

Have we been here before? Climate change, and the contrasting fates of human settlements in the Atlantic islands

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Human Security and Climate Change

An International Workshop
Holmen Fjord Hotel, Asker, near Oslo, 21–23 June 2005

Organizers:

Centre for the Study of Civil War, International Peace Research Institute, Oslo (PRIO) &
Centre for International Environmental and Climate Research at the University of Oslo (CICERO)
for the Global Environmental Change and Human Security Program (GECHS)



ABSTRACT

A recurring theme in studies of our past is the extent to which climate fluctuations may influence society, modify human interactions with the environment, trigger famines, drive changes in settlement and prompt migration. The North Atlantic Islands of the Faroes, Iceland and Greenland permit the analysis of human colonization, adaptation and long-term settlement undertaken by similar groups of people (Viking Age settlers from NW Europe) in contrasting island environments across significant and changeable climatic gradients. A pan-Atlantic view of the last 1,100 years can consider key aspects of peoples' experiences of, and responses to, different environmental and cultural challenges and, ultimately, their very differing experiences of success and failure. These issues become most pronounced in Greenland, with its successful Inuit and ultimately unsuccessful Norse settlement. The precise reasons for the final extinction of the Norse in Greenland are uncertain. Amongst many different explanations there is the possibility that in the 15th Century 'it got cold and they died'; such a brutally deterministic explanation can be refined to present a convincing case that an inability to adapt and adopt fundamentally different lifestyles in the face of climate change may have made inevitable a fate that could have been avoided. Perhaps the Norse Greenlanders chose not to live like the Inuit, and so they died. On the other hand perhaps extinction was all to do with trade; fundamental changes to the economic systems that first brought the Norse to Greenland could have made inevitable a marginalisation of the colonies that effectively sealed their fate. The possible role of climate change in this classic story of extinction provides a poignant historical underpinning to considerations of human security in the face of present and future global change. Delving deeper into the ways in which climate fluctuations maybe translated into various impacts, and reasons why impact may occur even in the presence of apparently effective management mechanisms, we explore the notion of unpredictable change in relation to differing cultural and environmental 'memories'. In Iceland, many different experiences of success and failure, of impact and sustainability, can be explored in relation to rich, well constrained data sets of both environmental and cultural information. Over the last 1,100 years the Icelanders have experienced a wide range of different climate changes, their responses to these challenges and the consequences of their choices offer some instructive perspectives on contemporary global change. To what extent have we been here before, and will we cope any better in the future?

Introduction

At a time when global climate change can be seen to be taking place, there is a pressing need to assess how this may affect human society. To what extent may these changes exacerbate environmental degradation, drive settlement collapse, cause famine, spur migrations or trigger conflict over resources? It is clear that climate change, and the different weather it produces, can have a wide range of impacts, many negative, some positive, but all with the potential to reduce human security. Crucially, however, opinions differ as to the importance of climate on its own, and in comparison to unrelated processes of social, political and economic change (Diamond, 2005). Furthermore, even if climate change can be shown to have produced a direct impact (such as crop failure or livestock mortality) perhaps the most important question of all is why people did not (or could not) act to avoid or mitigate the bad effects of the weather. As with so many other environmentally-related issues that cross-cut disciplinary boundaries, assessments of relative emphasis, sensitivity, thresholds, significance and nuance are vital.

The deeper time dimension

Study of the past can be an effective way to explore these themes of change and impact, but there are a number of important caveats. Time periods need to be sufficiently long to have encompassed discrete episodes of climate change and allow the trajectories of other, unrelated environmental and cultural trends to be established. In practice this means studies that extend to before the time of instrumental data collection and into periods of variable and incomplete proxy records of both environmental and cultural change. In the past, both our knowledge of the bygone societies that experienced climate change, and the details of the climate changes themselves, may be both limited and flawed. If we think of recent events hypothetically viewed from centuries or millennia in the future with similarly incomplete knowledge, major events such as the collapse of the Soviet Union might be attributed to late 20th Century global warming. Or indeed, could the catastrophic eruption of Tambora in 1815 AD – probably the largest volcanic eruption of the last 10,000 years and responsible for the following ‘year without summer’ – be seen as the trigger for an outpouring of European conquest and settlement across the globe?

