the project, cereals were confined to grains obtained from barley, wheat, rye and oats. Barley was prioritised because it is well-suited to northern regions.

The NORA region has the potential to produce cereals for feed and food and it is important to use this potential to create jobs and enhance economic growth in the area. In Iceland, for example, cereal production has been identified as the agricultural sector that has the most potential for expansion. Regional use of cereal grain crops for food and feed will mean less reliance on imported grain. It therefore has the potential to reduce carbon footprint and can support policy makers to obtain the overall goal of the future bio-economy by incrementally decreasing the use of petroleum based products.

Expanding the cultivated area of cereals into new regions will enlarge the market for cultivars that are bred specifically for the unique environment in the north and this will secure such breeding efforts and give better economic returns.

Tourism is increasing sharply in various northern areas. This means that more food is needed in regions visited by tourists and here regional products are of special interest. This opens up new opportunities for local farmers and companies to increase their production with benefits for the

regional economy. Foods from northern cereals have a healthy image because of low contaminant levels and few pests. Introduction of northern cereals for local foods and new Nordic food will increase the demand for cereals.

Regional markets for cereal products are not well developed in the northern areas. Development of regional niche markets will be valuable and would increase economic benefits for local communities. Introducing new cereal varieties at the regional level would increase the possibilities of developing new products.

Partners

The following partners are involved in the NORA project on new opportunities for northern cereals. Cooperation has started with Greenland Agricultural Consulting Services which will become a full partner during the second year of the project.

Matis – Icelandic Food and Biotech R&D (http://www.matis.is) coordinates the project. Matis is a non-profit institute under the Ministry of Industries and Innovation. Matis employs about 100 people, and has grown from approximately 70 employees in 2007. The role of Matis is to engage in food research, innovation and safety to increase the value of food through research, development, dissemination of knowledge and consultancy. Matis' multidimensional activities include innovation and R&D regarding consumers, food analysis (chemical analysis and microbiology), food processing, biotechnology and genetics. In recent years Matis has been developing knowledge and food production clusters all around Iceland to support local food production. Matis has helped farmers and companies to develop products and also participated in cereal development projects with the Agricultural University of Iceland.

Agricultural University of Iceland (AUI, Landbúnaðarháskóli Íslands, http://www.lbhi.is) is an educational and research institution in the field of agriculture, land resources and environmental sciences under the Ministry of Education, Science and Culture. The main focus is on natural sciences, i.e. natural history, the conservation and sustainable use of land and animal resources, including traditional agriculture, horticulture and forestry, environmental and landscape planning, restoration sciences, and sustainable development. The overall role of the university is to pursue high quality education in the academic fields supported by competitive nationally and internationally oriented research programs. AUI plays an important role in its local community and for the country as a whole as it is a vital pillar for rural development in Iceland. It has a unique position among universities in Iceland; it has a number of sites distributed in rural communities around the country and thus offers a close proximity to the people it serves and the natural resources on which they base their

livelihood. The university has a long history in cereal research and has helped farmers to improve their cultivation techniques

Bioforsk North, Norway (http://www.bioforsk.no). Bioforsk, the Norwegian Institute for Agricultural and Environmental Research, is a national research institute with headquarters in Ås. Bioforsk North, the Arctic Agriculture and Land Use Division with headquarters at Holt in Tromsø, is representing the three northernmost counties in Norway; Nordland, Troms and Finnmark, stretching from latitude 65°N to 71°N, including both coastal and continental climates. Bioforsk North, focuses on arctic agriculture and conducts research and development activities linked to northern growing conditions, food products and recreational services with a distinct northern profile**.** Bioforsk North works to document how the special climate conditions in Northern Norway affect taste, healthy compounds and other qualities in the products. There is also a focus on northern production systems and the interaction between business development and environmental considerations. Through the Holt Division of the Northern Norway Competence Centre in Tromsø, Bioforsk North is laying the foundation for development and innovation.

Agricultural Centre, Faroe Islands (AC, Búnaðarstovan, http://www.bst.fo) is an institution belonging to the Ministry of Fisheries and Agriculture. Different services for farmers are located at the Centre: (1) Administration of financial agricultural support for farming. (2) Agricultural consultancy. (3) Education in agriculture. (4) Research in Agriculture and Horticulture. For this purpose the Centre has access to cultivated land for field trials as well as uncultivated areas for animal grazing. Experiments are carried out in collaboration with local farmers on their fields.

Agronomy Institute, Orkney College (University of the Highlands & Islands). The Agronomy Institute (AI, http://www.agronomy.uhi.ac.uk) is a research centre of the University of the Highlands and Islands (UHI) and is based at Orkney College, one of the academic partners in UHI. The AI works with growers and end-users to develop crops, plant products and their markets in Scotland's Highlands and Islands region. The AI has access to land and machinery for running agricultural field trials and has good collaborative links with local growers, cereal stakeholders (including distilleries, a brewery, water mills, bakeries and a seed merchant) and the Orkney office of SAC Consulting which is the main advisory organisation for farmers in Scotland. Apart from cereals, the AI is also active in research on crops for biomass and natural products. AI has experience in developing local markets for cereals and has access to research and quality criteria which have been developed in the UK.

Agrifoods Development Branch -Forestry & Agrifoods Agency (Government of Newfoundland and Labrador). The Agrifoods Development Branch of the Forestry and Agrifoods Agency (http://www.nr.gov.nl.ca/nr/agrifoods), is responsible for promoting the continued development, expansion and diversification of competitive and sustainable primary and value-added agriculture and agrifoods businesses. The Branch provides programs and services as follows: (1) Technical advice on the production, processing and marketing of food and other agricultural products in a manner that maximizes profits while also acting responsibly towards food safety, animal welfare and sound land and environmental stewardship. (2) Professional veterinary assistance in the prevention and treatment of disease as well as the avoidance of residues in food products. (3) Analytical services from the Animal Health Laboratory and the Soil, Plant and Feed Laboratory. (4) Operation of mandatory food safety programs. (5) Support of research into new agricultural products and practices, as well as animal diseases of economic and public health importance. (6) Funding opportunities to encourage growth and diversification in the agrifoods industry.

The Agricultural Consulting Services, Greenland (http://www.nunalerineq.gl/english/raad/index-raad.htm). The Agricultural Consulting Services are an institution with relations to the Farmers' Association. The institution is under the Greenland Department of Fisheries, Hunting and Agriculture. The Consulting Services aim to support Greenland´s agricultural development. The institution serves all sectors of agriculture in Greenland. Among the tasks are research in agriculture, horticulture and forestry, public relations and cooperation with foreign institutions. The Agricultural Consulting Services are located in Qaqortoq, South Greenland.

3. Conditions for cereal cultivation

Locations

The North Atlantic (NORA) Region includes Greenland, Iceland, Faroe Islands and 9 coastal counties of Norway. All these countries participate in the NORA project *Northern Cereals – New Opportunities*. Two participants come from countries outside the NORA Region: Orkney (Scotland) and Newfoundland and Labrador (Canada). Table 1 gives information on the regions that are reviewed in this report. From Norway the three northernmost counties participate: Nordland, Troms and Finnmark. The participant from Orkney will include studies in Shetland. In Scotland, Orkney and Shetland are often called "the Northern Isles". The participation of Faroe Islands, Shetland and Orkney provide an interesting comparison since all have maritime climate and stretch from 59°north to 62° north. Although the largest part of Greenland is ice, the ice-free region is 410,449 km^2 (Statistics Greenland 2013), larger than the other regions reported in Table 1. The parts of Greenland that are best suited for agriculture are the regions around the villages Qassiarsuk and Qaqortoq, located between 60° north and 61° north, which is south of Iceland. The region of Newfoundland and Labrador is the most easterly province of Canada.

As seen in Table 1 the regions under investigation are very variable due to geographical locations. Cultivation of cereals in these regions is a great challenge, principally for climatic reasons considered in the next section.

Table 1. Information on regions.

Region	Total area of region km^2	Area of arable land km^2	Geographical location
Faroe Islands	1,400		62° north
Greenland region[1]	600,000		Between 60° and 61° north
Iceland	103,000	3,000	Between 63° and 66° north
Newfoundland	405,212		Between 47° and 51° north
N-Norway	113,093	900	Between 65° and 71° north
Orkney[2]	990	256.1	59° north
Shetland[2]	1,466	13.0	60° north

[1] Approximate area of the regions around the villages Qassiarsuk and Qaqortoq. The total area of Greenland is 2,166,086 km^2.
[2] Orkney and Shetland arable areas are the total areas of crops, fallow and grass younger than 5 years (Scottish Government, 2013).

Weather conditions – Rainfall and temperature

Data for rainfall and temperature for selected locations are reported in tables 2 and 3. Rainfall is high in most locations and this is unfavourable for cereal production especially during autumn when it can create harvesting problems. Temperature is very variable and, again a challenge for cereal producers as low temperatures can delay both planting and grain ripening.

Iceland is warmed by the Gulf Stream and the climate is described as maritime cold-temperate to sub-arctic. The annual rainfall ranges from 500 mm north of Vatnajökull to over 2000 mm in South Iceland (Arnalds et al., 2001). Cereals are produced in different districts of the country. Weather conditions are different between districts and change from one year to the next. Generally the best conditions for cereal production are in South Iceland and inland valleys in North Iceland. Storms during autumn are often the most problematic conditions farmers have to deal with. The average sowing time is in the first week of May.

