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Catena 42 (2001) 175–192

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Crossing the thresholds: human ecology and historical patterns of landscape degradation

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Abstract

In discussions of landscape sensitivity, human activities have generally been regarded as external forces contributing to landscape change, with a focus on the impacts of cultivation methods, fertiliser practices, grazing pressures and atmospheric pollution. However, there has been comparatively little study undertaken that integrates physical and social systems in a historic context to explain the basis of human activity in sensitive landscapes. Where such attempts have been made, the manner of common land management has figured prominently, with 'tragedy of the commons' concepts used to explain land degradation and to provide a foundation for policy response. This has also been the case in Southern Iceland and in this paper we assess the extent to which common land domestic grazing pressures were the primary external force causing soil erosion and land degradation during the period of occupation from ca. 874 AD. We first provide field observation of soil erosion, temporally defined by tephrochronology, to highlight the extent of land degradation during this period. The 'tragedy of the commons' explanation of degradation is then assessed by evaluating historic documentary sources, and by environmental reconstruction and modeling of historic grazing pressures. These analyses indicate that regulatory mechanisms were in place to prevent overgrazing from at least the 1200s AD and suggest that there was sufficient biomass to support the numbers of domestic livestock indicated from historic sources. We suggest that failure to remove domestic livestock before the end of the growing season and an absence of shepherding were more likely to contribute to land degradation than absolute numbers. Lack of appropriate regulation of domestic livestock on common grazing areas can be attributed to

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PII: S0341-8162(00)00137-5

limited cultural knowledge of changing and rapidly fluctuating environmental conditions.

Keywords: Historical ecology; Andisols; Soil erosion; Tephrochronology; Common land; Grazing; Cultural knowledge

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1. Introduction

Since the mid 1980s, there has been realisation that explanation of landscape change cannot solely rely on a mechanistic understanding of the inherent sensitivities and resilience of landscapes to externally imposed variations in climate and human activity. Driven largely by issues of land degradation, the social and natural sciences have increasingly been attempting a holistic study of landscape change under varying political, socioeconomic and historical contexts that contrast capitalist with socialist and colonial with precolonial settings (Blaikie and Brookfield, 1987). However, human ecological concepts applied to questions of landscape sensitivity have often lacked rigorous assessment and have frequently failed to provide historical depth resulting in ill-judged assessments and policy responses.

One enduring aspect to social explanations of landscape change has been the issue of land tenure and common land in particular. Much of this debate has been stimulated by Harden's 'Tragedy of the Commons' paper in which he utilised the concept of a communal pasture to illustrate the point that individual self-interest will result in the abuse of a commonly held resource leading to land degradation (Harden, 1968). The 'tragedy of the commons' argument as it applies to livestock and rangeland landscapes can be summarised as follows: a herdsman puts his animals on a pasture that he uses in common with other herdsmen. Although there are signs that the condition of the pasture will worsen with additional stocking, it is only rational for each herdsman to add more animals to his herd because he gains the full benefits of each additional animal while sharing the cost of overgrazing with the other herdsmen. (McCay and Acheson, 1987). Hardin went on to conclude that to avoid tragedy (land degradation and loss of the grazing resource), the commons could be privatised or kept as public property to which rights to entry and use could be allocated. While this view ignores spatial and temporal variation in landscape sensitivities, it is one that remains widely accepted as a social foundation of land degradation with some according it universal application. Furthermore, it has been used as a basis from which environmental resource management policy has been attempted in a wide variety of environmental contexts (Feeny et al., 1990).

In this paper, we seek to assess the extent to which the 'tragedy of the commons' model can be used to explain the historical occurrence of land degradation in landscapes where grazing of domestic livestock has been, and continues to be the primary human activity. In doing so, more comprehensive explanations of the relationship between soil erosion, land degradation and grazing domestic livestock are derived and new hypotheses identified. An ideal place to develop a historical approach to testing the model is Iceland, where it has been estimated that at least 40% of top soils have been removed since the island was first settled in the 9th century AD (Friðriksson, 1972; Thorsteinsson et al., 1971). Explanation of this loss in Southern Iceland and other areas of the North Atlantic region including Shetland, Faeroe and Greenland, has implicitly been given as a classic ‘tragedy of the commons’ situation, a result of domestic livestock grazing of *afréttur*, the summer mountain grazing areas. Indeed the denuded areas of Iceland have been described as ‘ovigenic’ or made by sheep landscapes (Buckland and Dugmore, 1991; Sveinbjarnardóttir et al., 1992), although removal of woodland and turves for fuel and as construction materials may also have contributed to landscape degradation. Following this explanation has, predictably, been classic government intervention responses that include reseeding programmes, inducements to farmers encouraging them to remove livestock from mountain and hill pasture areas, and more recently, participatory approaches (Arnalds, 1998; Arnalds et al., 1987). Iceland also has one of the most detailed tephrochronologies in the world, permitting a precise assessment of the patterns and timing of land degradation, and which can be temporally related to a detailed record of climatic and vegetation change immediately before and during the period of human occupation. There are also good documentary sources of land management practices in the form of sagas and law books which date from the high middle ages (12th–14th centuries) as well as comprehensive farm surveys from the early 1700s.

