Non-English lettering in green: Ææ – Øø – Öö – Åå – Ðð - Þþ – Áá – Éé – Íí – Óó – Üü – Úú
Non-English words/names in the Bibliography have NOT been marked in color, as this involves half the words, and would be counter-productive.
All Graphs are available as .tif files
Unable to disable automatic numbering of chapters

Christian Keller

The Northern Frontier - North Atlantic Farming during the Viking and Middle Ages

Abstract: Christian Keller: The Northern Frontier – North Atlantic Farming during the Viking and Middle Ages.
During the ninth and tenth centuries AD islands in the North Atlantic; the Faroes, Iceland, and South Greenland, were colonized by Norse settlers. The communities established were based on fixed farms, a dairy-economy, limited crop production, and maritime hunting and fishing.
Animal husbandry in sub-arctic regions may seem a clumsy solution compared to the elegant adaptation displayed by high-arctic hunting cultures, but the Norse use of livestock permitted the utilization of vegetation resources that were otherwise useless to humans. This allowed larger and more complex communities. Summer pastures, and improved home-fields for production of winter fodder supported the livestock around the year; and the dairy economy was far more energy-effective than an equivalent meat-based economy would have been. The farm produce was supplemented with fish, marine mammals, and waterfowl.
This paper argues that the Norse farm, in addition to being a socio-economic production unit, was the single most important ideological and religious entity in Norse society.
Over the later decades paleo-environmental investigations and archaeology have cooperated in gaining a modern understanding the Viking and medieval Norse communities in the North Atlantic, and their adaptation to diverse and shifting environments. The concept 'Economic Man' may be a useful term for studying the human / environment interface, but the aims, goals, and decisions of the medieval Norse were crafted within a mental universe. Culturally, the Norse were conditioned to a life where the farm was the axis mundi, and where all auxiliary economic activities ultimately served to protect the core.

Key words: Agriculture, dairy economy, environmental degradation, farm, Faroes, Greenland, Iceland, landnám, Little Ice Age, livestock, Medieval Warm, Medieval, Norse, North Atlantic, pastoral economy, Scandinavia, Viking.

1. Introduction

In 2007 the most enthusiastic member of the EARTH Steering Committee Sofus Christiansen passed away. During his career Dr. Christiansen authored several papers on North Atlantic agriculture (Christiansen 1990; 1991; 1996; Christiansen and Guttusen 1987). To pay tribute to him the present paper revisits his 1991 article 'North Atlantic Farming Culture in a Comparative Ecological Perspective' (The originally Danish title is translated by the present author).

Books addressing the Norse expansion into the North Atlantic are numerous and easily accessible (Fitzhugh and Ward 2000; Graham-Campbell 2001; Gulløv 2004; Seaver 1996; Marcus 1980). This aim of the present paper is not to celebrate the Viking achievement, but to discuss the spread of dairy agriculture across the North Atlantic and its growth and adaptation during the Viking and Middle Ages.

A frequently addressed issue in the literature is the ability, or inability, of the Norse to adapt to North Atlantic conditions, and subsequently to handle the environmental hazards posed by the Little Ice Age. The disappearance of the Norse Greenlanders in the fifteenth century is a frequently cited show-case in environmentalist literature, demonstrating 'failure to adapt' (as in Diamond 2005, 248-276, but see Seaver 1996 for balance).

The spread of European agricultural economy to the North Atlantic islands was part of what is sometimes called the Norse Diaspora; the expansion by the Scandinavian Norse as far east as Byzantine, and as far west as Newfoundland. This happened during the Viking Period (AD 750-1050); so named to indicate the infamous Norse raids on churches, monasteries, and towns in the Christian world (Sawyer 1982; Konstam 2002/2005; Graham-Campbell 2001; Sawyer and Sawyer 1993; for Eastern expansion see Franklin and Shepard 1996; Noonan 1998).

The later decades have seen research efforts in the Faroes, Iceland and Greenland dedicated to understanding the mechanisms of the Norse colonization, its impact on the pristine eco-systems, and the human response to the subsequent environmental challenges posed by a cooling climate and environmental degradation. Numerous tephra-layers (i.e. layers of volcanic ash from eruptions) form isochrones over the Icelandic landscape, and provide a detailed chronology on a level which surpasses conventional dating methods. This facilitates high-resolution diachronic studies (Þórarinsson 1944; 1970; 1981; Grønvold *et al.* 1995; Dugmore *et al.* 2000). The present paper focuses on the economy and social values of the Norse farming communities, seen against a backdrop of climate change.

The famous medieval Icelandic literature in the vernacular (often imprecisely called 'sagas') has a strong focus on the 'Commonwealth Period' in Iceland (ca AD 870-1260), and has been studied for centuries by philologists and historians (Ólasson 1998). The interaction between Man and Nature is a frequently addressed subject in this research, but it has mainly been studied as a spiritual matter. Ecology does not enter into it (Dumézil 1977; duBois 1999; Näström 2001; and 2002; Steinsland 2005).

Recent paleo-environmental investigations suggest the Norse should indeed be seen as environmental agents: decisions concerning land-management, live-stock investment, and rules of ownership, had both short-term and long-term implications for the landscape and its resources.

Iceland in particular has been exposed to man-induced landscape degradation; hence it is sensible to study not only the effects of past decisions upon the environment, but also the social and ideological framework within which these decisions were made.

It is the view of this author that the farm was the cultural core of Norse society, both in a social, economic, and spiritual sense. The survival of this core was an absolute prerequisite for survival of the society; hence it was buffered from environmental threats by all kinds of auxiliary economic activities. The nature of these activities varied with the local access to wild resources, and involved fishing, egg-collecting, hunting of sea-mammals, and catching of waterfowl (Nørrevang 1979; McGovern *et al*. 2006; McGovern *et al.* 2007).

In a historical perspective certain ‘wild’ resources such as walrus ivory from Greenland, and stockfish from Iceland and the Faroes (and indeed from Norway) were favoured for export. The farm economy has traditionally been seen as the mainstay of daily subsistence, but recent isotope analyses of skeletal material bear witness that in most farms people depended on ‘wild’ resources as a substantial part of their diet. Unlike the situation in medieval Norway, hunting and fishing in the North Atlantic was organized as farm chores. Hence all decisions concerning economic activities in the North Atlantic ultimately originated in the social context of a farm.

2. Prelude and ‘landnám’.

The Norse ‘landnám’ (Old Norse ‘taking of land’’, i.e. colonization) of the North Atlantic Islands would not have been possible without the preceding development of the farm in Scandinavia during the Iron Age. The long and harsh winters required indoor stabling and feeding of livestock. Manure from the stables was spread on the home-fields, which in turn produced food and fodder for man and beast. By the time of the Migration Period (AD 550-750) the fixed farm had long since become the basic social institution of the Norse world, both in a physical and mythical sense. Hence it was well established in the minds of the North Atlantic settlers from the ninth century. In principle the North Atlantic farm was a single family farm of a type commonly found in Sweden and Norway, although they come in many shapes and forms. The organization of the society in relatively small units was a typical adaptation to the limited and patchy resource distribution, but it was also a convenient way to organize a kin-based society.

The vertical aspect was also important: lowlands and valleys had good conditions for early plant production, but the productive areas were limited. Mountain pastures were abundant, but the growing-season was short, so maximum utilization during the summer months was essential. To minimize transport, a system of milking stations or more elaborate shielings were established away from the farm, to make use of the more remote resources. The shieling system characterizes the decentralized farming needed in areas with patchy resource distribution (Hitzler 1979; Albrethsen and Keller 1986; Mahler 1989; 1990; 1991a; 1991b; Sveinbjarnardóttir 1989; Hastrup 1989; also in Laws of Early Iceland (Grágás) K § 182 in Dennis *et al.* 2000, 11-112).

As mentioned, farms could only contribute part of the resources needed by their occupants; a plethora of ‘wild’ resources were also needed. The coasts, lakes, rivers, forests, and mountain-sides were harvested for what they could offer; leaves and seaweed were used for fodder and for soil improvement, peat and firewood were collected for cooking, heating, and charcoal-production, bog-ore was taken for iron extraction, driftwood and grass turf for construction purposes (McGovern *et al.* 2007; Simpson *et al.* 2003; Vésteinsson and Simpson 2004; Sveinbjarnardóttir *et al.* 2007; 2008). Fish were caught, seals and whales hunted, eggs collected, and birds caught. There was, in other words, a steady trickle of biomass from the surroundings of the farm to its centre, and it was all part of the farm economy.

Combined with a cool climate, the biomass accumulation favoured farm-mound formation. A farm-mound is a classic archaeological formation in the North Atlantic; like a miniature tell consisting of turf and midden material, normally with good archaeological preservation conditions.

The northern frontier for agriculture runs across the North Atlantic on a diagonal course from the south west to the north east. Hence the temperature drops dramatically as one moves west from the west coast of Norway, on a course to Greenland.

This is due to the North Atlantic Drift which moves warm water on a diagonal course from the Gulf of Mexico to Scandinavia. This ensures favourable climatic conditions along its axis Fig.s 1 and 2 (from Christiansen 1991, 46-47). The drift also brings warm, humid Atlantic air from the south-west to collide with cold, dry polar air from the Arctic. This creates the North Atlantic Polar Front, which propels a constant stream of low-pressures on an easterly track, carrying rain and wind to Britain and Scandinavia.

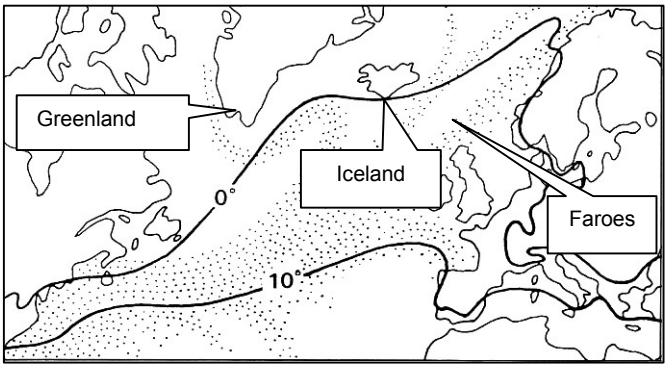

Fig. 1
Medium isotherms for 0 and 10 degrees centigrade for January. (From Christiansen 1991, 46 Fig. 1)

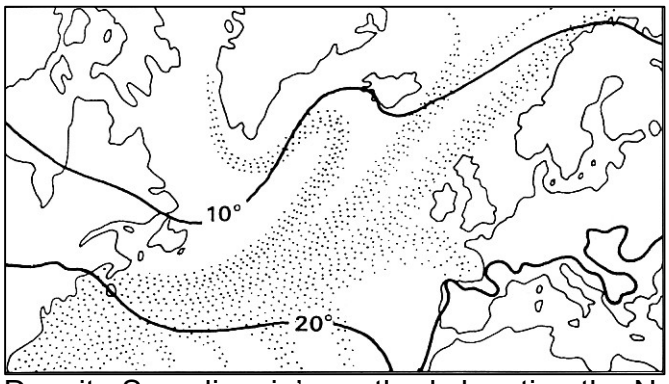

Fig. 2
Medium isotherms for 10 and 20 degrees centigrade for July. (From Christiansen 1991, 46 Fig. 2)

Despite Scandinavia's northerly location the North Atlantic drift permits fully fledged agriculture except in the most northerly parts. The capitals of Stockholm and Oslo lie on the same latitude as Cape Farewell in Greenland, and Hudson Bay in arctic Canada, but are surrounded by pleasant agricultural landscapes. Agriculture in these parts started more that four thousand years BC.