In North Norway there is a high climatic variability within the region which stretches from latitude 65˚N to 71˚N and includes both coastal and continental climates. The precipitation is much higher by the coast, but is very low in the northernmost county of Finnmark where a large part of the area has a more continental climate. There is also a big climatic difference between years.

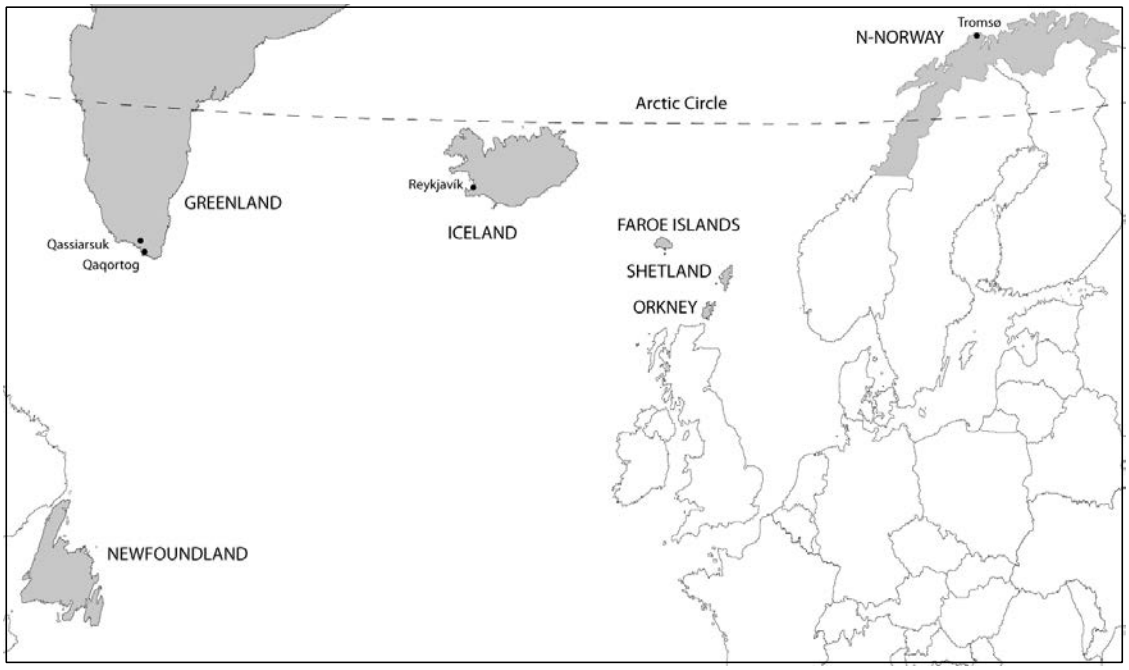

Figure 1. The North Atlantic Region, together with Newfoundland, Orkney and Shetland.

In North Norway it is of most importance to be able to sow early in spring. In Helgeland it is in late April/early May, in Finnmark it is late May or first week of June.

Due to the cold growing season in Faroe Islands sowing should be carried out as early as possible. The great challenge related to this is the precipitation. There is normally heavy rainfall during winter but in April it normally becomes drier, some years earlier than others. The earliest possible date for sowing cereals would be between the beginning of April and mid-April, but in most years this is not before about April 20th. In some years it may not be possible before the beginning of May and in the worst case even later.

Harvesting should be done as early as possible. As for sowing in spring, rainfall often causes difficulties during harvesting. As seen in Table 2, the precipitation in September is considerably higher than in August. So it would be preferable to sow early cultivars that could be harvested in August rather than September.

There are no local climate records at the farms where research will be carried out, but the precipitation at the farms is similar to precipitation in Tórshavn and the temperature is similar to temperature measured at The Agricultural Centre in Kollafjørður. Data for Tórshavn were used for Table 2 and data for Kollafjørður for Table 3.

Sowing in Orkney starts normally between early- and mid-April and is completed by the end of April/early-May. There have been some recent years where it has been possible to start planting in late March. Earlier planting is not usually possible because of wet soil conditions.

For dried grain, harvesting should be completed in September as the weather deteriorates in October (rain and wind). Some early varieties of barley can sometimes be harvested in late August. Oats are later to be harvested than barley and this is usually between mid-September and mid-October. Spring wheat (early North European varieties) have usually been harvested from late September to mid-October. If cereals are treated with preservative (propcorn), they can be harvested earlier at a higher moisture content.

Shetland. As a result of wetter winters, soils dry out later in Shetland so that planting also tends to be slightly later than in Orkney. Similarly, lower temperatures in the growing season mean that cereals mature more slowly, resulting in a slightly later harvest than Orkney. But, in the south of Shetland, where larger scale arable farming takes place, farms on sandy soils can be planted and harvested earlier than elsewhere on the island (e.g. 1-14 April and 7-14 September). Elsewhere planting can be in the last week of April or first week of May and harvesting from mid-September to mid-October.

Table 2. Rainfall (total per month) in different regions. Mean for the years indicated.

Month	S-Iceland Reykjavik 2003-2012	N-Iceland Akureyri 2003-2012	N-Norway 2003-2012	W-Newfoundland Deer Lake 2002-2012	E-Newfoundland St. John's 2002-2012	Greenland 2006-2013	Faroe Islands Tórshavn 2003-2013	Shetland Lerwick 2003-2012	Orkney Kirkwall 2003-2012
January	86	56	86	107	132	48	172	154	107
February	91	38	76	78	123	65	111	116	75
March	84	49	86	66	138	40	135	98	70
April	75	24	65	46	94	71	113	64	59
May	40	27	69	72	94	49	70	65	50
June	35	19	67	84	100	44	60	61	48
July	43	29	73	91	89	62	80	76	45
August	62	38	72	99	108	115	108	99	74
September	96	61	124	104	131	96	146	100	94
October	81	77	109	97	156	55	155	129	122
November	79	72	96	82	140	106	171	147	110
December	104	63	96	116	154	54	157	136	108
Total: Per year	876	553	1,019	1,043	1,459	805	1,478	1,243	959
Average: Per month	73	46	85	87	122	67	123	104	80
Average: April-Sept.	59	33	78	83	103	73	96	77	62
Min	35	19	65	46	89	40	60	61	45
Max	104	77	124	116	156	115	172	154	122

Sources: Iceland: The Icelandic Meteorological Office. N-Norway: Norwegian Meteorological Institute. Faroe Islands: Danish Meteorological Institute. Shetland: Data from Lerwick accessed from http://www.tutiempo.net/en/Climate/United_Kingdom/GB_4.html Orkney data from Kirkwall Airport accessed from http://www.tutiempo.net/en/Climate/United_Kingdom/GB_4.html

Table 3. Temperature (average per month) in different regions.

Month	S-Iceland Reykjavik 2003-2012	N-Iceland Akureyri 2003-2012	N-Norway 2003-2012	W-Newfoundland Deer Lake 2002-2012	E-Newfoundland St. John's 2002-2012	Greenland 2007-2012	Faroe Islands Kollafjørður 2003-2013	Shetland Lerwick 2003-2012	Orkney Kirkwall 2003-2012
January	0.8	-0.4	-7.5	-8.4	-4.3	-4.1	4.3	4.1	5.0
February	1.3	-0.1	-8.4	-9.1	-5.0	-4.0	4.3	4.0	5.0
March	2.2	1.2	-5.3	-4.9	-2.5	-2.7	5.0	5.0	5.9
April	4.3	3.4	-1.0	2.7	1.6	0.2	6.4	6.6	7.7
May	6.9	5.8	3.2	7.7	6.2	4.1	7.8	8.2	9.3
June	10.4	9.7	7.0	13.1	10.9	6.5	10.3	10.5	11.7
July	12.2	11.6	10.8	17.3	15.4	8.4	12.1	12.6	13.5
August	11.7	11.1	10.0	16.9	15.5	8.7	12.0	12.8	13.4
September	8.7	7.9	6.0	12.7	11.8	6.3	10.4	11.2	12.0
October	4.7	3.0	1.1	7.2	7.0	2.7	7.6	8.5	9.7
November	2.3	0.3	-3.0	5.3	3.1	-0.7	5.6	6.3	7.4
December	0.8	-0.7	-5.4	-5.1	-1.7	-2.8	4.4	4.3	5.1
Average: Year	5.5	4.4	0.6	4.6	4.8	1.9	7.5	7.8	8.8
Average: April-Sept.	9.0	8.3	6.0	11.7	10.2	5.7	9.8	10.3	11.3
Min	0.8	-0.7	-8.4	-9.1	-5.0	-4.1	4.3	4.0	5.0
Max	12.2	11.6	10.8	17.3	15.5	8.7	12.1	12.8	13.5

Sources: Iceland: The Icelandic Meteorological Office. N-Norway: Norwegian Meteorological Institute. Faroe Islands: The Agricultural Centre. Shetland: Data from Lerwick accessed from http://www.tutiempo.net/en/Climate/United_Kingdom/GB_4.html Orkney data from Kirkwall Airport accessed from http://www.tutiempo.net/en/Climate/United_Kingdom/GB_4.html

Greenland. The average temperature for Qaqortoq is higher than for N-Norway. However this location in Greenland has the lowest summer temperature reported in Table 3. Cereal field tests are carried out inland on the coast of a long fjord where the temperature is expected to be 2 °C higher than in Qaqortoq.