2. Landscape degradation in Southern Iceland

The district around Eyjafjallajökull has been developed as a study area to explore the biophysical and social aspects of land degradation because of the range of landscapes present and the natural barriers that define the *afréttur* (sg., *afréttir* pl.) areas shared by the farmsteads at the foot of the glacier (Fig. 1). The barriers formed by the Mýrdalsjökull ice cap and the Markarfljót and Jökulsá rivers effectively constrain rangeland grazing, giving a coherent district for the assessment of grazing impacts. The area extends from the coastal *sandur* to the upland glacier margins and includes inland valleys. Soils in the study region are dominated by andisols derived from volcanic tephra and aeolian materials primarily of volcanic origin (Soil Survey Staff, 1998; Shoji et al., 1996; Parfitt and Clayden, 1991; Jóhannesson, 1960). The clay mineralogy of Icelandic andisols is generally characterised by abundant allophanes, imogolite and poor crystalline ferrihydryte, and these soils tend to have high phosphorus retention. Analyses of soil thin sections indicate the silty nature of these soils with low organic carbon contents and low bulk densities, making them highly susceptible to erosion (Arnalds et al., 1995; Wada et al., 1992; Simpson et al., 1999).

During the Holocene, the study area has been frequently covered by fallout from nearby volcanic systems, resulting in the formation of at least 78 discrete tephra layers which exhibit a range of macroscopic features reflecting major differences in geochemical composition, eruption mechanism, total tephra volumes and principal direction of fallout. The timing of eruption or tephra falls can be recorded in historical sources (Thórarinsson, 1967), correlated to annually laminated ice cores (Grönvold et al., 1995) or dated using radiocarbon measurement on associated organic materials. The tephrochronology used here is based on the regional framework established by a number of workers (Thórarinsson, 1944, 1967, 1975; Einarsson et al., 1980; Haraldsson, 1981;