At present these ideas seem utterly improbable, but the Bronze Age eruption of Santorini has been invoked as a possible trigger of cultural changes in the Aegean that influenced the development of Hellenistic culture and, ultimately, Western Civilization (Buckland *et al.*, 1997). On firmer grounds, climate change, and related multi-decadal-to-multi-century droughts, have been connected to both simultaneous and subsequent changes in complex societies, such as the end of the Akkadian Empire in Mesopotamia, about 4200 years ago, the Moche exodus from coastal Peru about 600 AD, the Classic Maya collapse in Central America about 750-900 AD, and, in the Bolivian-Peruvian Altiplano, the abandonment of densely settled urban centres of the Tiwanaka culture about 1100 AD (deMenocal, 2001). The timing of changes in agricultural practice, settlement patterns and detailed palaeoenvironmental records, together with strong arguments as to how climate could drive cultural responses (through, for example, effects on rain-fed croplands without irrigation systems) have been combined to create strong arguments for some sort of causal relationship.

As questions of timing are so important, the limitations of radiocarbon chronologies may severely constrain possible explanations as to the role of climate based on studies of the past. Typically AMS radiocarbon dates contain a fundamental measurement uncertainty of around 60-80 years at 1σ (about a 68 % probability that actual date lies within the age range quoted). To increase the probability of a correct answer to over 95 % (2σ) usually requires a date to be quoted as a range more than 100 years long. Calibration, that translates radiocarbon dates into calendar years, and so makes possible integration with historical events and archaeological timescales, widens uncertainty still further. So, for example, the radiocarbon dating for the abandonment of Tell Leilan in Syria, and the relation of this

desertion to the incipient collapse of the Akkadian Empire is 4170 \pm 150 calendar years BP, or in other words, between 4020 and 4320 years ago (deMenocal 2001). If we consider radiocarbon dating in isolation, an ‘end date’ that may be anywhere within a period of three centuries makes it difficult to argue for closely related causal relationships. Either the dating is such that the probability envelopes overlap (in which case it is not possible to say which event may lead or lag the other) or the dating of archaeological and environmental changes are clearly different (in which case the separation may be such that arguments for causal connections may appear weak).

Fortunately, in the case of this Akkadian example there is good evidence that a layer of volcanic ash produced by a single eruption is present in both the archaeological record of Tell Leilan and sediment cores from the Gulf of Oman –the key source of environmental data. The tephra represents a key additional piece of dating evidence reinforcing the view that the Akkadian collapse and climate change were synchronous. Without this additional chronological control it would not be possible to rule out the possibility that the actual date for archaeological change could be towards the younger margin of the probability envelope (closer to 4020 years ago rather than 4320 years ago) and the onset of drought could have been towards the older margin of the probability envelope (closer to 4150 years ago rather than 3900 years ago). In other words, on radiocarbon dating *alone* it would be possible to argue that Imperial collapse could have begun *before* the onset of climate change. In this *hypothetical* case the significance of climate change could then be shifted, from a situation where weather is seen as a driver of change, to one where it might be argued to exert pressure (maybe the critical additional pressure) that forced a system already in a state of crisis, into a state of collapse. In this type of situation, the crucial question as to why people didn’t respond with effective counter measures has a possible explanation. A society in crisis may respond poorly to additional natural challenges.

As with so many studies of past events, some of the most fascinating details of why climate change could be related to wholesale socio-political change, may be enigmatic and offer some daunting research challenges. But if we have high-resolution environmental and cultural data, and good chronology, and if the ideas involved are expressed as clearly as possible and critical tests identified, then, step by step, we may gain a better understanding of what happened in the past, and think on possible lessons for the future.