The climate in Greenland is arctic to subarctic, cool winters and cold summers in which the mean temperature does not normally exceed 10 °C, the traditional definition of polar climate (Statistics Greenland, 2013).

Growing Degree Days

Growing Degree Days (GDD) are heat units used to describe the development of biological processes. For cereals, GDD are often calculated over the whole growing season from sowing to harvesting. The calculation of GDD, based on daily mean air temperature minus a base temperature of 0°C are shown in the following formulas.

Growing Degree Days (GDD) =∑DD over the growing season.

Daily Degrees (DD) = $(T_{max}+T_{min})/2 - T_{base}$

When the calculated DD is below zero it is set equal to zero for the calculation of GDD.

Here the base temperature T_{base} = 0°C.

Other base temperatures are sometimes used. For example, in Canada, growing degree days are assessed as those above 5°C, not 0°C, as at freezing (0°C) plant metabolism is negligible (Gordon & Bootsma 1993).

Results for typical Growing Degree Days (base temperature 0°C) for partner regions are shown in Table 4. The highest GDD occurs in Orkney and the lowest in Iceland, with Norway, Faroe Islands and Newfoundland in between. If GDD is calculated with a base temperature of 5°C, the results are considerably lower. For example, in Newfoundland the typical GDD for barley with a 0°C base temperature is 1594 GDD, but with a 5°C base temperature it is 1000 GDD. Clearly, the calculation methods should be described when GDD is reported.

Typical sowing and harvesting times are indicated in Table 4 along with the GDD. The dates differ very much between regions. The earliest sowing time is for Orkney.

Table 4. Typical sowing time, typical harvesting time and calculated Growing Degree Days (GDD) for base temperature 0 °C.

Region	Cereal	Variety	Period	Sowing time	Harvesting time	GDD
				Month Day	Month Day	Above 0 °C
Iceland						
South/West	Barley		2003-2012	May 1	Sept 5	1,300
North/East	Barley		2003-2012	May 5	Sept 15	1,250
N-Norway						
Vega, Norland	Barley	Tiril,Edel,Tyra	2003-2012	April-Early May	Sept	1,739
Troms	Barley	Arve, Gaute	2003-2004	May-Early June	Sept	1,211
Pasvik,Finnmark	Barley	Tiril	2009-2013	Early June	Sept	1,317
Faroe Islands	Example 1			April 20	Sept 30	1,677
Faroe Islands	Example 2			May 1	Sept 15	1,456
Orkney	Barley	Bere	2013	April 5	August 30	1,654
Orkney	Barley	Tartan	2013	April 5	Sept 14	1,847
Orkney	Oats	Haga	2013	April 5	Sept 14	1,847
Orkney	Wheat	Anniina	2011	April 16	Oct 12	2,127
W-Newfoundland	Barley			Early-mid May	Sept 15	1,594
E-Newfoundland	Barley			Early May	Sept 15	1,485
W-Newfoundland	Winter wheat			September 10	August 15	1,720
E-Newfoundland	Winter wheat			September 2	August 15	1,580

Sources: Iceland: Agricultural University of Iceland. N-Norway: Bioforsk. Faroe Islands: Agricultural Centre. Orkney: Agronomy Institute. Newfoundland: Agrifoods Development Branch.

Climate Change

A handbook of climate trends across Scotland has been published on the internet (Met Office, 2006). Growing Degree Days (5°C base temperature) were about 950 GDD in North Scotland in 1960s. About a 24% increase in GDD had occurred by 2003. The length of the growing season was about 217 days in the North of Scotland in 1960s and by 2003 this had increased by about 31%. This resulted from the growing season starting earlier and ending later. An increase in winter precipitation of almost 70% and a slight reduction in summer precipitation (7%) was also reported for the North of Scotland since the 1960s.

The Agronomy Institute has carried out an independent analysis of more recent data from Kirkwall airport and Lerwick comparing the periods 1989-2000 with 2001-2012. This shows similar trends for

temperature and GDD and also indicates less rainfall in the spring (which, in Orkney, is probably allowing earlier cultivations and planting). See Table 5.

Table 5. Results from analysis of data for Shetland and Orkney.

Variable	Kirkwall, Orkney		Lerwick, Shetland	
	Average 1989-2000	Average 2001-2012	Average 1989-2000	Average 2001-2012
Average Annual Daily Temperature (°C)	8.1	8.7	7.4	7.8
GDD (5°C) 15 Apr-30 Sep	970	1,115		
GDD (0°C) 15 Apr-30 Sep	1,810	1,955	1,682	1,792
Rainfall (mm) 1 Feb-30 Apr	284	212	373	282

Source: Agronomy Institute.

Guðleifsson (2004) reviewed the effects of climate change for Icelandic agriculture. He assumed that cereal production would be the agricultural sector most affected. Barley yield would increase by 1.0 ton/ha for every 1.0°C increase in summer temperature. Barley yield could increase by 1.5 tons/ha until year 2050. Growing degree days would increase and the cultivation of cereals in Iceland would become more reliable.

Haraldsson et al. (2007) used a model to predict future climate conditions in Iceland. They predicted a considerable increase in growing degree days and assumed that barley would almost always be fully mature at the end of the 21st century. They also predicted that wheat would be fully mature under the best conditions in Iceland.

The Norwegian Meteorological Institute has published a report (Hansen Bauer et al., 2010) titled "Climatic basis for vulnerability studies of the agricultural sector in selected municipalities in northern Norway" available online (met.no). An example projection was used to calculate possible future changes in growing season, growing degree days and snow season towards 2021-2050 in selected municipalities in N-Norway. An increase in growing season of 1 to 4 weeks was calculated for most places, while the increase in growing degree days varies from below 100 to 200. They predict 3 to 7 weeks reduced snow season towards the mid-century in the region. Uleberg et al. (2014) state that despite challenges such as unstable winters, increased autumn precipitation, increased drought stress in spring and early summer and more weeds and diseases, an extension of the current short growth season combined with higher temperatures can give new opportunities for agronomy in Northern Norway. This could increase use of legume and more productive perennial forage grasses and potentially increase the production of vegetables and grains.

Soil and fertilizers

Icelandic soils have a special character compared to other regions. Iceland ecosystems are influenced by volcanic eruptions and volcanic ash deposits are widespread. Soils that form in volcanic deposits are called Andosols and are unique in character. Andosols are often sensitive to disturbance because they lack a layer of silicate minerals (Arnalds et al., 2001). Information on the three important soil types in Iceland can be found in Table 6. The need for nitrogen fertilizer depends on soil type, ranging from 50 to 110 kg N/ha. Expansion of cereal cultivation will make use of all three types of soil. Most likely the available land will include organic soils (20%), Andosol (40%) and sandy soils (40%). The recommended pH for cereal fields in Iceland is pH 5.5 to pH 7.0.

Table 6. Information on soil types for barley cultivation in Iceland and fertilizer recommendations.

Region	Cereal	Period	Soil type	Barley fields ha	Fertilizer kg N/ha	Fertilizer kg P/ha
Iceland	Barley	2012	Organic soils	1,500	50	20
Iceland	Barley	2012	Andosol (volcanic mineral)	1,500	70	20
Iceland	Barley	2012	Sandy soils	1,500	110	20

Source: Agricultural University of Iceland.

In North Norway barley is mainly grown on sandy soils. Along the Helgeland coast the land is close to the sea and has a high content of lime sand with a relative high pH (up to 7.5). The phosphorus content is high and the recommended rates of application of N and P are 100-120 and 10 kg/ha, respectively in Helgeland. In Alta, Finnmark, the fertilizer recommendation is similar to Helgeland as the soil is also rich in phosphate. In Pasvik, Finnmark, barley is grown on mires since the area is dominated by this type of soil. The N fertilizer recommendation is about 60-80 kg/ha. The challenge is to fertilize sufficiently to be able to get mature barley. Today, all barley production is used for silage.

In Sandur region in the Faroe Islands, the soil is naturally well drained with a high content of sand and in this area the fields can normally carry heavy machines. In Hoyvík region, however, the soil is a mixture of peat and clay with a lower carrying capacity. Phosphorus content is normally very low in Faroese soil and pH is also very low, in many places around pH 5-5.5. Analyses of soil samples are important for experimental cultivation of cereals.

In Orkney there are significant areas of organic peaty soils but their sole agricultural use is for rough grazing. Some are still cut for peat for domestic heating. Most arable crops are grown on non-

calcareous gleys (usually surface-water gleys), brown forest soils and, in a few places, on calcareous sands (Dry and Robertson, 1982). The first two soils are formed from glacial drift derived sandstones and flagstones of the Middle Old Red Sandstone and are generally poorly drained. The soils derived from calcareous sands are windblown deposits derived from marine sands and usually have a high pH and crops may suffer from manganese deficiency. Where cereals are grown on these soils they tend to be earlier maturing than on the heavier soils.