The North Atlantic islands were technically a wilderness until they were colonized by the Norse, i.e. their landscapes had never been subject to agriculture (Marcus 1980; Fitzhugh and Ward 2000; Vésteinsson *et al.* 2002). In Iceland a sophisticated society developed during the Viking Period; a commonwealth based on 'góði' (i.e. regional chiefs), a national law, and a hierarchic system of 'Þing-sites', (i.e. assembly sites). Christianity was introduced around AD 1000 (Sawyer *et al.* 1987; Sanmark 2004; Vésteinsson 2000; Kristjánsdóttir 2004), and Iceland soon became a literate society which produced a wide range of books, both in Latin and in the vernacular (Nordal 1952; 1954; Byock 2001).

The Norse 'landnám' in the Faroes is normally set to AD 825 (which is debated, see Arge 1991; Arge *et al.* 2005), the 'landnám' of Iceland to ca AD 870 (Hjálmarsson 1993; Byock 2001; see also Friðriksson 1994). Greenland was colonized from Iceland ca AD 985 (Grønnow 2004, 221-434; Seaver 1996,14-43).

The environmental impact of the 'landnám' is evident from the pollen records; the original Birch forests and Salix shrubs were cut down and the stubs were burnt to create a grass-covered rangeland for livestock (Fredskild 1973; Einarsson 1963;

Edwards 2005; Edwards *et al.* 2005a; Edwards *et al.* 2005b; Lawson *et al.* 2006; Schofield *et al.* 2006).
All buildings were made from turf, or a combination of turf and stones. Wood was a scarce commodity which was reserved for roof construction, and for boats, hence drift-wood beaches were highly valued assets. Other farm-owned assets were boat-houses and fishing- and hunting-stations on the outer coast (Rieck 2002; Edvardsson 2005).
The farm-land consisted of fertilized home-fields for grass production (Sveinbjarnardóttir *et al.* 2007; and 2008; Thomson *et al.* 2005; Thomson and Simpson 2007), and shielings (Hitzler 1979; Albrethsen and Keller 1986; Mahler 1989; 1990, 1991a; 1991b; Sveinbjarnardóttir 1989). There was also rangeland which in some regions was split by a sophisticated system of turf-built boundary walls (Einarsson *et al.* 2002). These walls are also mentioned in the early Icelandic laws, called Grágás. (See K § 181, K § 205, and § 206 in Dennis *et al.* 2000, 113-138).
In the pollen records of Iceland and Greenland the environmental footprint of the colonists is strong and clear from the start; the 'landnám' manifests itself as a sudden impact rather than a slow trickle, suggesting the colonizers were well organized with a substantial maritime lifting capacity for people and livestock (Dugmore *et al.* 2000; Dugmore *et al.* 2005; Dugmore *et al.* 2006; Dugmore *et al.* 2007a; Dugmore *et al.* 2007b).
The manipulation of the original vegetation came at a price which was not immediately apparent; today it is reckoned that 90 percent of the original forests and 40 percent of the soils of Iceland have disappeared since 'landnám', partly due to grazing, partly due to volcanic activity. 73 percent of the present-day surface is affected by erosion. The Icelandic landscape has a large proportion of andisoils, i.e. volcanic soils, which are particularly vulnerable to erosion (Arnalds *et al.* 1997; McGovern *et al.* 2007; Dugmore *et al.* 2009). The moraine soils of Greenland are more robust, but tectonic movement caused a loss of coastal plains perceivable even during the time of settlement (Mikkelsen *et al.* 2008).
Ecologically, it may seem like the North Atlantic communities had overreached. During the mid thirteenth century the Faroes, Iceland and Greenland were included in the Scandinavian kingdoms through a series of political events, and by the mid fifteenth century Norse Greenland was deserted (Seaver 1996; McGovern 1980; 1981; 1986; 1994; 2000; McGovern *et al.* 1988; Buckland *et al.* 2008). In 2005 Jared Diamond argued that the Norse Greenlanders failed to survive because they were unwilling to adapt to the arctic environment (Diamond 2005, 248-276). Perhaps it is better to say that the Norse abandoned Greenland when they saw that it was no longer possible to uphold society as they knew it. Norse communities consisted of farms, and farms consisted of livestock. If the livestock succumbed, there were no farms, and no society…

3. Cereal cultivation and the northern frontier

The colonization of the North Atlantic took place in a favourable climatic period known as the MW (Medieval Warm), which was challenged by the thirteenth to fourteenth century onset of the LIA (the Little Ice Age) (Grove 1988; Fagan 2000), Fig. 8.
On a gradient from 'warm' to 'cold' the Faroes lie in the 'warm' zone, Iceland hangs in the balance, while Norse Greenland is 'cold' (Fig. 1).

Calculated from Christiansen's Table 4 (1991,47)	Nuk	Ivigtut	Reykjavík	Tórshavn	Lerwick	Trondheim	Kråkenes	Bergen	Kirkwall	Stornoway	Tiree	Belmullet	Cork	Scilly Isl	Brest
Grass day-degrees	492	864	1251	1551	1887	1919	1989	2115	2157	2364	2637	2781	3096	3453	3156
Cereal day-degrees	157	406,1	663	853,1	1076	1324	1174	1332	1316	1513	1556	1696	1981	2314	2178

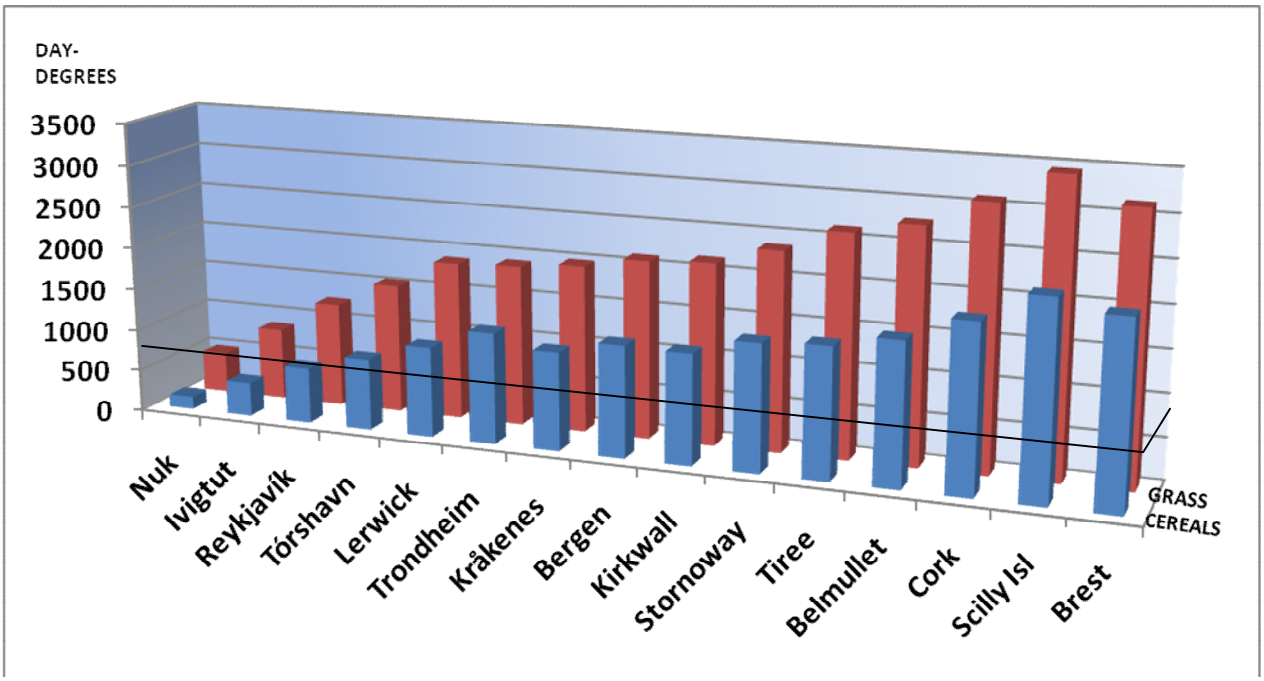

Fig. 3
'Grass day-degrees' (red, rear) and 'cereal grade-degrees' (blue, front) from 15 meteorological stations in the North Atlantic, according to Christiansen's calculation (Christiansen 1991, 47). The stations are ranged from the North West (left) towards the South East (right). Greenland = Nuk and Ivigtut; Iceland = Reykjavík; The Faroes = Tórshavn.
See Fig. 4 for the geographical location of these stations.
Christiansen argued for a minimum of 750 cereal-day-degrees (750 'cereal day-degrees' marked with black line in the diagram). Christiansen's concept 'cereal-day-degrees' was a closer fit with the agricultural reality than standard day-degrees (below).

This is in line with the descriptions of in the medieval manuscript 'Konungs skuggsjá' (i.e. 'The King's mirror') from the mid thirteenth century, which states that 'most people in Greenland have never tasted bread'. Cereal cultivation in the Faroes, on the other hand, is well known from recent historic times, and goes back to the early stages of settlement (Mairs 2007, 67-83).
In his 1991 article Sofus Christiansen addressed the climatic frontier of agriculture in the North Atlantic by examining the temperatures required for grass- and cereal production, and the temperatures across the North Atlantic. In these days of computer modelling Christensen's approach seem terribly dated, but his effort is worth revisiting both to commemorate him and because it is a quick approach to basic facts about the North Atlantic and agriculture.

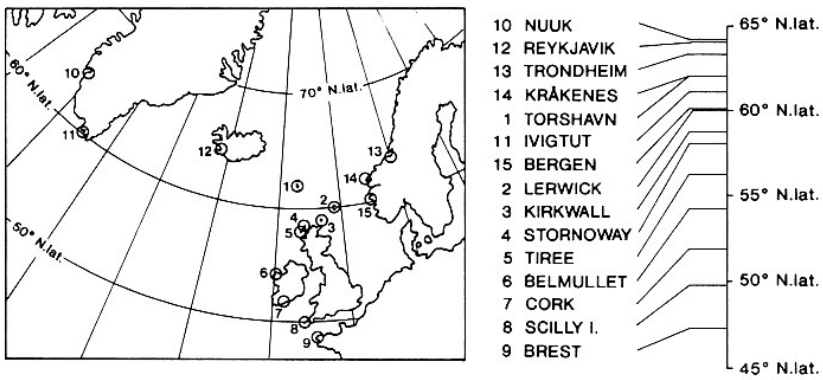

Fig. 4
The geographical location of the meteorological stations in Fig. 3 (from Christiansen 1991, 47).