The Norse in the North Atlantic

A long way away from the potentially drought-sensitive complex societies of low latitudes, the Norse settlement of the North Atlantic islands offers a complimentary area in which to explore the relationship between climate change and people (Diamond, 2005). Although Norse settlement of Faroe, Iceland and Greenland occurred comparatively late, it spans a sufficiently long period to include notably different climatic episodes and major cultural changes (Grove, 1988; Jones, 1986; Karlsson, 2000). When considered as a whole the North Atlantic islands permit the analysis of human colonization, adaptation and long-term settlement undertaken by similar groups of people (Viking Age settlers from NW Europe) in contrasting island environments across significant climatic gradients. A pan-Atlantic view can consider key aspects of people’s experiences of, and responses to, different environmental and cultural challenges, and ultimately, their very different experiences of success and failure. Importantly, the culture and its historical context are well known, and we have some excellent written sources (eg Friðriksson, 1994; Karlsson, 2000; Vasey, 1996; Vésteinsson, 2000). High quality regional environmental data is available from Greenland ice cores, and in addition tephrochronology-environmental dating based on layers of volcanic ash- permits accurate correlation of multiple data sources (historical, archaeological and environmental) (eg Buckland *et al.*, 1991; Dugmore *et al.*, 2004; Meeker and Mayewski, 2002; Thórarinnsson, 1967, 1975, 1981). Quite remarkable new perspectives have also been gained from faunal records based on hundreds of thousands of identified bones from

archaeological contexts that give unrivalled insights into the subsistence and economies of the past (eg McGovern *et al.*, 2005).

Of all the different human stories to have come out of the Atlantic islands perhaps the best known is that of the extinction of the Norse settlement in Greenland. The colonies were established shortly before the year 1000 AD, the last known outside contact was in the early 15th Century, and by the 16th Century the Norse Greenlanders had disappeared (McGovern, 2000). As in all good mysteries, this enigmatic, unresolved ending has many possible explanations. Perhaps the last Norse Greenlanders died in conflict with the Inuit, or the plagues that devastated Iceland for the first time in 1402-3 might have reached Greenland a decade later. Alternatively, raids by Barbary pirates may have effectively destroyed the settlements, or the last Norse Greenlanders may have tried to sail away, or perhaps they simply starved to death. Dominating all possible explanations is that of climate change (McGovern, 1994; Buckland *et al.*, 1996). It is generally accepted that early settlement was boosted by warmer, more benign climatic conditions. The assumption is that the development of colder, stormier conditions pushed settlement from marginality to crisis. The extent of pack ice could have seriously affected shipping and compromised hunts for marine mammals, in particular walrus. Hand in hand with the development of more extensive pack ice, shortened growing seasons, less fodder production, longer overwintering periods and more demanding conditions for raising cattle, sheep and goats would have made the subsistence base of Norse Greenland more precarious (Barlow *et al.*, 1997). It may be that these all-encompassing climatically-driven changes are all that really mattered; that they alone made the Norse Greenlanders' way of life too marginal and then it was simply a question of *when* the colonies failed rather than *if*. This inevitable descent to destruction might have been accelerated by other factors (McGovern, 1994). An inability or unwillingness to adapt, to adopt an Inuit lifestyle and embrace radical change may have critically reduced chances for survival, and accelerated the final collapse. There is no evidence that the Norse Greenlanders adopted Inuit arctic-adapted technology, such as the toggle harpoon. Perhaps this lack, that may have fatally compromised their ability to survive, could be explained by intense cultural conservatism, as could the oppressive control of an elite who did not wish to see change that might have weakened their own position. This argument does, however, all rest upon the assumption that change of lifestyle was necessary and essential, and to explore this radically different interpretation we must return to the question of why the Norse colonized Greenland in the first place.

Trade opportunities, life (and death)

Let's return to the wonderful 'foundation myth' for Greenland, the written record of how the Norse settlement came to be. According to written sources, it all began with Eiríkr Þorvaldson, better known as Eirik the Red, who had to flee Norway on account of some killings. Settling in Iceland he was involved in more killing and was sentenced to three years outlawry by the local assembly. With few options now available, he left Iceland intent on exploring unknown lands that had been sighted to the west. What happened next is recorded in the Book of the Icelanders (*Íslendingabók*) a short chronicle of Iceland's early history written between 1122-1133 AD by Ari Þorgilsson the Learned (Karlsson, 2000). In it, the now famous story is told that;

“The land which is called Greenland was discovered and settled from Iceland. Eirik the Red was the name of a Breidafjord man who went out there from here and took land in settlement at the place which has ever since been called Eiríksfjord. He gave the land a name, and called it Greenland, arguing that men would go there if the land had a good name... When he began to settle the land, that was fourteen or fifteen years before Christianity came to Iceland (ie between 984-986)” (Karlsson, 2000; p29)