Since almost all farms in Orkney which grow cereals are beef or dairy enterprises, they have access to plentiful supplies of organic manures which are applied to the land as slurry or farm yard manure. Fields also tend to be in arable cultivation for only 3-5 years so that relatively low amounts of mineral fertiliser need to be applied. Typically, this is about 60 kg/ha of each of N, P and K and is normally based upon a soil analysis. Soil pH is normally kept above 6.0 for growing barley, usually by applying beach sand.

The Shetland landscape is dominated by peat and about 40% of the islands are covered by peat. Peat is also a major component of several of Shetland's soil complexes. Cultivated ground is restricted mainly to the coastal fringes, to those soils which are close to sources of shell-sand for amelioration and to those on crystalline limestone or on localised drifts from ultrabasic rocks (Leslie Association in Unst and Fetlar). On areas of windblown sand the soils are mainly brown calcareous soils, calcareous gleys and regosols (Dry and Robertson, 1982).

Newfoundland soils are sandy-loam and will be expected to follow that soil type across expansion areas. Most soils have low pH (4.9-5.5) as the region is a part of the Boreal Forested area. The fertilizers typically use ammonium nitrate as a nitrogen source in spring and fall planting (winter wheat), however early mid-summer applications may incorporate urea instead as a slower release. Phosphorus and potassium are added to cereals based on the soil reports that are taken prior to seeding and what the crop requirements will be for that year (i.e. what the crop is expected to take out of the soil). N, P and K are added before planting and only nitrogen is applied thereafter until harvest.

Greenland. The mountains in South Greenland consist primarily of acidic rocks such as granite, gneiss and sandstone. Soils that develop from these rocks are acidic and low in nutrients. Many types of soil have a limited capacity to absorb water, and occasionally there is a lack of precipitation, particularly in the inner fjord areas. Droughts occur during the summer, causing low coarse fodder yields and economic difficulties. Permafrost, which is defined as soil that is at or below the freezing point of water (0°C) for at least two years, is found sporadically in the lowlands of Southwest Greenland.

4. Cereal cultivation

Cereal fields, yield and varieties

Iceland and Orkney have the largest areas under cereals but it is estimated that the greatest production occurs in Orkney as can be seen in Table 7. Iceland is second for production. Small amounts are harvested in North Norway and Newfoundland. In the Faroe Islands and Greenland there is presently no cereal production.

Table 7. Cereal areas and production in the partner regions.

Region	Year	Cereal area ha	Barley area ha	Barley production tons 85% d.m.
Iceland	2012	4,501	4,400	16,800
Faroe Islands	2012	0	0	0
N-Norway	2012	315	297	700
Orkney	2012	4,394	4,287	21,435[1]
Shetland	2008	85	62	248[2]
Newfoundland	2013	38	8	15[3]
Greenland	2012	0	0	0
Total		9,358	9,057	41,130

Sources: Iceland: Farmers' Association of Iceland and Agricultural University of Iceland. N-Norway: Bioforsk. Faroe Islands: Agricultural Centre. Orkney: Agronomy Institute. Newfoundland: Agrifoods Development Branch.
[1] Orkney production has been estimated assuming an average yield of 5.0 t/ha
[2] Shetland production has been estimated assuming an average yield of 4.0 t/ha
[3] High Moisture Barley (HMB)

Iceland. About 25% of the area of Iceland (2.5 million hectares) is below 200 m above sea level. About 600,000 ha are good agricultural land and only about 120,000 ha of this area are hayfields. Therefor plenty of land is available to expand cereal cultivation. Most of the available land is in South Iceland where conditions for cereal cultivation are best within Iceland.

Stefansdottir (2014) studied the food production from livestock and crops in Iceland. Cattle and vegetables created the largest yield, both measured in weight and value (money). Cereals were the third biggest source of production by weight, but this was not reflected in their value. The reason for this is that most of the barley grown in Iceland is used at the farm where it is produced. The markets for local cereals are little developed in Iceland.

Selection of barley varieties differ between South and North Iceland. 6 row varieties are often suitable for North Iceland (Tiril, Judit, Wolmari). Iskria from the Agricultural University is much used in South Iceland. Early maturity is a requirement for barley varieties used in Iceland.

The main barley variety used in N-Norway is Tiril, a 6-row with early maturity. It is now used instead of Arve which was used before. Arve is not available now, but was an even earlier variety than Tiril and farmers in N-Troms and Finnmark would prefer Arve instead of Tiril. Brage is also used in Finnmark. In Helgeland, Edel (6-row) and Tyra (2-row) are used in addition to Tiril. They are a bit later than Tiril, but give higher yield in good years.

In Orkney most cereals grown are spring varieties. Winter varieties do not survive well because of damage from wind and soil waterlogging. There are about 4262 ha of spring barley and the most common varieties are Waggon, Propino, Westminster and Concerto; only about 25 ha of winter barley is grown. The old varieties Tyne and Golden Promise are still liked for earliness and a small area (about 30 ha) of the landrace, Bere, is still grown. For oats, 108 ha are grown and the most common varieties are Firth, Atigo, Canyon and Belinda. One farmer still grows the old variety Ayr Bounty. For wheat, about 4 ha are grown. The most common varieties are, depending on availability, Anniina, Demonstrant or Paragon. Rye and rape are not grown in Orkney.

In Shetland barley was grown on 62 ha in 2008. The most common variety was Waggon. Oats were grown on 23 ha in 2008. Wheat, rye and rape were not grown (Scottish Government, 2013). Although there is more agricultural land in Shetland (149,713 ha) than in Orkney (92,481 ha), the land in Shetland is of poorer quality so that relatively little is “crops and fallow” or “grass under 5 years”, as demonstrated by the following table (Scottish Government, 2013).

Table 8. Comparison of Shetland and Orkney fields.

	Shetland ha	Orkney ha
Crops and fallow	269	5,641
Grass under 5 years	1,028	19,969
Grass over 5 years/rough grazing	147,020	65,786
Woodland and Other land	1,395	1,085
Total agricultural area	149,713	92,481

With sheep generally being better suited to rough grazing than cattle, these differences are also reflected in livestock numbers and there are more cattle in Orkney (85,285 compared with 5,342 in

Shetland) but more sheep in Shetland (280,793 compared with 120,448 in Orkney) (Scottish Government, 2013).

Newfoundland and Labrador are at the very beginning stages of cereal production (2012-2013 was the first year of the cereal program). Insular Newfoundland is exploring cereal cultivation, not Labrador as of yet. All cereals are being grown on the Island of Newfoundland and include winter wheat and barley. In the fall of 2012, approximately 30+ ha of winter wheat was planted and in the spring, 8 ha of barley. Important cultivars have not been decided as that is one of the objectives of the cereal program. However, three varieties of winter wheat are in testing (Brome – Semican, Emmit – Hyland Seeds, and Warthog – Semican) and two varieties of barley (Island – Mccardle Seeds, and Leader – Eastern Grains). There are several stands of oats and peas in combination, but they are harvested as silage rather than grain.

Newfoundland has very rocky soils, making agriculture expensive and time consuming. Currently we make up only 1% of agricultural land in Canada with just over 36,000 ha in production. The government is heading up the current cereal expansion to try to offset the costs as all grain requirements on the island must be imported. Arable land is at a premium; however the government is working closely with farmers to identify lands that are suitable for agriculture and assist in clearing and addition of soil amendments. Therefore the area available for cereal expansion is increasing each year. Additionally, older forage fields in need of renovation and vegetable fields in need of rotation are prime candidates for grain. We estimate that there could be well over 200 ha devoted to cereal production each year as it stands. Land availability is not the biggest question for farmers; it is the capital investment required and how to purchase a combine and a grain drill on a limited income.

Farms

Table 9 presents information on farms, cereal areas and production. The main producers of cereals are Orkney and Iceland. The totals for all regions are 1,057 farms; 9,354 ha of cereal fields and an estimated yearly cereal production of 38,060 tons.

Iceland. Information on farms is reported in table 9. Barley is mostly grown on dairy farms. Average yield per farmer is about 30 tons dry grain and is preferably used on the farm. A few pig farmers grow barley on larger scale, up to 300 ha each, for use on the farm. But domestic market is still undeveloped and commercial barley growing is not applied.

Table 9. Farmers and their cereal production.

Region	Cereal	Period	Number of farmers	Area ha	Average grain yield tons/ha	Grain production tons/year
Iceland - South	Barley	2008-2012	227	2,260	3.4	7,700
Iceland - West	Barley	2008-2012	65	760	3.4	2,600
Iceland - North	Barley	2008-2012	151	1,280	3.8	4,800
Iceland - East	Barley	2008-2012	24	160	3.3	600
Iceland - Total	Barley	2008-2012	467	4,460	3.5	15,700
N-Norway	Cereals	2012	33	315		700
N-Norway	Barley	2012	29	297	3.8	700
Orkney	Barley	2012	468	4,286	5.0	21,435
Orkney	Oats	2012	29	108	5.0	540
Orkney	Wheat	2012	2	4	5.0	20
Shetland	Barley	2008	17	62	4.0	248
Shetland	Oats	2008	32	23	4.0	
Newfoundland	Winter wheat	2013	7	57	2-3.5	107
Newfoundland	Winter triticale	2013	1	5.7		
Newfoundland	Barley	2013	1	8	1.9	15
All regions			1,057	9,354		38,060

Sources: Iceland: Farmers' Association of Iceland and Agricultural University of Iceland. Norway: Statistics Norway. Result is based only on applications for incentives and is therefore underestimation. Orkney and Shetland: Agronomy Institute. Newfoundland: Agrifoods Development Branch.