Normally, the climate conditions for farming are presented as a sum of day-degrees per year. Christiansen wanted to get a more close-up picture, so he designed his own conceptual framework: he explained that the minimum temperature for grass-growth is ca 2 centigrade, while the minimum temperature for cereals is ca 5 centigrade. Days with temperatures above 2 day-degrees made what he called 'grass-day-degrees', and days with more than 5 day-degrees he called 'cereal day-degrees' (centigrade). Such days were counted at each meteorological station to indicate the conditions for grass- and cereal-production across the North Atlantic, see Fig. 3. In principle he simply 'sliced off' the number of days where the temperature did not exceed 2 respectively 5 day-degrees at each station.
Christiansen argued that a steady reproduction of cereals require a minimum of 100 – 120 days with temperatures above 10 centigrade, preferably exceeding 15 centigrade towards the end of the growing-season. He also suggested that cereals need at least 750 'cereal day-degrees' to ripen (loc.cit).
Unfortunately it is not so easy to compare Christiansen's 'cereal day-degrees' with data-sets based on standard day-degrees, even though such comparisons are indeed relevant: In Northern Scandinavia the northern limit for cereal production lies close to the historical ethnic boundary between the Sámi and the Norse populations. Lars Ivar Hansen has given the following information about cereal production in these areas based on standard day-degrees, see Fig. 5 (from Hansen1990, 63 with reference to Fjærvoll 1961).

TYPE OF CEREALS	**DAY-DEGREES**
Early strands of barley	1170
Other strands of barley	13-1400
Medium to late strands of oats	13-1500
Medium to late strands of spring wheat and spring rye	1600
(Based on Hansen 1990, 63)	

Table Fig. 5
The minimum number of day-degrees for a selection of cereals, according to Lars Ivar Hansen 1990, 63. Hansen's original table is simplified here.

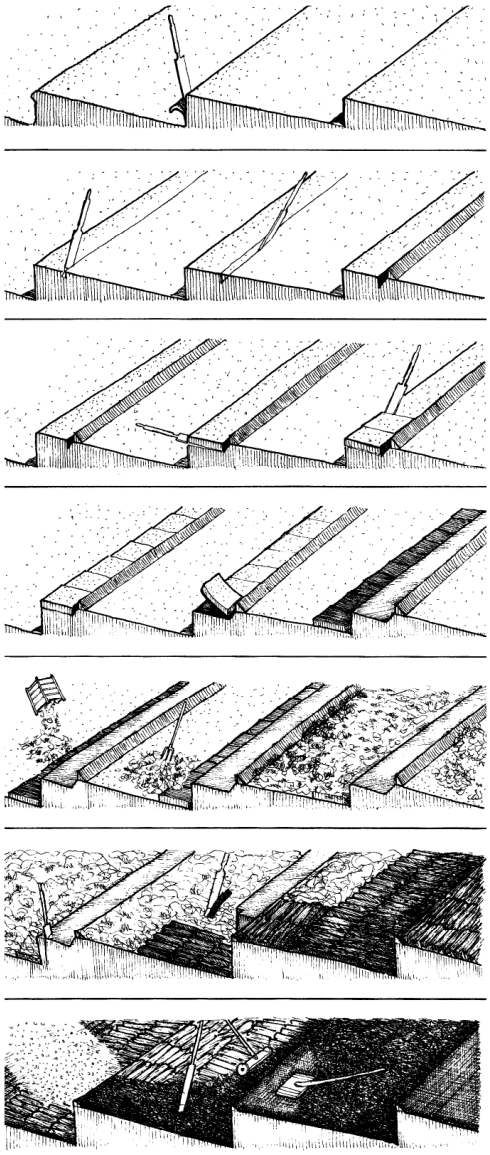

Fig. 6
The cultivation sequence of the typical Faroese type of hoe agriculture called ‘reinavelta’.
The cultivation was often made in a seven years rotation system with cereals one year and grass for the six consecutive years. Hence there were often seven such terraced fields per lot. (From Joensen 1980, 22-33).

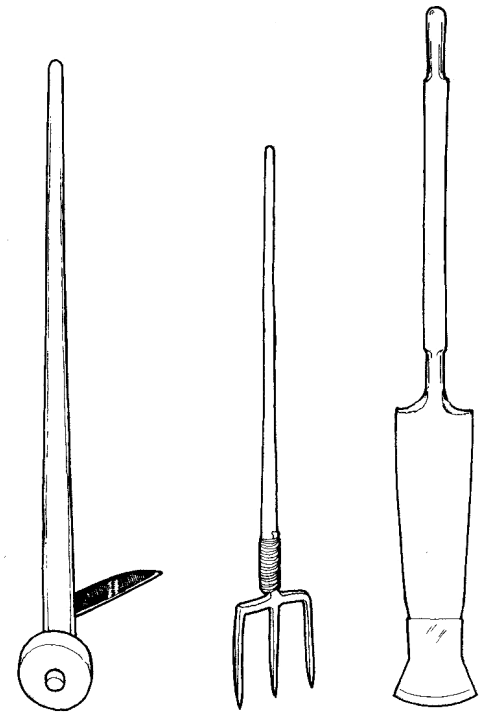

Fig. 7
Faroese farming implements:
'Ristari' or 'forskeri' (left), pitchfork (middle), and 'haki' (right). The 'haki' looks suspiciously like it has Celtic ancestors, but the name for it is in Old Norse.
(Figure from Joensen 1980, 23).

The frontier for cereal agriculture lies in the range of 1200 –1600 standard day-degrees. (For calculation of standard 'growing degree days' and examples, see http://en.wikipedia.org/wiki/Growing_degree_day).
Growing conditions for grasses and cereals do of course depend on other variables such as water, soils, nutrients, wind, and not the least exposure to summer frost. A detailed environmental simulation program from University of Sterling, the 'Búmodel', was developed to model agricultural production in the North Atlantic isles (Thomson 2003; Thomson *et al.* 2005; Thomson and Simpson 2007). The program is available at http://www.sbes.stir.ac.uk/research/environmental_modelling/)
Historically the northern limit for cereal cultivation in North Norway was at Malangen, near the town of Harstad in North Norway. Despite its location above the Arctic Circle the area has as much as 1250-1275 standard day-degrees (Hansen op. cit. 56-77).
The northern frontiers for agriculture, whether it is the 'cereal boundary' or the 'grass boundary', are indeed stress zones for agriculturalists; the weather in these regions is unstable and the climatic predictability is low. Farming everywhere is exposed to environmental hazards, but in high altitudes and on northern frontiers the risks are higher than usual: both cereals and grass may be ruined by rain, hail, or frost. Such mishaps may force farmers to slaughter or sell livestock because they cannot be supported through the winter. An unlucky decision in the spring may lead to abandonment in the fall.
There is not necessarily a one-to-one relationship between local agricultural conditions and global temperature fluctuations. Hence the fate of unsuccessful communities in the North Atlantic cannot be explained simply by referring to

temperature diagrams. Incoming drift-ice to fjords with agriculture may cause severe temperature drops in South Greenland and North Iceland, even during otherwise benign temperature regimes (Ogilvie 1992; 1998; Ogilvie and Jónsson 2001).
In the Faroes the temperatures from the period 1961 – 1988 were compared to the temperatures in the preceding 30-year period 1931 – 1960. Despite the global warming which occurred 1961-1988 (see Fig. 8) the temperature in the Faroes dropped in this period, due to increased cloud cover. The clouds were caused by more evaporation from the sea. In the same period the windiness increased from an average of 5.1 to 5.9 meters/second (Søgaard 1996, 24-26).
The Faroes featured a special cultivation system for cereals based on hoe agriculture, a bit like the lazy bed systems of Ireland and the northern British Isles, but terraced. There were several cultivation techniques; the most important is called 'reinavelta', see Fig. 7 (Joensen 1980, 22-40).
In Iceland a handful of sites with terraces and lazybed-like formations have been located archaeologically (Guðmundsson and Snæsdóttir 2001; Guðmundsson *et al.* 2004; Simpson *et al.* 2002). Place-names with the prefix 'Ákr-' (Old Norse 'cereal fields') support the notion that cereals were indeed cultivated in favourable spots in medieval Iceland.
As mentioned, there is no evidence of cereal cultivation in Norse Greenland. This does not mean that Greenland was totally without crops: in the archaeological record in the North Atlantic feature small, walled-in 'gardens' which are known historically as 'kólgarður' (cabbage gardens) or 'hvönngarður' (i.e. gardens for Angelica Archangelica, a rhubarb-like plant rich in vitamin C). It is safe to assume that cabbage and root-crops were cultivated in these gardens, even in Greenland. In addition to wild berries, the crops must have been important to prevent vitamin-C deficiency.

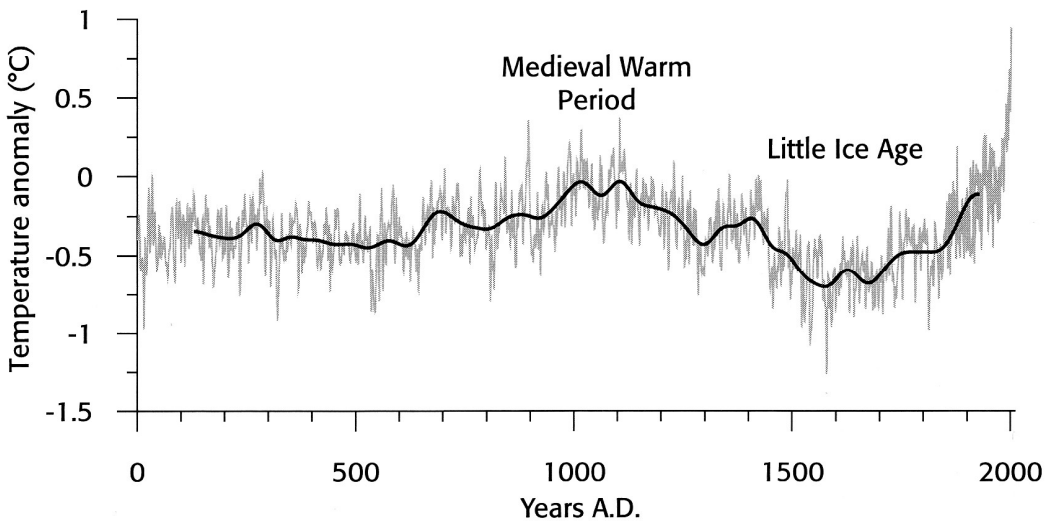

Fig. 8
Mean temperature curve for the last 2000 years in the Northern Hemisphere, based on high resolution tree-ring data, low resolution proxies from sediments, and instrumental records from the last two centuries. The curve is presented as deviations from the 1961-1990 average. (From Lagerås 2007, 30 referencing Moberg *et al*. 2005; see also Ogilvie 1992; Ogilvie and Jónsson 2001).