Apparently on the strength of this ‘sales pitch’ Eirik was able to mount a very large colonization effort. This leads to two assumptions; that at the time Greenland must have been somewhat warmer and more pleasant than today, and that sufficient land pressure existed in Iceland to drive an onward phase of colonization and settlement. Perhaps neither of these ideas is correct. To understand why, we must first consider the basis of the Iceland economy in the late 10th Century. Iceland is a land where you can live well on the basis of a pastoral subsistence economy, but perhaps a real problem for the Icelandic elite in the late 10th Century was how to become wealthy, or at least generate materials for trade. Wool was one possibility, but there were few other options. The few arctic fox in Iceland were no basis for a fur trade and the limited walrus colonies present at the time of Icelandic settlement in the late 9th century (and known on the basis of both place name and zooarchaeological evidence) had almost certainly been exterminated within a few decades of settlement. What Eirik probably brought back from Greenland was not simply word of settlement possibilities, but talk of ways to make money, of ivory in massive walrus colonies, and of fur. To utilize these possibilities over-wintering and permanent settlement would be required – and so there were both powerful incentives and a pressing need to establish the colonies. Certainly ivory, fur and other prestige items such as falcons and polar bears were later known as vital exports from Greenland.

With this perspective in mind, subsistence in Greenland could be seen as the means to underpin a cash economy, and not an end in its self. In Scandinavia, the Norse traded furs from the Saami in the north and the Finns in the east, to sell on the growing European market. As time passed Hansa merchants developed the fur trade from the Baltic region eastwards; elephant ivory from Africa began to provide unbeatable competition to walrus ivory in European markets and, perhaps most importantly, religious art moved away from the use of ivory. Other developments may also have eroded the trade position of the Greenlanders: the development of hemp ropes, for example, may have effectively replaced a market for cables made from walrus hide. Add increasing operational difficulties in Greenland (caused by colder, stormier weather and more sea ice) to a fundamental erosion of the Norse Greenlanders’ economic position, then their situation could have become dire. Other opportunities could have beckoned. In Iceland’s West Fjords a new ‘stock fish’ trade was developing. This trade in bulk, low cost commodities was offering an effective alternative to the prestige trade in ivory and fur that seems to have been rapidly losing viability. In other words, alternative ways to generate trade goods and wealth were becoming available in Iceland and the draw may have been responsibly for a critical haemorrhage of people from Greenland. In this context, apparently indications of a degree of organized withdrawal from the more remote Western Settlement area in Greenland are consistent with a phase of retrenchment. The economic perspective raises the possibility that change occurred because of choice rather than need. Perhaps the Norse did not adopt Inuit lifestyles because subsistence as such was not the key issue. Subsistence strategies may have been adequate, the key problems could have been those of economic viability and population; even quite limited out migration driven by changing trade could have had very serious consequences for long term viability.

Reconsidering the question of whether sufficient subsistence was available, there is evidence for an increasing marine content in the Norse Greenlanders’ diet, probably a reflection of a greater consumption of seals (Arneborg, *et al.*, 1999). This may have been sufficient to avoid a terminal subsistence crisis. In addition, it may be possible that population levels in Norse Greenland, were rather lower than previously assumed (Lynnerup, 1998). The ‘low population’ model is controversial, but does make the point that if current, generally accepted population estimates are too generous then issues relating to subsistence become re-defined. Lower population levels could imply fewer potential subsistence problems. Land degradation through soil erosion may not have actually been a problem if subsistence-level livestock requirements were low, and there was still sufficient intact vegetation cover to provide necessary grazing. The intensive exploitation of small landholdings around isolated farms

may be read quite differently if this was part of a rotating or shifting exploitation of the landscape, as opposed to a strategy demanded by a fully occupied landscape with no scope for movement. A picture of ‘desperation’ is transformed into one of ‘maximum exploitation (and recovery?)’.

Returning to the question of climate change, we now have two quite different ideas to consider. On the one hand climate change could have been the principle challenge that drove the Norse Greenlanders to extinction. From this point of view a subsistence crisis was the key problem. The area simply became too marginal for them to endure with their chosen lifestyle. Marginality could have been exacerbated by hierarchical social structures and inequality; a declining ability to both obtain and sell trade items to secure vital imports could have deepened the subsistence crisis and a failure to adopt alternative technologies from the Inuit could have made extinction inevitable.