The number of farms producing cereals in North Norway was 33 in 2012 (Table 9). In the period 2000-2012 the number of farms has been variable but in the range 25-50. Most farmers in N-Norway grow barley in combination with milk and sheep production. Only two farmers in Nordland are solely focusing on barley production. In Nordland the production is on average about 3.8 tons/ha, but can be 4.6 tons/ha in good years and up to 5.0 tons/ha. In Lofoten most of the barley is used as feed for goats, but also for cows and sheep. Enough land is available to increase the today's cereal production in North Norway. Table 10 gives information for the three Norwegian counties. There are additional farmers growing barley, especially in Finnmark, but they only grow small areas and not all of them apply for incentives.

There has not been commercial production of cereals in the Faroe Islands for the last 50-60 years. However, a few dairy farmers are interested in starting production of barley for feed. In the year 2014 barley production is planned at two farms: Sigert Patursson in Hoyvík near Tórshavn and Jóannes Johannesen and Hjørdis H. Jensen in Sandur in Sandoy.

Table 10. Information on three Norwegian counties.

Cereal production 2011	Area ha	Number of applications for incentive
Nordland	336	35
Troms	1	2
Finnmark	2.5	1

Source: Norwegian Agricultural Authority (Statens Landbruksforvaltning).

In Orkney, all cereal farmers grow cereals to produce feed for their livestock enterprises. Primarily this is for beef (553 holdings) but there are also other enterprises:

- Dairy – 46 holdings (all use cereals for feed and grow their own cereals).
- Pigs – 55 holdings (all use cereals for feed but may not all grow cereals). One farmer mentioned that he needed 120-150 t of barley pa for his 20-sow unit (c. 10 piglets each)
- Sheep – 528 holdings (all use cereals for feed).
- Poultry – 350 (all use cereals for feed but may not all grow cereals). A new specialist egg-production unit is interested in growing wheat locally for feed. The current need would be for about 45 t of wheat per year but this is expected to double as the unit comes into full production.

Livestock numbers for Orkney are: Dairy cattle: 3,625; beef cattle: 53,674; other cattle: 27,986; sheep: 120,448; pigs: 686; poultry: 10,657; horses: 705.

Expansion of the cereal area in Orkney could only be done by reducing the area under grass (19,969 ha of grass under 5 years old in 2012) but currently farmers need most of this for livestock. Farmers mainly grow cereals for their own feed needs. Occasional surpluses may be sold and a few farmers deliberately grow excess for sale:

i.) Feed grain which is exported to Shetland

ii.) Certified seed

iii) The Agronomy Institute has helped to develop a number of small markets for grain:

- Bere grown for distilling (3 growers, c. 60 t/yr)
- Tartan malting barley grown for Highland Park distillery (5 growers, c. 50 t/yr)
- Oats for milling (1 grower, c. 3 t/yr)
- Wheat for milling/specialist feed (1 grower, c. 5 t/yr)

iv) In addition, a further 15 t of Bere is grown for milling/own seed by Barony Mills.

v) Straw for bedding is an additional cereal commodity which is valuable in Orkney and is often sold between farmers, imported or sometimes exported (small quantities) to Shetland – depending on the season.

vi.) There is a very small market for oat straw which is mainly used for making Orkney chairs. It is estimated that about 2ha are grown for this purpose.

In Shetland, most cereal farmers grow cereals for their own feed needs, mostly for arable silage. Most farmers produce sheep (1,204 holdings) and only 172 enterprises are for beef, 10 for dairy and 29 for pigs.

Livestock numbers for Shetland are: Dairy cattle: 641; beef cattle: 2,751; other cattle: 1,950; sheep: 80,793; pigs: 177; poultry: 5,613; horses: 1,333.

Cereal production is insufficient for demand and both grain and straw are imported from Orkney and Aberdeen. There is some sale of high-moisture content barley for feed (about £160/t) by a few growers in the south of Shetland who have sufficient land to grow excess. Land is available for expansion of cereal growing as there has been a long-term trend for this area to decline and to be returned to grass since at least the 1960's. There is now a trend for a reduction in sheep numbers which could allow some grassland to be returned to cereal production.

There are no commercial cereal producers in Newfoundland and Labrador. For the current government-led cereal program there are 6 producers participating in 2013-2014, which will change each year and may include up to 3 more. We are limited as our program has only 1 large combine and 1 no-till grain drill.

Five farmers are dairy producers and one farmer is a vegetable producer. Participation in the program is limited to dairy producers (with one exception) because the government is funding the cereal expansion research. This way the farmer uses the grain that is harvested from their land and offsets his own feed costs.

Developments during the last 10 years

Table 11 shows the increasing barley production in Iceland in the period 2003 to 2012. The area of cereals grown in Iceland has increased from 2,600 ha in 2003 to 4,500 ha in 2012, or by 73%. The yield has increased by 71% over the period. In the year 2013 the barley production decreased to 9,800 tons due to unfavourable weather conditions, particularly in South Iceland.

Cereal farming is a new branch in Icelandic agriculture and is surely on the edge of the possibilities. It has though brought new thinking into feed production. Field rotation has replaced haymaking from permanent, often 20 – 50 years old, hayfields and has given a general benefit for the agriculture as a whole. The use of the plough has increased dramatically and followed by new sown and high productive hayfields.

The barley yield per hectare has increased during the last decade because of increased know-how among the farmers and also favourable weather conditions. The most important factor might though be the progress in plant breeding in the Nordic region as a whole. It has been estimated at the Agricultural University of Iceland that plant breeding in Iceland has increased the yield by 0.5% for 2-row barley and 1.1% for 6-row barley per year.

Table 11. The increase in area of cereal fields and barley production in Iceland from 2003 to 2013.

Year	Cereal area ha	Barley production Tons, 85% d.m.
2003	2,600	9,800
2004	2,878	11,100
2005	3,636	10,500
2006	3,588	11,500
2007	3,576	12,200
2008	4,328	16,400
2009	4,764	16,200
2010	4,295	16,800
2011	4,381	11,800
2012	4,502	16,800
2013	4,250	9,800

Source: Agricultural University of Iceland. 98% of the cereal area is barley. Barley production is calculated at 85% d.m.

Information from Norway is presented in Table 12. Data are taken from Statistics Norway (Statistisk sentralbyrå).

Orkney. There has been little change in the area under cereals in the past 10 years.

While most farmers would like early varieties, they plant later ones because of their higher yields. Following research trials starting in 2010, 'Vilde' (from SW Seeds) was introduced as an early feed barley suitable for undersowing from about 2011. But seed is expensive and most farmers are more attracted by the higher yields of later varieties.

Table 12. Areas of cereals and barley grown and barley production in N-Norway in the period 2003-2012. Data are based on applications for incentives.

Year	Cereal fields ha	Barley fields ha	Barley production tons
2003	244	186	493
2004	315	254	636
2005	366	315	428
2006	352	309	561
2007	298	276	461
2008	340	309	799
2009	377	342	511
2010	378	348	742
2011	335	318	617
2012	315	297	700

Source: Statistics Norway

The Agronomy Institute (AI) ran variety trials with malting barley for Highland Park (HP) in 2009 and 2011 which identified 'Tartan' as suitable for Orkney (good malting properties combined with good field characteristics). Since 2010, a supply chain has been managed by the AI for HP. This consists of 5 growers each growing 2 ha to supply to the distillery – it supplies HP with about 50 t/yr.

There has been a slight increase in the area (5ha to 30 ha) planted with Bere, a Scottish landrace, as a result of the development of a new market for specialist whisky with Bruichladdich Distillery.

Following research trials, there has been small scale local adoption of early maturing oat varieties from North Europe (Fiiaa, Belinda) since about 2006. Most recently, Haga has been introduced to replace Belinda which is earlier maturing. Agronomy Institute research trials suggest Haga gives comparable yields to later UK varieties and this could have good potential for growing in the north of Scotland. Oats are becoming more popular as they appear to be less damaged than barley in the spring by geese. They are also appreciated as a sheep feed and a specialist feed for bulls.

There has been small scale local adoption of early maturing wheat varieties from North Europe (Anniina, Demonstrant) since about 2006. Disappointing harvests in 2011 and 2012 and difficulties in obtaining early varieties are reducing interest in wheat for milling, though.

Improved agricultural machinery allows farmers to make better use of narrow windows of opportunity for planting and harvesting. The trend for an increasing amount of drilling and combining to be done by contractors is continuing, particularly as increasing machinery output allows them to work faster.

Planting – individual contractors can plant 24 to 32 ha per day; only about half this was possible 10 years ago. Some contractors like single pass, others are still using 2-pass. One contractor planted about 1000 ha in 2013. Changes in machinery (e.g. Vaderstad disc drill) is expected to increase this output and on some soils may allow direct drilling.

Combining – larger combines can harvest about twice the area of 10 years ago in the same time. e.g one contractor with a combine with a 6 m cutter bar and 4-wd managed to harvest 29 ha in one day (more typical rates are c. 1.2 ha/hr). He has 2 combines and has the potential of harvesting about 40 ha daily. In 2013 he harvested about 440 ha for his customers. In spite of the apparent advantage of contractors with large combines, farmers may have to wait for a contractor and for small areas of specialist cereals it may be useful for farmers to have the independence of their own combine.