4. Farming economy

As already stated, the farm is seen as the basic building block in the Norse society; it was essential in all the Norse settlements, even in Greenland. Zoo-archaeological evidence suggests that the colonists all over arrived with much the same 'starting kit' of livestock, consisting of cattle, sheep, goats, pigs, horses, and dogs (McGovern *et al*. 2001; McGovern *et al.* 2007). Crops, animals, technology, skills, and social organization constituted the 'cultural capital' which was introduced to the islands by the Norse (Mairs 2007, 39). As things developed, they would design their flocks, land, and economic strategies to suit the local conditions

Pigs were important initially, but their popularity waned after the first centuries. Their ability to reproduce fast would have been essential at 'landnám', as would their capacity for digging up roots in the cleared areas; but the same properties ultimately made them hard to control (McGovern *et al.* 2007; *Arge et al.* 2009; also in Laws of Early Iceland (Grágás) K § 207 in Dennis *et al.* 2000, 139).

Cattle was important both as a traditional measure of wealth in Norse society, and as the key to the dairy economy which was the mainstay of the farming economy in the North Atlantic. Cattle are excellent meat producers, but a pure meat economy is highly energy demanding. The dairy economy is less resource demanding: a zoo-archaeological 'dairy-profile' is characterized by a high percentage of neonatal bone fragments in the middens, indicating that a high percentage of calves were culled to maximize milk off-take for humans. The energy gain for dairy production vs. meat production is on the order of four to one, which makes it the most efficient way to utilize a limited fodder supply (From McGovern in Lucas 2009; also Halstead 1998; Hambrecht 2006).

It is an interesting side issue that the surplus of calves in the dairy economy may have been the direct prerequisite for the Icelandic medieval literature by making cheap vellum available for parchment production. This is not a marginal issue: today ca 700 vellum manuscripts from Iceland are preserved, corresponding to ca. 35,000 hides, or 10,000 calves per century. (Halldór Hermannsson 1929 referenced in Nordal 1952; and 1954). These represent the preserved manuscripts only; the initial book production would have been much larger. Literature was a spiritual undertaking, but books were agricultural products.

Given the hierarchic organization of Norse society, it is hardly surprising that zoo-archaeology shows more of a 'meat-production profile' at the high-status farms, i.e. most of the cattle at these farms were allowed to live beyond the peak of their growth curve before they were butchered (McGovern *et al.* 2007; McGovern in Lucas 2009).

Sheep was a necessary component in the 'starting kit' as the main contributor to clothing. From the thirteenth century zoo-archaeological investigations show a clear increase in the number of sheep relative to cows (McGovern *et al.* 2007; see also Mainland and Halstead 2005). This may have several reasons; cattle are extremely labor demanding and need indoor feeding for a better part of the year (nine months in Greenland), and consume a lot of home-field grass during this period.

The relative increase of sheep in the sheep / cow ratio may be explained by two different (but not mutually exclusive) models: one environmental and one fiscal.

In the face of a cooling climate sheep would be a better option than cattle because they are less demanding in terms of winter feed; and on the pastures they can dig up grass even under the snow. The graph in Fig. 8 shows that the Little Ice Age reached its coldest in the sixteenth century; but a close inspection will reveal that the decline

of the Medieval Warm starts in the thirteenth century. In regions as marginal as the North Atlantic this could be significant (Mainland and Halstead 2005). A shift of emphasis from cattle to sheep would be a sensible response to a cooling climate. Alternatively, Iceland produced two commodities of commercial value; fish and woolen cloth (Perdikaris and McGovern 2008). In the thirteenth century each Icelandic farmer paid a tax of 20 ells of 'vaðmál' (homespun cloth) to the Norwegian king. 'Vaðmál' was also used for other pecuniary transactions such as land-rent. Hence the increase in sheep relative to cattle may reflect a growing interest in wool as a commercial product (see also Butler 2006, 29-50).
As already mentioned, overgrazing and erosion has been a huge problem in Iceland (Gerrard 1991; Dugmore *et al.* 2000; Dugmore *et al.* 2006; Mairs *et al.* 2006). Extensive grazing by free-ranging sheep appears to be to blame, but mechanisms to prevent overgrazing were in place already by the twelve hundreds, so there is no saying that overgrazing had to happen (Laws of Early Iceland (Grágás) K § 201 – § 204 in Dennis *et al.* 2000, 131-137; Simpson *et al.* 2001, 176; see also Thomson *et al.* 2005; Thomson and Simpson 2007).
In the Faroes, a special system to design flock size on communal grazing was developed (the concept 'skipan'). The 'Seyðabrævið' ('the sheep-letter') from June 24 AD 1298 introduced rules for eliminating 'wild' sheep (Christiansen 1991, 48).
The home-field was the 'heart' of the farm. Its size and productivity were closely linked to the size of the herd: manure from the stables was needed to fertilize the home-field, which in turn produced the better part of the winter fodder. Additional fodder was collected from meadows, bogs, and at the shielings (Amorosi *et al.* 1998), but still a certain home-field / herd-size ratio had to be maintained. Soil analyses have showed that all across the North Atlantic the home-fields were cared for and improved (Adderley and Simpson 2005; Amorosi *et al.* 1998; Sveinbjarnardóttir *et al.* 2008).

5. Subsidiary subsistence economies

The farms could not survive without the surplus from 'wild' resources. The Faroes are famous for its pilot-whale drives, where schools of whales *(Globicephala melas)* are driven into the shallows and speared (Joensen 1976); but fishing and stockfish production has always been equally important. Eventually stockfish also became an important export commodity. Finally there was the bird catching; eggs were collected and waterfowl netted in the nesting colonies of puffin *(Fratercula arctica)*, common auk or common murre *(Uria aalge)*, and razorbill *(Alca torda)*, but also fulmar *(Fulmarus glacialis)* and the northern gannet *(Morus bassanus)* were caught (Joensen 1980, 105-118).
Iceland was first and foremost a place for fishing; zoo-archaeological examination of middens show that stockfish (dried fish mostly of the *gadid* stock) was part of the staple food for both coast- and inland settlers directly after 'landnám' (McGovern *et al.* 2006; McGovern *et al.* 2007). From early on the Icelandic Westfjords produced a surplus of stockfish which was traded to other parts of Iceland (Jón Viðar Sigurðsson pers. comm.). From the twelfth century stockfish and shark-liver oil became huge commercial export articles from Iceland (Edvardsson 2005; Amundsen *et al.* 2005; McGovern *et al.* 2007; Perdikaris 1999; Perdikaris and McGovern 2005; and 2008), together with woollen cloth. The size of the Icelandic stockfish export is hard to estimate, as much was sold in violation of rules imposed by the Norwegian king, but by the fourteenth century Icelandic stockfish was a well-known commodity on the European market (Wubs-Mrozewicz 2008).

Salmonidae (trout and arctic charr) for local consumption were caught in lakes and rivers, and in the Lake Mývatn region thousands of eggs from ca. 40 nesting duck species were harvested (McGovern *et al.* 2006; McGovern *et al.* 2007). Finally, seals were caught in some areas, mostly by net (Laws of Early Iceland (Grágás) K § 212 in Dennis *et al.* 2000, 142 and footnote 282). Like in the Faroes, waterfowl were caught at the nesting colonies.

Norse Greenland was the only area with a land mammal of some size; the caribou *(Rangifer caribou)* was hunted both in the Eastern and in the Western settlements, but appears to have ended up selectively on the table at the richest farms (McGovern et al 1996). The largest source of staple-food was the migratory seals; the harp *(Pagophilus groenlandicus)* and the hooded *(Cystophora cistata)* seals which pass the West Coast of Greenland on their way north in the early spring. The Norse Greenlanders caught them in huge numbers in some sort of communal effort, possibly organized in manners that resembled the Faroese pilot-whale drives (McGovern 1986; Diamond 2005, 231; McGovern *et al.* 2007).

Rhetorically Jared Diamond (2005, 240) asked why the Norse Greenlanders did not learn from the Thule Inuit to hunt ringed seal *(Pusa hispida)* with toggle harpoons. The answer is probably that they needed seals in such quantities that communal net catching of the migratory species was the only option.

Another issue – why the Norse Greenlanders did not eat fish (!) – was also raised by Diamond (2005, 229-230), The question is based on negative evidence: it is true that fish-bones are rarely found in Norse Greenland middens, while similar middens in Iceland are teeming with fish-bones, but this is not proof that the Greenlanders did not eat fish. Analyses of stable isotopes in human skeletal material show that the Norse Greenlanders did indeed eat both fish and marine mammals; they must simply have disposed of the fish-bones in ways which, at least this far, has made them invisible in the archaeological record. Most likely, they were utilized in some way as an energy source.

The stable isotope analyses on the skeletons of Norse Greenlanders show that the population started out with a diet consisting of some 30 % marine food at 'landnám' around AD 1000. By the fifteenth century the maritime component was in the range of 50 – 80 % (Arneborg *et al.* 1999; Dugmore *et al.* 2007, 26). This is normally seen as an ecological adaptation to a more marine diet in the face of the oncoming Little Ice Age.

Norse Greenland was famous for its export of walrus ivory, which was acquired in the region known in the written sources as 'Norðurseta' (the Northern hunting-grounds) which most scholars identify with Disko Bay (Gulløv 2004, 212). 'Arctic exotica' such as falcons, polar bears, fox pelts, narwhale- and walrus tusks, were cash-crop aimed for export. These commodities fetched good prices on the European market, but it is doubtful whether the hunters in Greenland benefited. More likely, the 'arctic exotica' brought status and luxury to the elite.

Even though the Norse Greenland export came to an abrupt halt around in the mid-fourteenth century, the wool- and stockfish-industries of Iceland and the Faroes continued to grow in the centuries after that. This is indeed a paradox, as the export was increased during adverse climate conditions (the Little Ice Age).

The combined effects of cooling climate and increased export represented a double stressor to the North Atlantic communities: in addition to the adverse climate conditions more and more of the local products were diverted to be consumed somewhere else (see O'Sullivan 2008, 48; Lambin 2005). Often this kind of development is associated with increased social complexity (see O'Sullivan loc. cit.).

This was the situation in Iceland, but it is also clear that during the Middle Ages the North Atlantic communities (except Greenland) came more and more under the influence of the European merchant economies. The European populations needed food, and the North Atlantic cod could be harvested in seemingly unlimited amounts. What is more, the cod was not vulnerable to the cooling of the Little Ice Age. To the Norse, this was a welcome subsidy to a diminishing farm production.

6. Farmers, fishermen or hunters?

How should the Norse in the North Atlantic be understood? Were they farmers who went fishing, or fishermen who went farming?