Alternatively, climate change might have been largely irrelevant, influencing the timing, but not necessarily the ultimate fate of the settlements. Basic subsistence might have always been possible, but economic marginalization, and the presence of alternative options back in Iceland (or indeed elsewhere in Scandinavia – especially in post plague-ravaged Norway) may have fatally undermined the rationale and means for occupying Greenland, and drawn people away from the island. For these reasons population contraction may have reached the point where subsistence and survival did become impossible. At a critically low-level perhaps any number of events from bad weather to disease or conflict could have provided the final push to extinction.

From an economic viewpoint therefore, Norse Greenland could move from an enigmatic anomaly, to being one of a series of examples of episodic European exploitation of the Polar Regions. The ruins of Norse Greenland could therefore exist for fundamentally similar reasons to the traces left by whalers, sealers, gold and coal miners elsewhere in the Arctic and Antarctic (Sugden, 1982), and just as it could be misleading to read the record of these other short-lived excursions into polar regions primarily in relation to periods of warmth or cold, calm or storm, so too could be the case of Norse Greenland.

Climate change and land degradation in Iceland

So is climate change anything more than ‘the executor of the unfit’? It could be a mistake to rule out climate change as a cause of real and substantial negative impacts on otherwise viable settlement in the Atlantic Islands. Iceland in particular provides an important comparison to Greenland, because Icelandic settlement has also experienced major episodes of expansion and contraction and these have at least in part been associated with major climatic challenges and widespread environmental impacts, although, once again, the extent to which these impacts were solely the result of climate change is debated (Karlsson, 2000). Even in medieval times Icelandic settlements supported many more people than Greenland (at least ten and possibly more than thirty times as many people), and unlike Greenland, Iceland could not be argued to exist just as some extreme form of olden-day trading base camp. It was a place that sought out, and where people stayed, because it was potentially a good place to live.

The idea of change potentially driven by climate is encouraged by notable anecdotes of farm sites disappearing beneath advancing glaciers (Grove, 1988). Environmental degradation has occurred on a large scale with extensive changes to vegetation cover (the reduction of woodlands to a fraction of their former extent) and widespread soil erosion (the loss of perhaps 20,000 km² of soil) (Thórarinnsson, 1961; Dugmore *et al.*, 2005a). Climate change has been argued to play a key role in this change (and so exert unwelcome pressures Icelandic society) because of a clear relationship between temperature and vegetation cover. In Iceland the boundaries of ecological zones (such as the upland limit of tree growth) are generally determined by temperature; temperature changes and boundaries will change.

Temperatures decline and grass growth is affected. In addition cold wet periods can critically affect other activities such as lambing, producing high neo-natal fatalities for sheep (Amorosi *et al.*, 1997).

Despite these clear associations with climate, it is apparent from the environmental record that environmental impacts such as soil erosion begin very soon after settlement in the late 9th century, and develop at times when climate change is not supposed to be an issue (Thórarinnsson, 1961; Dugmore *et al.*, 2000; 2005b). As a result we need to be able to disentangle the roles of climate change and non climatic factors in landscape degradation. One point of view, to put it crudely, is simply that people are very bad news for the environment and human settlement and degradation always and inevitably go hand in hand. This ‘*ultra Malthusian*’ view that environmental degradation in Iceland is simply and inevitably a result of over exploitation cannot, however, offer a complete explanation because we have evidence for environmentally-aware and responsive practices that have managed impact, holding it back from total catastrophe.