Currently, Waggon is the most common barley variety grown in Shetland. A small amount of Tyne and Westminster is also planted. Previously, Tyne, an earlier variety was grown but Waggon is preferred because it is more resistant to lodging. One farmer grew North European varieties (e.g. Filippa and Vilde) in one year and, although these succeeded, this was not continued.

Canyon and north European oat varieties (Fiia and Belinda) have recently been grown in the north of mainland. Oats are mainly grown for arable silage. A small area of Shetland oats (*Avena strigosa*) is also grown for straw.

There are thought to be around 6-8 combines on Shetland, but most of these are old and one farmer thought they were too heavy for the wet soil conditions around harvest.

Newfoundland. For the last 20 years, cereal research has occurred periodically on the Island in small plot trials. We have ramped up the program to test grain in larger, more natural agronomic settings after the small plot trials indicated promise and farmers were looking to lessen their feed cost burden. In 2012 we started the first year of a multi-year grain program for Newfoundland. We purchased a new self-propelled combine, new seeders, a thresher etc. to assist in the grain viability assessment. We are investigating two cereals – winter wheat and barley – because they are the most likely to reach maturity in our climate. There has been a problem attaining dry grain status as the end of our growing season is often the wettest. High moisture grain appears to be a potential solution to our problem. We can harvest earlier than dry grain and under more adverse conditions (we harvested a field while under a light rain). There are many things we still need to figure out such as which varieties are best suited to our region, pest management, soil fertility, and most importantly how to successfully no-till grain into a burned off grass forage field. The last point is important because dairy farmers have the highest need of grain on the island and their current land base is

usually a grass-legume forage blend. Tilling soil in the province is very problematic because it is so rocky and rock picking machines are not only expensive to buy, but also expensive to run. Farmer uptake would be substantially higher if we could find a system (herbicide combination) that could burn off an established forage field so that the no-tilled grain is able to grow without being overcome by rebounding grass forages later in the season. The current herbicide regimens and recommendations have not been effective so far.

5. Utilization of cereals

Cereals for feed and food

The use of cereals in Iceland is reported in Table 13. About 28% of the total amounts of cereals (barley, wheat and maize) were used as cattle feed in 2012, 23% as pig feed, 26% as poultry feed, 19% for the baking industry and 4% for the brewing industry.

Table 13. Barley, wheat and maize used in Iceland 2012.

Cereal	Cattle feed tons/year	Pig feed tons/year	Poultry feed tons/year	Baking industry tons/year	Breweries tons/year	Total tons/year
Barley - Domestic	15,800	900	0	100	20	16,800
Barley - Imported	3,200	5,000	0	3	3,400	11,600
Barley - Total	19,000	5,900	0	98	3,420	28,400
Wheat - Domestic	0	150	0	5	0	155
Wheat - Imported	0	9,700	17,900	16,300	0	43,900
Wheat - Total	0	9,850	17,900	16,305	0	44,055
Maize - Imported	5,400	4,700	5,400	200	0	15,700
Total cereal	24,400	20,450	23,300	16,603	3,420	88,200
Percentage use	28	23	26	19	4	100

Sources: Directorate of Customs, Farmers' Association of Iceland and Agricultural University of Iceland. Data for imported cereals are estimated from classification numbers for imported goods (Directorate of Customs) and the cereal use of different agriculture sectors is a rough estimate.

Cereal production in North Norway is exclusively for animal feed, especially for cattle, sheep and goats. Bakeries and breweries import all their cereals as either flour or malt. There are no separate data on imported cereal for Northern Norway therefore the statistic in table 14 is for Norway as whole.

All cereals used in the Faroe Islands in 2012 were imported. There is neither pig nor poultry production in Faroe Islands. In the statistics, cattle and sheep feed are put together, but most of the amount is for cattle. The use of cereals is as follows (Source: Statistics Faroes):

- For cattle 3626 tons 8.4 mill DKK
- For baking 6354 tons 41.9 mill DKK

- For brewing 0.4 tons

Table 14. Use of cereals in concentrate/grains in Norway.

Cereal	Year	Total tons/year
Barley - Domestic	2012	457,134
Barley - Imported	2012	104,938
Barley - Total	2012	562,072
Wheat - Domestic	2012	177,768
Wheat - Imported	2012	104,939
Wheat - Total	2012	282,707

In Orkney, most cereals are grown as feed for livestock and, in most years, most farmers are self-sufficient in barley (estimated above at about 21,400 t).

Specialist markets are as follows:

- Bere grown for distilling (c. 60 t/yr)
- Bere grown for milling (c. 13 t/yr; about 8 t of Beremeal is used locally by bakeries)
- Tartan malting barley grown for Highland Park distillery (c. 50 t/yr)
- Oats for milling (3 t/yr)
- Wheat for milling/specialist feeds for pigs and chickens. The use for milling depends on the success of harvest but can be up to 5 t/yr. Recently, a few small producers of chickens and pigs have also grown wheat for feed (2-3 t/year).
- Grain for export to Shetland (80-160 t/yr of cereals – barley and oats)
- Seed – it is estimated very approximately that about 15% of the cereal seed used (120 t out of 800 t) is farm-saved seed. By the 1997 Plant Varieties Act, this can only be used on the farm where it was grown. In addition, about 30 t of certified seed is grown in Orkney.
- Specialist straw. A small area (perhaps 2-3 ha) of oats is grown to produce straw for weaving for making straw-backed chairs or other products.

Cereals are imported to Orkney for baking, brewing and distilling.

Orkney has 3 main bakeries: Argo's, Rendalls, Browns. An Agronomy Institute study in 2010 estimated that the following quantities of flours were used by these bakeries:

- About 182 t of brown wheat flour were imported annually by these bakeries. Brown flour is more relevant than white flour because it could be replaced by locally grown flour (it is unlikely that locally grown flour would be bleached to produce white flour).
- About 4 t of oatmeal was imported by bakeries and 8 t by butchers (for haggis etc). In addition, a large oatcake manufacturer imported hundreds of tonnes of oatmeal but had no interest in trying to substitute any of this with local oatmeal as problems were anticipated with the consistency of product and supply.

Orkney has 4 main users of grain/malt for brewing and distilling: Highland Park Distillery, Scapa Distillery, The Orkney Brewery and Highland Brewing Co. Amongst these only Highland Park still has on-site malting facilities which allow it to produce a small amount of its own malt (c. 40 t) from locally grown barley. It also imports a large amount of grain for malting.

It is estimated that about 7000 t of malt and grain are imported annually for use by Orkney's distilleries and breweries (about 6,000 t by the two distilleries).

Specialist feeds are imported for pigs, chickens and horses and these usually including supplements and concentrates.

Shetland. About 120 t of preserved grain is produced annually and it is likely that most of the remaining area (about 55 ha) is used for arable silage. A small area of Bere (c. 1 ha) is grown for animal feed and seed.

Straw is very important for feeding and bedding. Local production is usually not sufficient for needs. Many lorry loads of bales are normally imported from Aberdeen and Orkney, but this is expensive because of transport costs. One source indicated a price of about £50 per round bale delivered to Lerwick in 2013; the price of a similar bale ex-farm on Orkney would be about £12 per bale. There is also a small amount of black oats (less than 1 ha) grown for straw for basketry (Shetland mainland) and chair making (Fair Isle).

Grain is imported for feed from Aberdeen and Orkney, but it is not possible to determine the exact quantity.

Based on UK average food consumption figures, the Shetland population (23,200) and an estimated visitor number of 104,000 (2005/6 visitor survey) with an average stay of 5 days, it is possible to estimate the amount of flour imported to Shetland per year (AB Associates, 2006; Shetland Islands Council; 2013):

- White flour for bread (228 t), biscuits (57 t), cakes and pies (79 t)

- Wholemeal flour (82 t)
- Brown flour (65 t)
- Other flour (14 t)

There are two breweries on Shetland and they both import all of their malt. There is also a plan for a small distillery to be established in 2014 or 2015. With the new distillery, the annual requirement for malt would be over 100 t.

The present use of cereals in Newfoundland is for animal feed (mostly dairy, some beef, poultry, sheep and other livestock). Since there is currently no commercial cereal production on the island, over 60,000 MT are imported annually. With the present fuel prices, political uncertainties, economic instabilities, natural disasters (drought, hurricanes) and diversion to biofuels the price of grain is very volatile for Newfoundland and there is no buffer as Newfoundland is not a producer.

Preservation of cereals

Iceland. Preservation methods for barley are reported in Table 15. About 60% of the harvested barley is dried. Harvested barley in Iceland contains usually 65% dry matter but it can happen that the dry matter is lower. Barley is dried until dry matter is about 85%. Since it is only possible to store wet barley for about 72 hours, the limiting factor is the capacity of the available dryers (Intellecta, 2009). Most dryers are owned by farmers and can be used by one or a few farms. Most dryers are located in South Iceland which is the main cereal production region.

Table 15. Preservation methods used in Iceland 2012 for barley.