The traditional approach has been to see them as farmers, simply because farms and farming activities are omnipresent in the written sources: in the land registers, in the tax cadastres, and in family sagas. Hunting and fishing has not received even a fraction of that attention, despite the obvious importance of marine food. The 'agrarian approach' to the Norse farm has been deemed biased by some scholars who argued that the farm did not represent the 'real' subsistence economy. The 'real' economy, they argued, was hunting and fishing (e.g. Bertelsen 1998, 261; 1999; and 2005; Edvardsson 2005).

'The big problem is whether we should consider the mixed economy [i.e. farming and fishing] as a strategy to cope with the marginality of farming or if we should think of it in terms of a structural dichotomy…' (Bertelsen 1999, 264-265).

The semantics are less relevant – the farm stands out as the single most important social and economic institution in the Norse world. This was true for the North Atlantic islands, and it was true for North Norway way into the Middle Ages. The Late Iron Age chieftain's hall at Borg in Lofoten in North Norway has a length of more than 80 meters; it is the largest hall ever excavated in Scandinavia, and a powerful symbol of the importance of farms (Munch *et al.* 2003).

It is easy to get lost in the various types of adaptation to the local resources, and to forget that Norse adaptation was about more than just staying alive. The European merchant economy evolved rapidly during the Middle Ages, as did the social complexity of the Norse societies. With the introduction of Christianity and the Roman Catholic Church, the complexity and the social stratification increased. The development from charismatic kingship in the Viking Period to states in the High Middle Ages added to the complexity.

The Norse communities were a fringe which at first supplied Europe (and the Middle East) with 'arctic exotica'. Soon, however, they were engaged in the European food trade as major suppliers of marine protein. The distribution was taken care of by European traders; the Hansards, the English, and the Dutch (Wubs-Mrozewicz 2008).

There has been a tendency to forget that events on the European scene (and market) had consequences at the northern margins of the world. Commercial fishing in the north Atlantic was not only about local climate and environment; it was increasingly about events that affected the European markets.

The value of farms was not only estimated on the bases of their agricultural qualities. The 'lunner' (i.e. privately owned assets such as driftwood beaches, egg- collection sites, drying-racks for stockfish etc) were seen as taxable farm resources.

As noted above, the Norse Greenlanders based much of their subsistence on migratory seals (McGovern 1986; Diamond 2005, 231; McGovern *et al.* 2007). Stable isotope analyses show that when the environmental conditions deteriorated they

increased their intake of marine food up to around 50 - 80 percent of the total (Arneborg *et al.* 1999; Dugmore *et al*. 2007, 26; Dugmore *et al.* 2007).

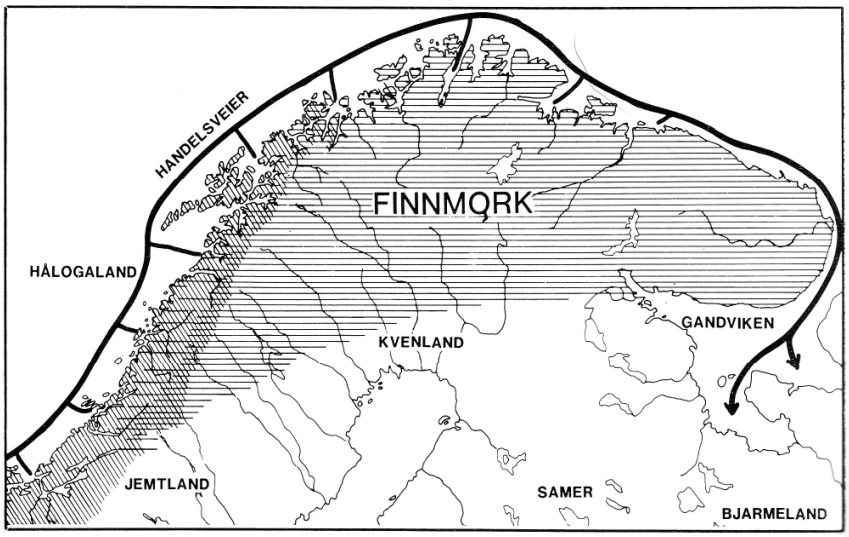

Fig. 9
Coastal settlement and trade-routes in Northern Fenno-Scandia ca. A.D. 900-1000. The coastal strip with permanent farm-based settlement (diagonal hatching) was the Norse 'Hålogaland'. The 'Sámi' settlement areas (horizontal hatching) was called 'Finnmork'. (From Årseth 1982, 10).

Ragnar Edvardsson describes how only 20 – 30 percent of the farm value in the Icelandic West fjords was based on agriculture, while 50 – 60 percent came from fishing. In more benign regions in Iceland the farming represented 60 – 80 percent of the value (Edvardsson 2005, 53; also Krivogorskaya *et al.* 2005).
For North Norway Reidar Bertelsen argues that some of the Iron Age sites based 75 percent of their subsistence on cattle and sheep, while others based 75 percent on marine resources (Bertelsen 2005, 22-23), although Perdikaris (1998, 104-108) concludes differently from the same material.
It is safe to state that fish was important, but this does not make the agrarian approach to the Norse communities 'wrong', nor does it make the hunting-and-fishing approach 'right'.
The farm aspect is a question of social organization: in the 'Landnámabók' ('the Book of Settlement' written in Iceland in the twelfth to fourteen century) and in the Icelandic law code 'Grágás' (Dennis *et al.* 2000) practically all legal rights and all access to resources are somehow linked to farms. So from an ideological as well as a judicial point of view, the Norse communities were farming communities. The farm was the common denominator; whether people *de facto* lived from farm produce (local or imported), or whether they lived from fishing, seal-hunting, whaling, and bird-catching. They still belonged to a farm.
In a cultural perspective it may be argued that the Norse expansion into the North Atlantic was the extension of an idea; the idea of the farm-based society. In some respects this may sound strange since it was the ship and the maritime capabilities of the Norse that made the expansion across the North Atlantic possible, and to a great extent secured the survival of the Norse. But the purpose, the incentive, the whole utopian idea of a new society was based on the idea of the farm.
In their 'real economy' the Norse communities depended heavily on 'wild' resources. In this perspective, the amount of labour and energy invested to keep the domestic animals alive over the winter may look completely out of proportion. Still, it is obvious that they did go that extra mile, again and again. This is hard to explain unless the farm also was essential also for social, non-economic reasons.

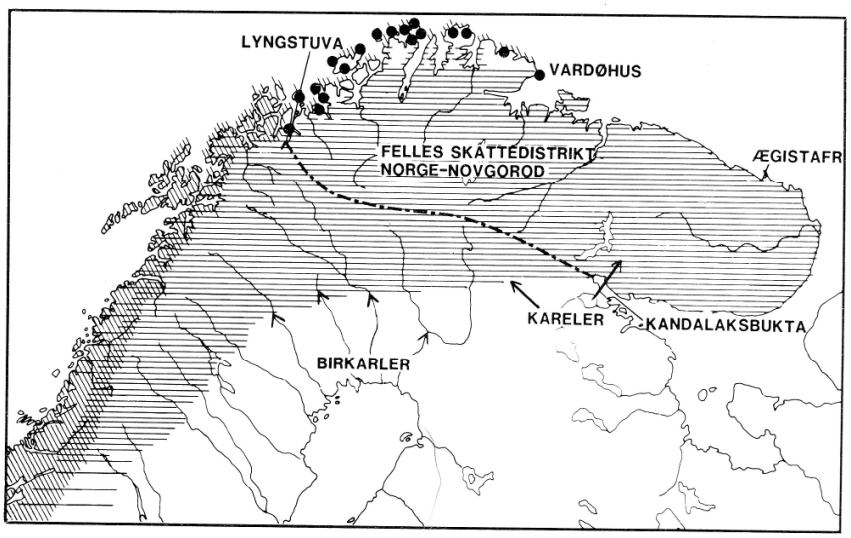

Fig. 10
Finnmork ca. AD 1300 – 1500. Note the expansion of Norwegian fishing-villages (black dots) on the outer coast of the 'Sámi' homeland 'Finnmork' in this period. The fortress at 'Vardøhus' was raised by Norwegian King Hákon V. Magnusson AD 1307 to guard the Norwegian sphere of interest, i.e. both the commercial fishing and the taxation of the 'Sámi'. In the interior the 'Sámi' were taxed by Norwegians; by 'Birkarlar' on behalf of Sweden; and by Karelians on the behalf of Novgorod (From Aarseth 1982, 14).

The commercial fishing which developed in the Lofoten region from the twelfth century triggered a Norwegian expansion to the north, into Sámi territory (Fig. 9). Pure fishing villages with no agrarian potential were established on the outer coast. It was a commercially driven expansion, a direct response to the growing market for stockfish in Europe.
This particular settlement pattern could only have developed under the umbrella of the Norwegian king: After the rise of the Lofoten stockfish trade in the twelfth century, the town of Bergen in West Norway was established as a royal and clerical fiscal point. Foreign traders to Norway were not allowed beyond this point, and this benefited a new class of North Norwegian 'big-men' who provided the logistics between the fishermen up north, and the foreign merchants in Bergen; lifting fish one way and agricultural produce the other.
It was this royal protection which allowed the establishment of specialized fishing-villages in North Norway. When commercial fishing developed in Iceland, it was without permanent fishing-villages; the Icelandic fishermen always retained their association with a farm; hence they had something to sustain them in periods of 'black sea'.
The picture which emerges of the 'northern frontier for agriculture' in the North Atlantic is complex. Norse societies appear as bundles of farm-based communities, but with a built-in economic duality; hence the term 'the green and the blue foot' of the Norse economy. This duality provided the Norse with alternative strategies; in times of agrarian crisis they could turn to the sea, and in case of 'black sea' they could turn to their farms.
Despite its dual resource base, the population in the North Atlantic islands suffered a double exposure which challenged their very existence: the stress of a rapidly cooling climate during the Little Ice Age coincided with a socio-political development from chiefly, ranked societies in the Viking Age to stratified societies in the High Middle Ages. This development was not home-grown, but reflected socio-political changes all over Europe. In a stratified society there are less people taking part in the actual production, and so the remainders have to produce more to maintain the social order.

This development must have been amplified by the fact that the climate was deteriorating. (See Vasey 1996 on population and ecology).
O'Sullivan explains that the environmental impact of stratified societies is inherently greater *per capita* than that of ranked societies (O'Sullivan 2008, 48). He writes: "The more complex the society, the greater the inequality and the greater the surplus required (Harris 1988). In that more and more local production is diverted to support non-local consumption (as opposed to local need), in strict ecological terms, the more complex a society, the more it lives beyond its (local) means." (O'Sullivan loc. cit.; also Lambin 2005; Holling and Gunderson 2002; Dugmore *et al.* 2007b).
The historic events that played out in the different areas and regions of the North Atlantic are many and complex, and cannot be understood simply by pointing to a few economic and environmental 'triggers'. Reality is always more complex than the theoretical models; but on a larger scale, this is the environmental and socio-political framework within which the farming in the North Atlantic existed.