Birds and marine mammals

Around Lake Mývatn duck eggs form an important harvest for local farms, with some 10,000 a year being collected. New evidence shows that duck eggs were being exploited over 1000 years ago, and although adult birds were also being killed and eaten as well, ducks (*Anatidae* spp.) were avoided and hunting for meat was focused on the Ptarmigan (*Lagopus mutus*) (McGovern *et al.*, 2005). A thousand years after exploitation began duck populations still flourish (because eggs are always left in the nests to hatch) and, significantly, Ptarmigan still endure in the heath and uplands. Elsewhere in the Atlantic this view of sustainable Norse practices is reinforced: in the Faroe Islands, Puffins (*Fratercula arctica*) make up a significant population of the early archaeofauna at the site of Sandur, showing that they were intensively exploited for food, but again populations still flourish on the islands (Church *et al.*, 2005). The record is not, however, one of universal continuity and endurance as there are notable examples of both localized extinction (walrus colonies no longer occupy the coasts of Iceland) and acts of species extinction (the last Great Auk (*Pinguinus impennis*) was killed in 1844 on a small island of Eldey off the coast of Iceland (Bárðarson, 1986)). The key point is, however, that there is empirical zooarchaeological evidence for practices that have been sustainable over more than 1,000 years.

Grazing management

The notion of sustainability also occurs in records of medieval land management as contained in passages of the Old Icelandic law code, *Grágás* (Dennis *et al.*, 1993; Simpson *et al.*, 2001). The code was replaced after the end of the Icelandic Commonwealth period in 1262 AD, but offers key insights into early land management in Iceland. Grazing of the rangelands was owned, managed and regulated. Stocking levels were determined by the stage at which livestock began to lose weight. If the animals became thinner through the year then stocking levels were deemed to be too high. This is strong evidence that upland environmental degradation was not simply a result of over exploitation and a ‘*tragedy of the commons*’.

Woodlands

In Iceland today, woodlands are but small remnants of the pre-historic forests. On the one hand this may be viewed as a result of inappropriate land management. Indeed there are many historical examples of conflict as a result of disputes over this declining resource, as through much of Icelandic history native woodland was the key source of charcoal, vital for the effective maintenance of tools and effective farm operations. But perhaps a key point when considering the fate of Icelandic woodlands is that they have actually survived through into the modern era (if in a much reduced form) - a better record than that of Rapa Nui/ Easter Island (Flenley and Bahn, 2003). In Iceland, measures were taken to conserve declining woodland resources when they had reached the point that further reductions

could have been potentially catastrophic. In Southern Iceland, for example, lowland woodlands were cleared rapidly (Hallsdóttir, 1987). At the farm of Stóra Mörk, for example, reference to tephra layers in peat sections show that woodlands in the area of the present home fields were cleared between 870-920 AD, and probably within the first 30 years of settlement (Mairs *et al.*, 2005). Up valley, charcoal production pits (also preserved in aggrading soil profiles containing more tephra layers) record the use of birch wood (*Betula pubescens*) between 920-1341 AD (Dugmore *et al.*, 2005b). No production pits have been found in this area that post date the early 14th Century, and there is no birch woodland in the area today. At the inland margins of the valley isolated areas of woodland survive to this day in a district called Þórsmörk, and this area was intensively managed for charcoal production through to early modern times. So there is a pattern of progressive woodland destruction and continued survival in isolated areas close to the upland ecological margin. The implication from the environmental record is that actions were taken to conserve resources before they were completely destroyed, a view reinforced by the written record.

In Þórsmörk where the woodlands' survived, there lie the ruins of four farm sites known, on the basis of both the written record and artifact evidence from the sites themselves, to have been established early and abandoned before the 14th Century (Tómasson, 1996). Recent environmental work has shown that the occupation of these sites coincided with major localized episodes of soil erosion (Dugmore *et al.*, 2005b). After the Þórsmörk farm sites were abandoned, the affected areas began to regenerate and soils began to reform. Once again, precise dating control is given by the distribution of well-dated layers of volcanic ash. Abandonment of these farm sites, lying at the upland limit of settlement in the region, might be argued to be a consequence of the localized destruction of grazing lands associated with the first introduction of domesticated animals. Importantly, however, destruction was limited to upland grazing areas. Within sheltered valleys containing woodlands today, there is evidence that woodland survived throughout the period of occupation. One possibility is that farm abandonment, while related to the increasing loss of grazing land, could in fact have been driven by a more general communal need to conserve a diminishing supply of woodland. Once the woodlands had been destroyed down valley, people could have recognized the importance of conserving the surviving remnant in Þórsmörk. The farms (and presumably their associated livestock) were removed and the woodland, now under the control of lowland landowners and the church, survived (Dugmore *et al.*, 2005b).