Region	Cereal	Method	Temperature °C	Percentage of harvest %
Iceland	Barley	Drying (geothermal or oil/geothermal)	50-70	60
Iceland	Barley	Ensilaged with propionic acid		20
Iceland	Barley	Ensilaged without added substances		20

Source: Estimation by the Agricultural University of Iceland.

In Helgeland N-Norway most barley (from 170 hectare) is harvested by combine harvester. Farmers in the area deliver the mature barley (80-81% dry) to a common facility at Berg in Sømna where the barley is dried at 15-20˚C air temperature (grain temperature is similar). Only a small amount of the barley (from about 5 hectare) is used for ensilage. In Finnmark, the barley is only about 60% dry and is solely used for ensilage and fed to cattle and sheep.

Orkney. The estimated proportion of the barley crop processed in different ways is as follows: Dried grain (20%), Propcorn (70%, up to 25% mc) and Whole Crop/Silage (10%). Information on grain drying methods is as follows: Usually harvesting is delayed until grain moisture in the field is below 22% because of the expense of grain drying. In wet years, though, harvesting may take place with a higher grain moisture content. Typical equipment used is a 12 t batch drier (e.g. Master 120 D), with the heating supplied by a diesel burner and the circulation system powered by a tractor P.T.O. For seed or malting, where germination is important, the temperature of the dryer is not allowed to exceed 38^{o}C (air temperature is typically 10-17^{o}C during September). With a 10-t dryer which is full, about 1 hr of drying is required to reduce the moisture content by 1%. For a full load at about 22% grain moisture about 120 L of diesel is required for drying (down to 13% mc) and about 60 L for running the tractor. Highland Park distillery require a grain moisture content of 13% or lower as they may store it for about 9 months before malting. Bruichladdich accept grain at 14% as it is malted fairly soon after delivery in December.

There has been an increase in the number of grain dryers in Orkney (currently 5 of 7-16 t capacity) which is allowing:

- An increase in the use of farm-saved seed.
- Retention of older varieties well-suited to Orkney which might otherwise be difficult or impossible to source (e.g. Bere, Tartan).
- Use of dried grain for specialist markets (e.g. malting, milling, feeds).
- Two growers produce certified seed which is sold locally. The high costs of batch drying mean that this seed is not actually very much cheaper than imported seed and growers often prefer to purchase imported seed.

With only one small (about 1 t capacity) grain dryer in Shetland, very little (probably less than 1 t) grain is dried (mainly grain for seed of the landraces Bere and Shetland oats). Grain from about 30 ha is treated with preservative. The remaining cereal crop (about 35 ha) is used for arable silage.

Newfoundland has a short growing season which at the end is very wet. We have found harvesting as high moisture to be the most successful (least risky) option for growing cereals. After investigating northern European production systems, we purchased a Murska bioprocessor that allows us to treat grain with a bacterial inoculant (or acid), crimp it, and store it in Ag Bags. We tested this system for the first time in 2013 and it has been a great success. No spoilage has been detected from all of our testing and farmers are already feeding their grain out (both winter wheat and barley). The farmers that have used the machine are impressed with its ease of use and versatility. However, it is an

added expense to purchase the machine, inoculant and bags and the Government of Newfoundland and Labrador owns the only one in North America at the moment.

6. Cereal research

Iceland. The Agricultural University of Iceland (earlier The Agricultural Research Institute) has carried out research and development of cereal cultivation in Iceland. Work on the barley breeding project started in 1960 and the work has been continuous for more than 50 years. Barley breeding has been successful and created adapted cultivars for the region. Barley research projects have included studies on weather conditions, fertilizer use, diseases and comparisons of barley varieties. In 2007 cooperation with Matis started to increase the utilization of barley for food. Climatic conditions for cereal production differ between areas within Iceland and further developments are therefore needed, e.g. in North-Iceland.

North Norway. Not much research has been carried out on barley cultivation in N-Norway in recent years. A few field tests have been undertaken, especially within organic farming. There are a few reports from this work. There has been more research in this field in Mid-Norway.

In 2006 two Icelandic varieties were tested in Pasvik, Finnmark. Those were Skegla and Iskria, both two rows. They gave slightly less harvest than Arve, which has been the best variety in this area. There were four field trials at four different farms. The dry weight was between 43-60%. Yield was around 2.3 tons/hectare for the Icelandic varieties (Røthe, 2006; Vink, 2003; Pasvikdalen kornkrosserlag 2004, 2005 & 2006). In 2002-2004 there was a survey on barley production in Troms County. Nine farms participated in the survey with a total of 22 hectare of barley cultivation. All farms except one used the cultivar Arve (Røthe, 2005).

Faroe Islands. In 2013, six different Icelandic barley cultivars were tested in Faroe Islands. The first experiment was sown in Sandur on Sandoy May 11th. The seed blew away in a great storm three weeks later. The experiment were thus resown June 4th at a farm in Hoyvík near Tórshavn. The results were as to be expected when sown so late. The grain not matured and also very damaged by birds.

In Orkney, the Agronomy Institute (AI) has been running a cereals research programme starting in 2002 which has been aimed at developing higher value markets for grain (Martin, 2009; Martin, 2010). The main areas of investigation have been the following:

1. Identifying new markets for Bere, a Scottish barley landrace with a long association with Orkney. In 2002, the only market for Bere was for producing beremeal, with the Bere being grown and milled by Barony Mill. The AI has collaborated with distilleries (Bruichladdich and Isle of Arran Distillers) and a brewery (Valhalla Brewery) and supplied Bere to them to develop whiskies and a beer. Currently the AI manages a supply chain (3 growers) growing about 25 ha of Bere per year.

2. Developing a barley supply chain for Highland Park (HP) distillery. Most distilleries only use modern types of malting barley for distilling. Although Orkney's climate and fertile soils have long been thought unsuitable for growing malting barley, HP was keen to identify a suitable variety for Orkney to allow it to produce an "All-Orkney" whisky. In 2009, the AI tested a range of malting barley varieties in a trial and provided grain samples to HP for micro-malting. As a result, the variety Tartan was identified as having a good combination of field characteristics and malting properties. HP then asked the AI to form a local supply chain, producing about 50 t of Tartan per year for the distillery. The 2013 crop was the fourth supplied to HP. Since Tartan has been withdrawn from the National List of recommended varieties, seed is no longer available and the supply chain is having to continue to maintain the variety as farm-saved seed.

3. Identifying early maturing cereal varieties for the north of Scotland. For producing dried grain, earliness is an advantage in Orkney because it allows cereals to be harvested at a low moisture content so that drying costs are minimised. The disadvantage is that earliness is usually accompanied by lower yields. This may not be such a disadvantage, however, if higher value markets are being supplied. There are relatively few early UK varieties because of the yield penalty associated with growing them. Several early varieties are available in northern Europe, however, and since 2005 the AI has tested North European varieties of wheat, oats and barley. The following are considered the most promising: Wheat – Anniina and Demonstrant; Oats – Haga and Belinda; Barley - Vilde.

Shetland**.** There has been no recent research on cereal growing in Shetland.

Newfoundland. There have been small plot trials conducted periodically since 1993. They were small varietal trials and successfully determined which varieties were high yielders for that time. Small grains were able to reach maturity ~60-70% of the time; however grain dryers had to be employed which many farmers did not possess. Since then, there have been several developments that make growing grain more feasible. Firstly, the number of growing degree days has increased in

Newfoundland that have extended the growing season by up to 10-12 extra days over the last 30 years (Bootsma, 2011). Additionally, advances in cereal breeding over the last decade have led to varieties that perform better in cooler climates. Finally, there has been much work elsewhere on the harvest and storage methodology of high moisture grain that makes it possible for cereals to be successfully grown in Newfoundland.

Cereal research ceased by the province approximately 12 years ago when we could not decrease the risk associated with a dry grain harvest and fuel and grain prices were relatively cheap. Currently, cereal research is in its infancy yet again as we are assessing new varieties that were not available before, on a larger scale, with new equipment and new sowing/harvest methods. We are assessing varieties for yields, seeding and harvest dates, nutritional contents and disease resistance. We also are looking into different sowing techniques as farmers are interested in finding a successful No-Till system because of the rocky soils.

7. Future of northern cereal cultivation

Possibilities to increase the production of cereals

Iceland. Considerable land is available to expand cereal cultivation. It has been estimated that annual production of cereal (barley) in Iceland could easily be increased from about 15,000 tons to 50,000 tons per year (Ministry of Industry and Innovation, 2011).

North Norway. There are possibilities to increase barley production in N-Norway. There is enough land, and especially in the southern part of the region, the temperature and length of growing season is adequate. The interest of farmers in some locations is lacking but in others they are interested to start or produce more. Encouragement from advisors and local farmers is important. Farmers in Nordland and southern Troms which have large areas of forage production can benefit through the incentives if they produce barley in addition to forage. Barley growing is also important within crop rotation. For new farmers to start, it is important for them to be able to share or rent the machinery, since this is the biggest investment. Some of the machinery today is getting old. Since this area is marginal for barley production today, years with unfavourable weather can reduce the interest of farmers. If farmers could sell a part of the harvest for a higher price as locally produced barley, this would encourage more farmers to grow barley. Barley production has become much more efficient in recent years, making it less time consuming and more attractive for farmers.