Bibliography

Adderley, P. W., and Simpson, I. A.
2005 Early-Norse Home-Field Productivity in the Faroe Islands. *Human Ecology* 33 (5) 7 11-736

Albrethsen, S. E. and Keller, C.
1986 The Use of Saeter in Norse Medieval Greenland. *Arctic Anthropology* vol. 23 Nos 1 and 2, University of Wisconsin Press

Amorosi, T., Buckland, P. C., Edwards, K. J., Mainland, I. L., McGovern, T. H., Sadler, J. P., and Skidmore, P.
1998 The Did Not Live by Grass Alone: The Politics and Paleoecology of Animal Fodder in the North Atlantic Region. *Environmental Archaeology* 1. 41-54

Amundsen, C., Perdikaris, S., McGovern, T. H., Krivogorskaya, Y., Brown, M., Smirowski, K., Storm, S., Modugno, S., Frik, M., and Koczela, M.
2005 Fishing Booths and Fishing Strategies in Medieval Iceland: An Archaeofauna from the Akurvík, North-West Iceland. *Environmental Archaeology* 10(1) 127-142

Arge, S. V.
1991 The landnám in the Faroes. *Arctic Anthropology* 28 (2), University of Wisconsin Press 101-120
2006 Uttangarðs. Relics in the Faroe outfield. Holm, I., Innselset, S., and Øye, I. (ed.s) 'Utmark'. *The outfield as industry and ideology in the Iron Age and Middle Ages.* University of Bergen Archaeological Series – International 1. University of Bergen 67-81

Arge. S. V, Sveinbjarnardóttir, G., Edwards, K. J., and Buckland, P. C.
2005 Viking and medieval settlement in the Faroes: People, place and environment. in *Human Ecology* 33 (5) 711-737

Arge, S. V., Church, M. J., and Brewington, S. D.

2009 Pigs in the Faroe Islands: An Ancient Facet of the Islands' Paleoeconomy. *Journal of the North Atlantic* Vol. 2. 19-32
http://www.eaglehill.us/programs/journals/jona/journal-north-atlantic.shtml

Arnalds, O., Thorarinsdóttir, E. F., Metusalemsson, S., Jonsson, A., Gretarsson, E., and Arnason, A.
1997 *Soil Erosion in Iceland.* Reykjavík: Icelandic SCS and the Agricultural Research Institute

Arneborg, J.; Heinemeier, J., Lynnerup, N., Nielsen, H. L., Rud, N., and Sveinbjörnsdóttir, A. E.
1999 Change of Diet of the Greenland Vikings Determined from Stable Carbon Isotope Analysis and ^{14}C Dating of their Bones. *Radiocarbon*157-168

Aarseth, B.
1982 Kystsamenes besetting I rikspolitisk sammenheng. *OTTAR, Tidsskrift for nordnorsk natur og kultur* Nr. 137 Vol. 4:1982, special issue *'Kystsamisk bosetting'* guest editor Bjørn Aarseth 10-29

Bertelsen, R.
1985 *Lofoten og Vesterålens Historie. Fra den eldste tida til ca. 1500 e.Kr.* Kommunene i Lofoten og Vesterålen
1999 Settlement on the divide between land and ocean. From Iron Age to Medieval Period along the coast of Northern Norway. Fabech, C. & Ringtved, J. (ed.s): *Settlement and Landscape. Proceedings of a conference in Århus, Denmark May 4-7 1998.* Jutland Archaeological Society. Aarhus 261-267
2005 "The Sea as 'innmark' or 'utmark'. Holm, I., Innselset, S., and Øye, I. (ed.s): *'Utmark' – The Outfield as Industry and Ideology in the Iron Age and the Middle Ages.* UBAS International 1. University of Bergen Archaeological Series. University of Bergen 21-30

Buckland, P., Edwards, K. J. Panagiotakopulu, E., and Schofield, E.
2008 Land management at the bishop's seat, *Garðar*, medieval Greenland. *Antiquity* Vol 82 Issue 315 March 2008 http://antiquity.ac.uk/index.html

Butler, A.
2006 *Sheep. The remarkable story of the humble animal that built the modern world.* Winchester, UK. New York, USA

Byock, J.
2001 *Medieval Iceland. Society, Sagas, and Power.* Berkeley: University of California Press

Christiansen, S.
1990 Faroese spade cultivation, reinavelta, its practice, function and history. Pp 143-153 in *Ródskaparrit*, 38-39. Torshavn
1991 Nordatlantisk landbrugskultur i komparativ økologisk belysning. Pp 46-50 in Jóan Pauli Joensen, Ruth Johansen og Jan Kløvstad (ed.s) *Nordatlantiske foredrag*. Norðurlandshúsið í Føroyum og rithøvundarnir. Tórshavn
1996 Gåsadalur - the old agricultural landscape. Pp.74-77 in Guttesen, R. (ed.) *The*

Faeroe Islands Topographic Atlas. Atlas of Denmark, 11(5). The Royal Danish Geographical Society, Copenhagen.

Christiansen, S. and Guttusen, R.
1987 Kornavl på Færøerne. *Carlsbergfondets årbog*

Dennis, A., Foote, P., and Perkins, R.
2000 *Laws of Early Iceland. Grágás II. The Codex Regius of Grágás with material from other manuscripts.* The University of Manitoba Press

Diamond, J.
2005 *Collapse – How Societies Choose to Fail or Survive*. Allan Lane, Penguin Group

Dugmore, A. J., Newton, A. J. and Larsen, G.
2000 Tephrochronology, environmental change and the Norse settlement of Iceland. *Environmental Archaeology* 5 21-34

Dugmore, A. J., Buckland, P. C., Church, M. J., Edwards, K. J., Lawson, K. J., McGovern, T. H., Panagiotakopulu, E., Simpson, I. A., Skidmore, P. and Sveinbjarnardóttir, G.
2005 The Norse landnám on the North Atlantic islands: An environmental impact assessment. *Polar Record* 41 21-37

Dugmore, A. J., Church, M. J., Mairs, K. A., Newton, A. J. and Sveinbjarnardóttir, G.
2006 An over-optimistic pioneer fringe? Environmental perspectives on medieval settlement abandonment in Þórsmork, south Iceland. Arneborg, J. and B. Grønnow (ed.s): *The Dynamics of Northern Societies*. Publications from the National Museum, Studies in Archaeology and History, Volume 10. Copenhagen 335-346

Dugmore, A. J., Borthwick, D. M., Church, M. J., Dawson, A., Edwards, K. J., Keller, C., Mayewski, P., McGovern, T. H., Mairs, K. A., and Sveinbjarnardóttir, G.
2007a The role of climate in settlement and landscape change in the North Atlantic islands: An assessment of cumulative deviations in high-resolution proxy climate records. *Human Ecology* 35 (2) 169-178

Dugmore, A. J., Keller, C. and McGovern, T. H.
2007b Norse Greenland settlement: Reflections on climate change, trade, and the contrasting fates of human settlement in the North Atlantic islands. *Arctic Anthropology* 44 (1) 12-36

Dugmore, A. J., Gisladottir, G., Simpson, I. A. and Newton, A.
2009 Conceptual models of 1200 years of Icelandic soil erosion reconstructed using tephrochronoloy. *Journal of the North Atlantic*, Volume 2. Eagle Hill Foundation / Northern Research Network 1-18

duBois, T. A.
1999 *Nordic religions in the Viking Age*. Philadelphia

Dumézil, G.

1977 (1973) *Gods of the ancient Northmen*. Berkeley

Edvardsson, R.
2005 Commercial and Subsistence Fishing in Vestfirðir. A Study in the Role of Fishing in the Icelandic Medieval Economy. Gavin Lucas (ed.) *Archaeologia Islandica. Occasional Papers on Icelandic Archaeology* Vol. 4.. Fornleifastofnun Íslands, Reykjavik 51-67

Edwards, K. J.
2005 "On the windy edge of nothing". A historical ecology of the Faroe Islands. *Human Ecology* 33 (5) 585-596

Edwards, K. J., Borthwick, D., Cook, G., Dugmore, A. J., Mairs, K. A., Church, M. J., Simpson, I. A., and Adderly, P. A.
2005a A hypothesis based approach to landscape change in Suðuroy, Faroe Islands. *Human Ecology* 33 (5) 621-650

Edwards, K. J., Lawson, I. T., Erlendsson, E. and Dugmore, A. J.
2005b Landscapes of contrast in Viking Age Iceland and the Faroe Islands. in *Landscapes* 6 (2) 63-81

Einarsson, Þ.
1963 Pollen analytical studies on the vegetation and climate history of Iceland in Late and Post-glacial times. Love, A. and Love, D. (ed.s) *North Atlantic biota and their history*. Pergamon Press, Oxford

Einarsson, Á., Hansson, O., and Vésteinsson, O.
2002 An Extensive System of Medieval Earthworks in Northern Iceland. Gavin Lucas (ed.) *Archaeologia Islandica. Rit Fornleifastofnunar Íslands* Vol. 2. Fornlefastofnun Íslands, Reykjavík 61 – 73

Fagan B.
2000 *The Little Ice Age. How climate made history 1300-1850*. Basic Books. New York

Fitzhugh, William W. and Ward, E. I. (ed.s)
2000 *Vikings. The North Atlantic Saga*. The Smithsonian Institution Press Washington and London, in association with National Museum of Natural History (New York)

Fjærvoll, K.
1961 *Korndyrkinga i Hålogaland i gammal tid. 1500- og 1600-åra*. Svorkmo

Franklin, S. and Shepard, J.
1996 *The Emergence of Rus 750-1200. Series Longman History of Russia.* Longman, London and New York

Fredskild, B.
1973 Studies in the vegetational history of Greenland. *Meddelelser om Grønland.* 203 (5)

Friðriksson, A.
1994 *Sagas and popular antiquarianism in Icelandic archaeology*. Ashgate, Aldershot

Gerrard, J.
1991 An assessment of some of the factors involved in recent landscape change in Iceland. Maizels, J. K. and Cheseldine, C. (ed.s) *Environmental change in Iceland: Past and present*. Klüwer. Netherlands 237-253

Gjerland, B. and Keller, C.
2009 Graves and Churches of the Norse in the North Atlantic – a Pilot Study. In Jette Arneborg, Georg Nyegaard & Orri Vésteinsson (ed.s). 2009, Norse Greenland. Selected papers from the Hvalsey conference 2008, *Journal of the North Atlantic.* Special volume 2:

Graham-Campbell, J.
2001 *The Viking World.* Frances Lincoln. London

Grove, J. M.
1988 *The Little Ice Age.* Methuen. London

Grønvold, K., Askarsson, N., Johnsen, S. J., Clausen, H. B. Hammer, C. U., Bond, G., and Bard, E.
1995 Tephra layers from Iceland in the Greenland GRIP ice core correlated with oceanic and land based sediments. *Earth and Planetary Science Letters* 135 149-155