A key point of this example is that even when exploitation of a resource and related environmental degradation appears ill-conceived (the near-total destruction of native woodland) successful corrective conservation measures were employed before the resource was totally lost.

Overall therefore we have notions of how to determine sustainable practice (monitoring the weight of livestock) evidence of management tools (ownership and regulation of grazing, legal sanctions for malpractice) examples of sustainable exploitation (duck eggs) and examples of corrective measures taken to conserve declining resources (woodlands for charcoal production). We do, however, have evidence of major environmental issues (extensive soil erosion) and a history marked by repeated examples of population decline and hardship. So why did people 'get it wrong'?

Problems of prediction

Possible explanations for why apparently good practices have produced very mixed results brings us back to the question of climatic impacts especially the consequences of the 'Little Ice Age' climate changes (Grove, 1988; Meeker and Mayewski, 2002).

Climate change could be most readily translated into bad effects for people and the environment by changes that are substantial, unpredictable, unexpected and repeated. Whether ‘bad’ becomes ‘catastrophic’ depends on how human societies can cope, and this is probably a reflection of social attitudes and structure, economic and political systems, as well as demographic fundamentals such as the potential labour force. Although a sudden episode of bad weather in any one year may be difficult, a sequence of bad years could rapidly change hardship into crisis and catastrophe as the ability to buffer change is rapidly used up. Extreme events capture the imagination and it is easy to accept the argument that major, abrupt changes may be significant, but what about the lower order changes-gradual, but significant shifts in climate that erode prosperity and drawn down both natural and social capital?

Returning to the example of rangeland management, problems in Iceland may well have developed even though people had environmental understanding and management mechanisms because of climate changes that unpredictably affected the onset and length of the growing season. Although sufficient biomass could grow through the summer to support the livestock grazing on the hills, a delayed start to the growing season could have resulted in grazing before any growth began and resulting damage to the stability of vegetation cover (Simpson *et al.*, 2000).

The problem created by short phases of heightened impacts on vegetation could have been compounded by three other factors:

- Firstly, minimal (if any) shepherding of livestock utilizing the rangelands, while economizing on labour demands and freeing people for other tasks (such as fishing), could have also significantly increased potential vulnerability to climatic impacts. Without day-to-day management of livestock grazing (to utilize the best or most robust areas of vegetation, and reduce pressure on vulnerable, eroding areas) regeneration would be difficult to promote.
- Secondly, although monitoring the weight of livestock brought down off the hills in the autumn is an effective way to maximize yield, it is probably insensitive to the onset of accelerated environmental costs as it is probable that landscape degradation would begin before livestock weight reduction became apparent. As a result, landscape problems could develop before the animal monitoring mechanism highlighted the issue. In this case draw-down of natural capital could have been an immediate consequence of unforeseen (and unmanaged) changes.
- Thirdly, the nature of soil erosion in Iceland has distinctive features that can effectively propagate initially limited impacts. Over most of the landscape vegetated at the time of Norse settlement soil cover occurred in the form of a deep (>50cm) sediment of aeolian origin with intercalated layers of volcanic ash (Thórarinnsson, 1961; Dugmore *et al.*, 2000). In the south of Iceland, lowland pre-settlement soil covers were commonly several metres deep. Once trees have been removed, the root zone is effectively confined to upper layers of the soil, and does not extend down into the underlying substrait of coarse-grained sediments. Soil erosion develops by exploiting breeches in the vegetation cover that allow frost, wind and rain to move sediment. Bare patches of exposed substrait develop bordered by steep, eroding faces of soil that under-cut, and eat into the surrounding vegetated areas. Soil erosion then proceeds as a loss of soil area. Once established, erosion is resistant to stabilization, as even low grazing intensities will tend to keep bare soil exposed on the eroding slopes permitting the continued effective action of the elements. It is useful to think of soil erosion having two key stages; a *triggering event*, which results in the breaching of the vegetation cover (and is usually related to

grazing), and a *propagation phase* which is driven by the intensity of frost action, rainfall, slope wash and wind acting on exposed soil. A simple return to the conditions prevailing before the onset of soil erosion does not necessarily result in a cessation of erosion, and in that respect soil erosion is best regarded as threshold change that has the form of a catastrophe cusp.