The available land may not always belong to farmers who are already growing barley. In certain areas, as in Alta, land is a limiting factor. The main limiting factor is the need for investment in machinery. Another challenge is the autumn rain which, in combination with wind, can destroy the field before the barley is harvested. Geese and crows are also a challenge since they eat seeds and reduce harvest. In Finnmark, there is a risk of 2-3 nights with frost in July which can stop the barley maturation process.

Faroe Islands. There is a lot of suitable land available but in some farms the available land is uncultivated pastureland for sheep grazing. So in order to increase cereal production, some places will need to cultivate new land or replace grass with cereals.

Orkney. Increased cereal production would mean alterations in the current land use. While most farmers could make small alterations to their land use without affecting stocking rates, they would

not make major changes if it required them to reduce stock numbers or if the returns from the new enterprise did not compare favourably with those from existing livestock production. Possible future changes to EU subsidies could change this situation, however.

Shetland. Land is available for expansion of cereal growing as there has been a long-term trend for this area to decline and to be returned to grass since at least the 1960s. There is now a trend for a reduction in sheep numbers which could allow some grassland to be returned to cereal production. If the area of cereals expands, this would probably require the purchase of some more up-to-date machinery. Grain drying facilities are currently inadequate in Shetland for producing dry grain.

Newfoundland. We are working closely with the Lands division of the province, private land owners and industry to secure more land for agricultural use. Agriculture has recently become a priority for the island which has led to an increased urgency for more land acquisitions. Additionally, several farmers already have land available, including many of our large vegetable farmers who require rotations that not only interrupt disease, but provide good value. Other large dairy farms have large forage growing operations that require field 'renovations' every 10 years. Considering most farmers have well over 15 fields, there should always be room for multiple renovations on each farm followed by a winter cereal.

Possibilities to increase the use of harvested cereals

Iceland. There are expected to be considerable possibilities to increase the use of cereals (mainly barley) for feed and in the food and drink industries.

Faroe Islands. Dairy farmers have the greatest potential for increasing cereal production in the Faroe Islands. For now they produce the grass they need for feeding and import all the concentrates to be used as feed. Concerning this subject Faroese farmers feel that they are in the same situation as Icelandic farmers, about 35 years ago.

Orkney. It is thought that there is little scope for increasing the amount of cereals grown for general animal feed as most farmers grow as much as they need and transportation costs make it expensive to export surpluses, except to Shetland. While mainstream UK varieties of barley are suitable for mid- to late-season harvesting in Orkney, there is interest in finding a replacement for old, early varieties like Tyne and Golden promise by early, disease resistant, higher yielding modern varieties.

There is potential for growing cereals for specialist feeds. For example, there is an increase in interest in oats as a crop for sheep and bull feed (some farmers claim oats are less susceptible than barley to damage in the spring from geese). Oats are normally later maturing than barley, however, and so

harvesting can be difficult. This is where earlier maturing north European varieties might offer an advantage. A recently opened egg production unit (1200 hens) is interested in investigating the growing of local wheat for feed. As the unit expands to a capacity of 2500 hens this would require 120 t of feed annually (90 t of wheat).

Orkney's Barony Mill, which produces stone ground flour, has sufficient spare milling capacity to double its current output of beremeal and oatmeal. For Orkney's breweries it would be too expensive to use locally grown grain as this would need to be sent away for malting and then transported back to Orkney. There is some interest from small scale enterprises in using enzymes with grain for brewing instead of malt, or in developing a capacity for small-scale local malting. If the costs of producing malting barley locally can be reduced and quality maintained, Highland Park might be interested in increasing the size of its supply chain.

Shetland. With the annual importation of both grain and straw, most interviewees feel there is considerable potential for increasing local cereal production for feed. The plans for developing a new distillery which is interested in exploring the possibility of sourcing some local grain for distilling is also a very positive development. With about 100,000 visitors per year, there is a potential market for local grain for flour although there is no functioning mill in Shetland at present.

Newfoundland and Labrador does not produce grain. Therefore, given that we import 60,000 MT of feed alone, we would have need for every tonne produced and our farmers would be grateful for a local option. There is a small niche market that would also like to have wheat, barley and other grains as a source for human baked goods; however, because the need is so great in our livestock industry, that is where government funds have been allocated.

Views of farmers, researchers and industry

Iceland. Interest in domestic products increased after the economic depression in 2008. The interest in Icelandic barley for food increased sharply although this trend has partly declined. The bakery industry used Icelandic barley for production of barley bread which became quite common in bakeries from 2009 to 2010 (Reykdal et al., 2012). The views of the public towards domestic cereals are generally positive. Cereal cultivation is well known among farmers and many of them have started cereal cultivation for feed. The views of farmers are positive although cultivation of cereals have not always been successful.

North Norway. Views were obtained by discussion with advisors (Norsk landbruksrådgivning) in the different regions of N-Norway. If farmers can sell barley for a higher price as a local product to

produce a food product, they would be more interested in growing barley. The production of barley is mainly limited by climatic factor, but economic factors are also important. Farmers in Pasvik would be interested in testing Russian winter barley varieties which are grown in Nickel, a town a few kilometres away.

Views on feed and food production were obtained by discussing with advisors (Norsk landbruks-rådgivning), the seed company (Felleskjøpet) and a brewery (Mack brewery). There is a particular interest in production of local beer based on barley from the region. The beer could be marketed as a seasonal product.

Faroe Islands. The staff at The Agricultural Centre has a good contact with most of the farmers in Faroe Islands through the advisory and teaching activities. Before this project started, we discussed cereal production with some farmers – mainly about barley, and the farmers involved in this project are really interested in starting production. This would mainly be for feed for their own livestock, but they also see an opportunity to earn money by producing niche products for breweries, restaurants and the baking industry. One of the farmers involved in the project has some experience with similar work since he produced vegetable niche products for restaurants for several years. The Faroe Islands are very small – distances are short and many people know each other. So, if the experiments become successful, it will be an easy task to present and publish the results to all farmers.

Sigert Patursson, a farmer at Hoyvík, has planned to produce barley for feed for his dairy cows, and in addition he will produce barley for the brewery Føroya Bjór. Jóannes Johannesen and Hjørdis H. Jensen farmers at Sandur will produce barley, basically as feed for their own dairy cows, but they are also interested in producing for restaurants, baking industry etc. where they already have some contacts.

Orkney. Views were obtained by personal interviews with growers, advisory staff and researchers. An expansion of cereal production would probably require farmers to take land out of grass. Some are able to do this without reducing stock numbers and, in this case, some are usually prepared to do this if the cereal venture is sufficiently profitable. This happened, for example, with Highland Park's malting barley supply chain. In Orkney, straw is always either useful or saleable and this provides an additional incentive for planting more cereals. One beef farmer currently grows wheat for a bakery company, demonstrating that farmers are prepared to grow for feed and food.

A key factor in developing new, or expanding existing, cereal markets in Orkney is to find/acquire appropriate cereal varieties for the Orkney climate. Generally, the machinery is available for harvesting and basic local processing.

Views of feed and food producers in Orkney were obtained by personal interviews. The Barony Mill is keen to double the amount of bere meal and oat meal it produces annually, but needs help to access markets beyond Orkney. One local company is interested in developing beer from local grain using enzymes instead of malt. Highland Park Distillery is keen to consolidate its current malting barley supply chain by making sure that quality is maintained and costs are reduced. This will strengthen the sustainability of the current supply chain and may allow its expansion in the future. A large local agricultural contractor is keen to increase the area of oats he grows (feed, probably some for export, and also for milling). A new egg production unit is interested in exploring the possibility of growing local wheat for chicken feed. At capacity, this will require about 90 t of wheat annually.

The Newfoundland program is government-led and currently for dairy producers only. We decided to perform this research after discussions with our farmers about their needs and what their highest on-farm operational costs were. Dairy producers are very interested in the program and they use all grain that is produced and all straw (a commodity that is steadily increasing in value for bedding, feed, and pest control for fruit growers). Interestingly, outside of Newfoundland and other parts of Canada straw is considered a waste product. That view is quickly changing.

Views were obtained through formal meetings, informal discussions, newspaper interviews etc. Newfoundland farmers have indicated that this “is a very timely project” as the price of grain is very volatile. “Increasing food security is essential” - most of the feed comes in on a ferry (Newfoundland is an island) and in poor weather conditions the ferry does not sail and farmers are left to borrow feed from other farms. “I have need for every bit of grain that is produced in Newfoundland.” Currently all grain requirements have to be shipped in.

8. Conclusions

The North Atlantic Regions are very variable due to geographical locations. Cultivation of cereals in these regions is a great challenge, principally for climatic reasons. However, cereal cultivation has been successful in many locations because of progress in cereal breeding, increased know-how among farmers and the availability of appropriate machinery and processing equipment.

There are strong indications that climate change will increase the potential for cereal cultivation in Nordic regions. This opens up possibilities to increase cereal production for feed and food. Considerable land is available to expand cereal cultivation in Iceland, N-Norway and Newfoundland. Less land is available in Orkney and Faroe Islands but cereal production can still be increased.

There are considerable possibilities to increase the use of domestic cereals (mainly barley) for feed and in the food and drink industries. This would result in economic advantages since increased domestic production would replace imported cereals and strengthen currency reserves. More diversified agriculture will support growth in Nordic regions and create jobs in rural areas.

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