Guðmundsson, G. and Snæsdóttir, M.
2001 *Meintir fornir akrar í Akurey á Kollafirði, í landi Hólavalla í Gerðahreppi, Ketilsstaða og Fagradals í Mýrdal; skýrsla vegna könnunar skurða er teknikk voru haustið 1999.* Fornleifastofnun Ísland. (Report FSÍ – The Archaeological Institute of Iceland)

Guðmundsson, G., Snæsdóttir, M. Simpson, I. A., Hallsdóttir, M., Sigurdeirsson, M. A., and Árnason, K.
2004 Fornir akrar á Íslandi. Meintar minjar um kornrækt á fyrri öldum. *Árbók Fornleifafelagsins 2004*. Reykjavík 79-105

Gulløv, H. C. (ed.)
2004 *Grønlands forhistorie*. Gyldendal, Copenhagen

Guttormsen, H.
1994 *Andøy bygdebok Volume I. Fra Omd til Andøy. Andøys historie fra de eldste tider og opp til 1800 e. Kr. f.* Andøy Kommune

Halstead, P.
1998 Mortality Models and Milking; problems of uniformitarianism, optimality, and equifinality reconsidered. *Anthropozoologica* 27 3-20

Harris, M.
1988 *Culture, people, nature: an introduction to general anthropology*. Harpet and Row

Hambrecht, G.
2006 The Bishop's Beef. Improved Cattle at Early Modern Skálholt, Iceland. Gavin Lucas (ed) *Archaeologia Islandica*. Rit Fornleifastofnunar Íslands Vol. 5. Fornleifastofnun Íslands, Reykjavík 82-94

Hansen, L. I.
1990 *Samisk fangstsamfunn og norsk høvdingeøkonomi*. Novus forlag, Oslo

Hastrup, K.
1989 Saeters in Iceland 900 – 1600. An Anthropological analysis of economy and cosmology. *Acta Borealia* 1-1989. Båstad 72-85

Hermannsson, H.
1929 'Icelandic Manuscripts' in *Islandica* Vol. XIX, Cornell University Library, Itacha, New York

Hitzler, E.
1979 *Sel-Untersuchungen zur Geschichte des isländischen Sennwesens seit der Landnahmezeit*. Instituttet for sammenlignende kulturforskning. Norwegian University Press

Hjálmarsson, J. H.
1993 *History of Iceland. From the Settlement to the Present Day*. Iceland Review

Holling, C. S. and Gunderson, L. H.
2002 Resilience and adaptive cycles. Gunderson, L. H. and Holling, C. S. (ed.s) *Panarchy. Understanding transformations in human and natural systems.* Island Press. Washington 25-63

Joensen, J. P.
1976 Pilot Whaling in the Faroe Islands*. Ethnologia Scandinavica* 5-42
1980 *Färöisk folkkultur*. Handbok i etnologi. Liber Läromedel, Lund

Keller, C.
1989 The Eastern Settlement Reconsidered. Some analyses of Norse Medieval Greenland. PhD Thesis. University of Oslo
1990: 'Vikings in the West Atlantic: A Model of Norse Greenlandic Medieval Society.' *The Norse of the North Atlantic* 61 Munksgaard 126-141

Krogh, K. J.
1982 Erik den Rødes Grønland. Nationalmuseets forlag. Copenhagen

Konstam, A.
Historical Atlas of the Viking World. Mercury Books. London

Konungs skuggsjá – the King's mirror

1250-1260 Udtog af Konúngs skuggsjó angaaende Grönlands beliggenhed og physiste mærkværdigheder m.m. *GHM (Grønlands Historiske Mindesmærker*) Vol. III, particularly p 33 (in Old Norse and Danish) 264-392. Also http://www.mediumaevum.com/75years/mirror/ ch. XVIII in English.

Kristjánsdóttir, S.
2004 *The Awakening of Christianity in Iceland. Discovery of a Timber Church and Graveyard at Þorarinsstaðir in Seyðisfjörður*. Gotarc. Gothenburg Archaeological Thesis. Series B No 31. University of Gothenburgh

Krivogorskaya, Y., Perdikaris, S., and McGovern, T. H.
2005 Fish Bones and Fishermen: the Potential of Zooarchaeology in the Westfjords. Gavin Lucas (ed.) *Archaeologia Islandica.* Occasional Papers on Icelandic Archaeology Vol. 4.. Fornleifastofnun Íslands, Reykjavik 31 – 50

Lagerås, P.
2007 *The Ecology of Expansion and Abandonment. Medieval and post-medieval agriculture and settlement in a landscape perspective*. National Heritage Board, Sweden

Lambin, E. F.
2005 – Conditions for sustainability of human–environment systems: Information, motivation, and capacity. Editorial: *Global Environmental Change* 15 (2005). 177-180. On-line at: www.sciencedirect.com

Larrington, C. (translation and editing)
1996 and 1999 *The Poetic Edda*. Translated with an Introduction and Notes by Carolyne Larrington. Oxford World's Classics. Oxford University Press

Lawson, I. T., Edwards, K. J., Erlendsson, E., Vésteinsson, O., Dugmore, A. J., Mairs, K. A., Church, M. J., Simpson, I., Adderley, P., McGovern, T. H.
2006 Betula pubescens and the settlement of Iceland. Arneborg, J. and Grønnow, B. (ed.s): *The Dynamics of Northern Societies*. PNM, Publications from the National Museum. Studies in Archaeology and History, Volume 10. Copenhagen 321-331

Lucas, G. (ed.)
2009 *Hofstaðir. Excavations of a Viking Age Feasting Hall*. Monograph No. 1, Institute of Archaeology, Reykjavik IN PREP

McGovern, T. H.
1980 Cows, Harp Seals, and Churchbells: Adaptation and Extinction in Norse Greenland, in *Human Ecology*, Vol. 8, No. 3. Plenum Publishing Corporation.
1981 'The economics of extinction in Norse Greenland' Wrigley, T. M. L., Ingram, M. J., and Farmer, G. (ed.s) *Climate and History*. Cambridge University Press, 404-433
1986 *The Paleoeconomy of Norse Greenland: Adaption and Extinction in a Tightly Bound Ecosystem*. PhD Dissertation
1994 'Ch. 6: Management for Extinction in Norse Greenland.' C. L. Crumley (ed): *Historical Ecology. Cultural Knowledge and Changing Landscapes*. School of American Research Press 127-154

2000 'Ch. 25: The Demise of Norse Greenland.' Ward, E. I. and Fitzhugh, W. W. (ed.s) *Vikings. The North Atlantic Saga*. Smithsonian Institution Press in association with the National Museum of Natural History 327-339
2009 Chapter 4. The Archaeofauna. In Lucas, G. (ed.) Hofstaðir. Excavations of a Viking Age Feasting Hall. Monograph No. 1, Institute of Archaeology, Reykjavik IN PREP

McGovern, T. H., Bigelow, G., Amorosi, T., and Russell, D.
1988 Northern islands, human error, and environmental degradation. A view of social and ecological change in the Medival North Atlantic. *Human Ecology* 16 (3). 225-270

McGovern, T. H., Amorosi, T., Perdikaris, S. and Woollett, J.
1996 Zooarchaeology of Sandnes V51: Economic change at a chieftain's farm in west Greenland. *Arctic Anthropology* 33 (2) 94-122

McGovern, T. H., Perdikaris, S., and Tinsley, C.
2001 Economy of Landnám: The Evidence of Zooarchaeology. Wawn, A. and Sigurdardottir, T. (ed.s) *Approaches to Vinland.* Sigurður Nordal Institute, Reykjavík 154-165

McGovern, T. H., Perdikaris, S. P., Einarsson, A., and Sidel, J.
2006 Coastal Connections, Local Fishing, and Sustainable Egg Harvesting: Patterns of Viking Age Inland Wild Resource Use in Mývatn District, Northern Iceland. *Environmental Archaeology* 11.1 187-206

McGovern, T. H., Vésteinsson, O., Fridriksson, A., Church, M. J., Lawson, I., Simpson, I. A., Einarsson, A., Dugmore, A. J., Cook, G., Perdikaris, S., Edwards, K. J., Thomson, A. M., Adderly, P. W., Newton, A., Lucas, G., Edvardsson, R., Aldred, O., and Dunbar, E.
2007 Landscapes of Settlement in Northern Iceland: Historical Ecology of Human Impact and Climate Fluctuation on the Millennial Scale. *American Anthropologist*, Vol. 109, Issue 1. American Anthropological Association

Mahler, D. L. D.
1989 Nye spor efter sæterdrift på Færøerne. Vilhjálmsson. V. and Christensen K. M. (ed.s) *Hikuin* Vol. 15 147-170
1990 Argisbrekka: New Evidence of Shielings in the Faroe Islands. Paper read at 'The Norse of the North Atlantic' Conference April 17-19, 1988. Bowdoin College, Maine. *Acta Archaeologica* vol. 91
1991a Shielings and their role in the Viking Age Economy – new evidnce from the Faroe Islands. *Proceedings of the Viking Conference*. Caithness-Orkney
1991b Sæterdrift på Færøerne i vikingetid og tidlig middelalder? – En model. Joensen, J. P., Johansen, R., and Kløvstad, J. (ed.s). *Nordatlantiske foredrag. Seminar om nordatlantisk kulturforskning i Norden Hus på Færøerne 27. – 30. August 1990* 29-41

Mainland, I., and Halstead, P.
2005 The Economics of Sheep and Goat Husbandry in Norse Greenland. *Arctic Anthropology* 42(1) 103-120

Mairs, K. A.
2007 *Islands and human impact: Under what circumstances do people put unsustainable demands on island environments? Evidenence from the North Atlantic.* PhD Thesis. School of Geoscience. The University of Edinburgh.

Mairs, K. A., Church, M. J., Dugmore, A. J., and Sveinbjarnardóttir, G.
2006 Environmental Change and Long-Term Settlement: The Mörk and Dalur Farm Complexes of Eyjafjallasveit, South Iceland. Grønnow, B., Arneborg, J., and Gulløv, H. C. (ed.s.) *The Dynamics of Northern Societies*. PNM, Publications from the National Museum, Studies in Archaeology and History, 10. Copenhagen. The National Museum of Denmark. 363–372

Marcus, G. J.
1980 *The Conquest of the North Atlantic*. The Boydell Press, Suffolk

Mikkelsen, N., Kuijpers, A., Arneborg, J.
2008 The Norse in Greenland and late Holocene sea-level change. *Polar Record* 44 (228) Printed in the United Kingdom 45-50

Moberg, A., Sonechkin, D. M., Holmgren, K., Datsenko, N. M., Karlén, W.
2005 Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data. *Nature* 433 613-617

Munch, G. S. Johansen, O. S., and Roesdahl, E. (ed.s):
2003 *Borg in Lofoten. A chieftain's farm in North Norway*. Arkeologisk skriftserie 1. Lofotr. Vikingmuseet på Borg. Tapir academic Press

Nässström, B. M.
2001, 2002 *Fornskandinavisk religion. En grundbok.* Studentlitteratur. Lund

Noonan, T. S.
1998 *The Islamic World, Russia and the Vikings, 750-900. The Numismatic evidence*. Ashgate Variorum, Aldershot – Brookfield ISA – Singapore - Sydney

Nordal, S.
1952 'The Presidential Address 1952: Time and Vellum. Some Remarks on the Economic conditions of the Early Icelandic Literature'. P 15 ff in M.H.R.A. *Annual Bulletin of the Modern Humanities Research Association*. November 1952
1954 'Tid och Kalvskinn. Några anmärkninger om de ekonomiske förutsetningarna för den forn-isländska litteraturen'.*Scripta Islandica*, Isländska Sällskapets Årsbok 5 / 1954. Stockholm and Copenhagen 5-18

Nørrevang, A.
1970 Land tenure, fowling rights and sharing of the catch in Faroese fowling. *Fróðskaparrit* 30-39

Ogilvie, A. E. J.