So although erosion could have been triggered by a mismatch between land use and the growing season, the initial damage may not have been immediately apparent as the monitoring mechanisms seem to have focused on the livestock, and once erosion started it did not necessarily stabilize even when climate conditions return to their previous norm.

Misleading memories

As a concluding thought as to why people may fail to appreciate that significant climate change has occurred, or be resistant to taking effective counter measures until too late, a quantification of ‘unexpected’ or ‘unpredictable’ change may be usefully gained from measures of cumulative deviation.

This measure is developed by determining the long term mean of a time series of data (say annual temperature). For each year the deviation from this long term mean is calculated, then starting at the oldest data point year one is presented as simply the deviation from the mean, year two is defined by that year’s deviation plus the deviation from year one, year three is defined by that year’s deviation plus the deviations from both year one and year two, and so on. This analysis is not used to assess climate changes as such (for example, the North Atlantic Oscillation) because the weather in any one year is independent of what happened in the previous year, but when considering people and the environment cumulative measures are most instructive. For example, bad weather one year does have a continuing effect through its impact on vegetation, and rain and wind year on year have cumulative effects on the development of soil erosion. Crucially the measure of cumulative deviation clearly shows when trajectories of change alter. This is important not only for the environment, but also people’s perception of it. Our views of what is likely to happen next year are based on knowledge accumulated over previous years. Today, just as in the past, we use experiences and memory to anticipate what will happen next. Inappropriate actions may happen most often when memories mislead, knowing when it’s the time to change is perhaps the most obvious statement of how to deal with climate change, but perhaps the most difficult to resolve. How long is a new situation going to last? Do we just continue in the ways we always have, or do we take difficult decisions to alter what we do?

Difficult choices faced medieval Icelanders after climate trajectory changes in the mid 15th century (Dugmore *et al.* forthcoming) In Greenland, these times when past experience became an increasingly inappropriate guide to the future, might just have signaled the end of the Norse settlements.

Conclusions

Studies of past environments offer valuable insights into the relationships between people and climate change, and offer instructive examples of previous outcomes.

- As many alternative ideas come into play it is important to have rich, multi-layered data sets that include wide ranges of environmental and cultural records. High resolution, seasonal, annual and sub-decadal chronologies are essential, as are many different scales of enquiry. The human dimension needs to be evaluated on seasonal timescales, and spatial resolutions extending from individual settlement sites and land holdings, to groups of settlements in regional landscapes, and trade and socio-political relationships across continental scales.

- Crucial distinctions have to be made between climate effects on subsistence and cash economies. Where subsistence is based on a wide range of resources (such as marine and terrestrial food supplies) this broad base may reduce one sort of vulnerability, because it exploits a range of plants and animals that could have wider or different sensitivities to climatic change. It may, however, promote another sort of vulnerability by limiting labour availability (by for example, restricting shepherding and rangeland management because of the labour needed to fish or hunt). Commercial opportunities may connect communities across wide areas, but in doing so they may also create increased potential for disruption as a result of climate change. This may happen because there is a greater chance that climate change may affect one part of the interconnection system, and so have cascading effects outwith the areas actually affected by the changing weather. In addition economic or socio-political changes in one geographical area that alter trading relationships with another area may also have the effect of also pressurizing the local subsistence base.
- Questions of scale are crucial. We can, for example, see how the fate of farms at the upland limits of settlement may have been affected by changes in the lowlands, so that despite localized environmental degradation (soil erosion), the key environmental change that determined abandonment was most probably degradation elsewhere (loss of woodland) and the needs that arose from that (conservation of surviving woodland at the upland margin). Likewise commercial changes in Europe may have been a key driver in creating sensitivities to climate change on the other side of the Atlantic in Norse Greenland.
- Asymmetric thresholds or catastrophe cusps may be crossed even in the presence of ‘sustainable’ and responsive management strategies where changes are unpredictable and environmental impacts are not immediately significant or apparent.
- Cumulative measures of change are good analytical tools because they help focus attention on the implications for both cultural and environmental ‘memories’ when the past is no longer an effective guide to the future.

Acknowledgements

We gratefully acknowledge the support of the Leverhulme Trust (through the programme *Landscapes circum Landnám*) and the National Science Foundation of America.

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