1992 Documentary evidence for changes in the climate of Iceland, AD 1500 to 1800, Bradley, R.S., and P.D. Jones (ed.s) *Climate Since AD 1500.* Routledge, London 92-117

Ogilvie, A. E. J.
1998 Historical accounts of weather events, sea ice and related matters in Iceland and Greenland, AD 1250 to 1430. Frenzel, B (ed.) Documentary climatic evidence for 1750-1850 and the 14th century. *Palioklimatforschung* 23, special issue: ESF Project 'European Palaeoclimate and Mann' 15, European Science Foundation, Strasbourg. 25-43

Ogilvie, A. E. J., and Jónsson, T.
2001 „Little Ice Age" Research A perspective from Iceland. *Climate Change* 9-52

Olsen, M.
1928 *Farms and Fanes of Ancient Norway. The Place-names of a country discussed in their bearing on social and religious history*. Instituttet for sammenlignende kulturforskning. Oslo, Leipzig, Paris, London, Cambridge, Mass.

Ólasson, V.
1998 *Dialogues with the Viking Age.* Heimskringla, Mál og Menning Academic Division, Reykjavík

O'Sullivan, P.
2008 The 'collapse' of civilizations: what palaeoenvironmental reconstruction cannot tell us, but anthropology can. *The Holocene* 45-55 Net version at: http://hol.sagepub.com/cgi/content/refs/18/1/45

Pedersen, E. A.
1998 "Transformations to sedentary farming in eastern Norway: AD 100 or 1000 BC? Charlotte Fabech & Jytte Ringtved (ed.s) *Settlement and Landscape. Proceedings of a conference in Århus, Denmark, May 4-7 1998*. Jutland Archaeological Society. Århus 45-52

Perdikaris, S.
1998 *From Chiefly Provisioning to State Capital Ventures: the Transition from Natural to Market Economy and the Commercialization of Cod Fisheries in Medieval Arctic Norway*. UMI Dissertation Information Master Service. PhD Dissertation, The Graduate Center, CUNY
1999 From Chiefly Provisioning to Commercial Fishery: Long-Term Economic Change in Arctic Norway. Conway, P. R. (ed.) *World Archaeology* 30 (3) 388-402

Perdikaris, S. and McGovern, T. H.
2005 King Alfred, King Knut, and the Codfish: New Evidence for the Beginning of North Atlanic Commercial Fisheries. Paper presented at the *2005 Society for American Archaeology meetings*, Salt Lake City, September 12-17.
2008 Viking Age Economics and the Origins of Commercial Cod Fisheries in the North Atlantic Sicking, L. and Abrey-Ferreira, D. (ed.s) *Beyond the Catch. Fisheries of the North Atlantic, the North Sea and the Baltic, 900-1850*. Series: The NorhernWorld, 41. Brill. 61-90

Rieck, F., Danker, J., Kapel, H. and Raahauge, K.
2002 *Skib, naust og maritime aktiviteter i det norrøne Grønland. Rapport om prøveundersøgelser af et formodet skibsnaust og en smedje ved Ikigaat/Herjolfsnæs, Nanortalik kommune, sommeren 2001*. Feltrapport 2. SILA – Nationalmuseets Center for Grønlandsforskning og Nationalmuseets Marinarkæologiske Undersøgelser. Januar 2002

Sanmark, A.
2004 *Power and Conversion – a Comparative Study of Christianization in Scandinavia*. University College London 2002 Ph.D. Thesis. Department of Archaeology and Ancient History, Uppsala University

Sawyer, B., Sawyer, P. H., and Wood, I. (ed.s):
1987 *The Christianization of Scandinavia. Report of a Symposium helt at Kungälv, Sweden 4 – 9 August 1985*. Viktoria Bokförlag

Sawyer, P. H.
1987 *Kings and Vikings. Scandinavia and Europe AD 700-1100*. Routledge. London and New York

Sawyer, P. H. and Sawyer, B.
1993 *Medieval Scandinavia. From Conversion to Reformation, circa 800-1500*. The Nordic Series, Volume 17. University of Minnesota Press. Minneapolis. London.

Seaver, K.
1996 *The Frozen Echo. Greenland and the Exploration of North America, ca. A.D. 1000-1500*. Stanford University Press, Stanford, California

Simpson, I. A., Dugmore, A. J., Thomson, A. M., and Vésteinsson, O.
2001 Crossing the Thresholds: Human Ecology and the Historical Patterns of Landscape Degradation. *Catena* 42 175-192

Simpson, I. A., Vésteinsson, O., Adderley, W. P., and McGovern, T. H.
2003 Fuel Resources in Landscapes of Settlement. *Journal of Archaeological Science* 1401-1420

Simpson, I. A., Adderley, W. P., Guðmundsson, G., Hallsdóttir, M., Sigurgeirsson, A, and Snæsdóttir, M.
2002 Land Management for Surplus Grain Production in Early Iceland. *Human* Ecology 30 423-433

Skarði, Jóhannes av
1970 *Faroese Cultivating and Peat Spades*. Ulster Folk Museum 1970

Steinsland, G.
2005 *Norrøn religion. Myter, riter, samfunn*. Pax forlag. Oslo

Scofield, E. J., Edwards, K. J., and McMullen, A. J.

2006 Modern pollen-vegetation relationships in subarctic southern Greenland and the interpretation of fossil pollen data from the Norse landnám. *Journal of Biogeography* (OnlineEarly Articles)

Sveinbjarnardóttir, G. 1990 Shielings in Iceland – An Archeological and Historical Survey. The Norse in the North Atlantic. *Acta Archaeologica* Vol. 61.

Sveinbjarnardottir, G., Erlendsson, E., Vickers, K., McGovern, T. H., Milek, K. Edwards, K. J., Simpson, I. A., and Cook, G.
2007 The paleoecology of a high status Icelandic farm. *Environmental Archaeology* 2007 Volume 12, Number 2. Maney Publishing 187-206

Sveinbjarnardóttir, G., Simpson, I. A., Thomson, A. M.
2008 Land in Landscapes circum Landnám: an Integrated Study of Settlements in Reykholsdalur, Iceland. *Journal of the North Atlantic*. Eagle Hill Foundation 1-15

Søgaard, H.
1996 Klima, vind og vejrlig på Færøerne. *Topografisk Atlas Færøerne*. Det Kongelige Danske Geografiske Selskab og Kort og Matrikelstyrelsen. C.A. Reitzels Forlag, Copenhagen 24-26. English edition same year: Guttesen, R. (ed.): *The Faroe Islands Topographic Atlas. Atlas of Denmark*, 11(5). The Royal Danish Geographical Society, Copenhagen.

Thomas, J.
1996 "The cultural context of the first use of domesticates in continental central and northwestern Europe". Harris, D. (ed.) *The Origins and Spread of Agriculture and Pastoralism in Eurasia.* UCL Press. London 310-322

Thomson, A. M.,
2003. *A modeling approach to farm management and vegetation degradation in pre-modern Iceland*. PhD Thesis, University of Stirling, Stirling, 301 pp. http://dspace.stir.ac.uk/dspace/handle/1893/23

Thomson, A. M. and Simpson, I. A.
2006 A Grazing Model for Simulating the Impact of Historical Land Management Decisions in Sensitive Landscapes: Model Design and Validation. *Environmental Modeling and Software* 21 1096-1113
2007 Modeling Historic Rangeland Management and Grazing Pressures in Landscapes of Settlement. *Human Ecology* 35 151-168

Thomson, A. M., Simpson, I. A. and Brown J. L.
2005 Sustainable rangeland grazing in Norse Faroe. *Human Ecology* 33 (5) 737-761

Thomson, A. M. and Simpson, I. A.
2007 Modelling historic rangeland management and grazing pressure in landscapes of settlement. *Human Ecology* 35 151-168

Vasey, D. E.
1996 Population regulation, ecology, and the political economy in preindustrial Iceland. *American Ethnologist* 23 (2) 366-392

Vésteinsson, O.
2000 *The Christianization of Iceland. Priests, Power, and Social Change 1000-1300.* Oxford University Press

Vésteinsson, O., McGovern, T. H., and Keller, C.
2002 Enduring Impacts: Social and Environmental Aspects of Viking Age Settlement in Iceland and Greenland. *Archaeologia Islandica* 2. Fornleifastofnun Íslands. Reykjavík 98-136

Vésteinsson, O. and Simpson, I. A.
2004 Fuel. Utilization in Pre-Industrial Iceland: A Micro-Morphological and Historical Analysis. Gudmundsson, G. (ed.) *Current Issues in Nordic Archaeology: Proceedings of the twenty first Conference of Nordic Archaeologists*, September 6-9, 2001. Archaeological Institute, Iceland. Reykjavík 181-187

Widgren, M.
1998 "Reflections on landscape and settlement transformation" Fabech, C. & Ringtved, J. (ed.s): *Settlement and Landscape. Proceedings of a conference in Århus, Denmark, May 4-7 1998.* Jutland Archaeological Society. Århus 31-34

Wubs-Mrozewicz, J.
2008 Fish, stock and barrel. Changes in the stockfish trade in northern Europe c. 1360-1560' Sicking, L. and Abrey-Ferreira, D. (ed.s): *Beyond the Catch. Fisheries of the North Atlantic, the North Sea and the Baltic, 900-1850*. Series: The Norhern World, 41. Brill 86-101

Þórarinsson, S.
1944 Tefrokronologiska studier på Island. *Geografiska Annaler* 26 1-217
1970 Tephrochronology and medieval Iceland. In Berger, R. (ed.): *Scientific methods in medieval archaeology*. University of California Press. Berkeley
1981 The application of tephrochronology in Iceland. Self, S. and Sparks, S. J. (ed.s): *Tephra Studies*. D Reidel 109-134

---0---

Word count this file:
Text only: 7 299 words
33 036 characters without space
807 lines
Text, Figures and bibliography:
29 pages
11 265 words
62 217 characters without space
1 425 lines
Figures in the present file deviate a little bit from the individual figure files
All Figures available as .tif-files