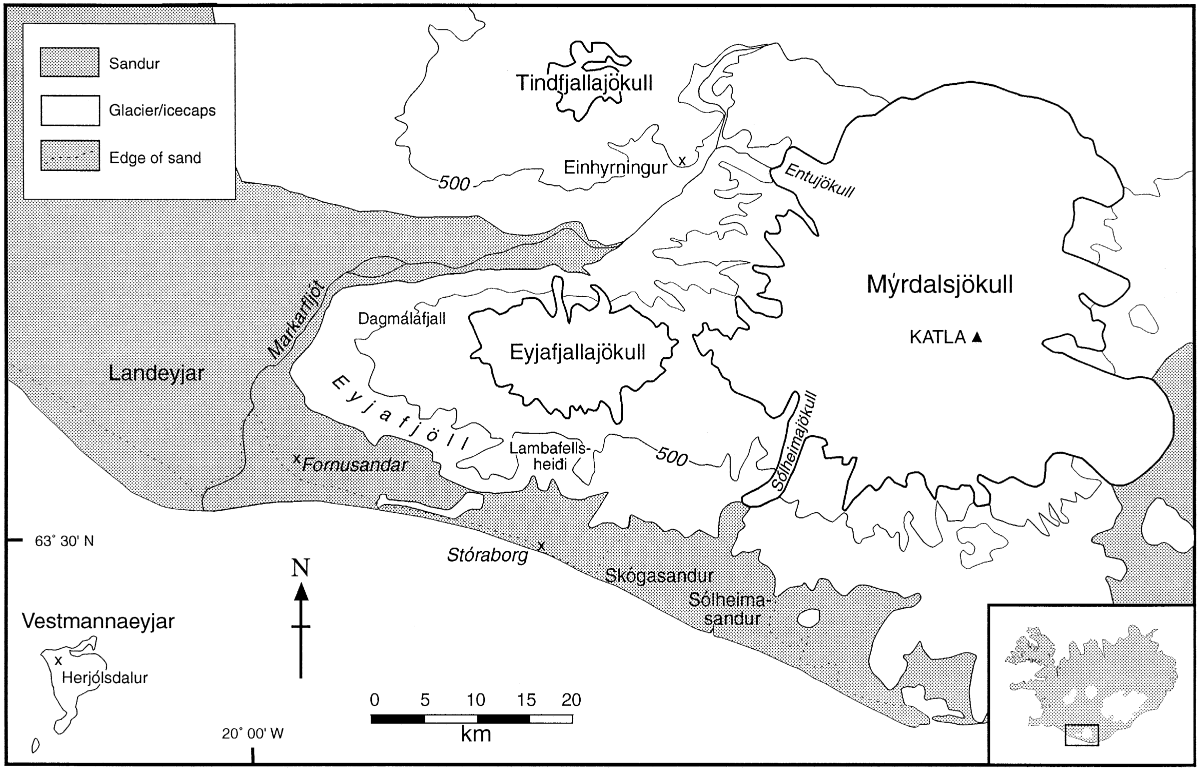

Fig. 1. Eyjafjallahreppur, Southern Iceland.

Larsen, 1981, 1982, 1984, 1996; Dugmore, 1989; Halfliðasson et al., 1992). Tephras may be grouped to define broader culturally and environmentally significant phases and assess change over clearly defined periods of time. Firstly, the stratigraphy below the *Landnám* tephra (871 ± 2) preserves a record of landscapes without human impact. Secondly, the *Landnám* tephra combined with either KR920 and/or E935 can be used to assess the initial Norse colonisation and the first generation of settlement. Thirdly, the stratigraphy bounded by KR 920 and/or E 935, and the Hekla tephra of 1510 AD (H 1510) encompasses the changing conditions of the medieval warm period. Fourthly, H 1510 and the Hekla tephra of 1947 AD (H 1947) bound the sedimentary record of the major cold phases of the little ice age as defined by glacier advances. Finally, H 1947 provides an unambiguous modern stratigraphic marker that effectively coincides with the onset of post World War II agricultural change and the first national survey of land degradation using stereographic vertical aerial photography.

Within the study region, over 200 soil profiles correlated using tephrochronology have been used to reconstruct patterns of sediment accumulation as an indicator of land degradation (Dugmore and Buckland, 1991; Dugmore and Simpson, in press). Generally similar rates of accumulation in prehistory (prior to ca. 874 AD) can be interpreted as a reflection of regional fallout over stable vegetated areas, although this period includes a climatic range of similar magnitude to those of the occupation period. Colonisation and settlement clearly induced accelerated soil erosion which first developed in the upland, ecologically marginal areas, and then spread to the lower, initially less marginal areas (Dugmore and Buckland, 1991). Rates of denudation have been estimated as high as 20 mm/year, although 4 mm/year is a more representative figure. Thin section micromorphology is currently identifying sediment sources in accumulation areas and suggests that local aeolian sediment is the dominant source, but with slope wash and regional aeolian sediments also making a significant contribution. These observations of sediment movement permit general models of landscape change to be constructed that illustrate changes in vegetated areas and the development of eroded areas over time, clearly indicating that limiting thresholds of landscape change were crossed as a result of human activity, setting in progress long-term erosion (Fig. 2). Until now, overgrazing of common land areas by domestic livestock has been perceived as the primary cause of land degradation in this area. The validity of this view is now assessed through the examination of historic documentary sources, and by new environmental reconstruction and modeling of grazing pressure over the period that Iceland has been occupied.

3. Documentary sources of common land grazing practices

Early settlers initially appropriated mountain pastures and parts of highland pastures in Iceland, particularly in the north, remained private property belonging to individual farmsteads or churches. In the south these pastures evolved towards communal forms of ownership. Common grazing areas were known as *afréttir*, and can be considered as a logical outcome in a landscape where biomass production is comparatively low and large grazing areas are consequently required, and is consistent with the minimisation of costs to the graziers (Eggertsson, 1992). In the south, the only part of Iceland where there are large communities of farmsteads without direct access to mountain pastures, they were considered to be the common property of communes at least since the 15th century (DI VI, pp. 81–82) and almost certainly from considerably earlier times. Communes or *hreppar* (pl.) were the basic administrative unit in Iceland and are known

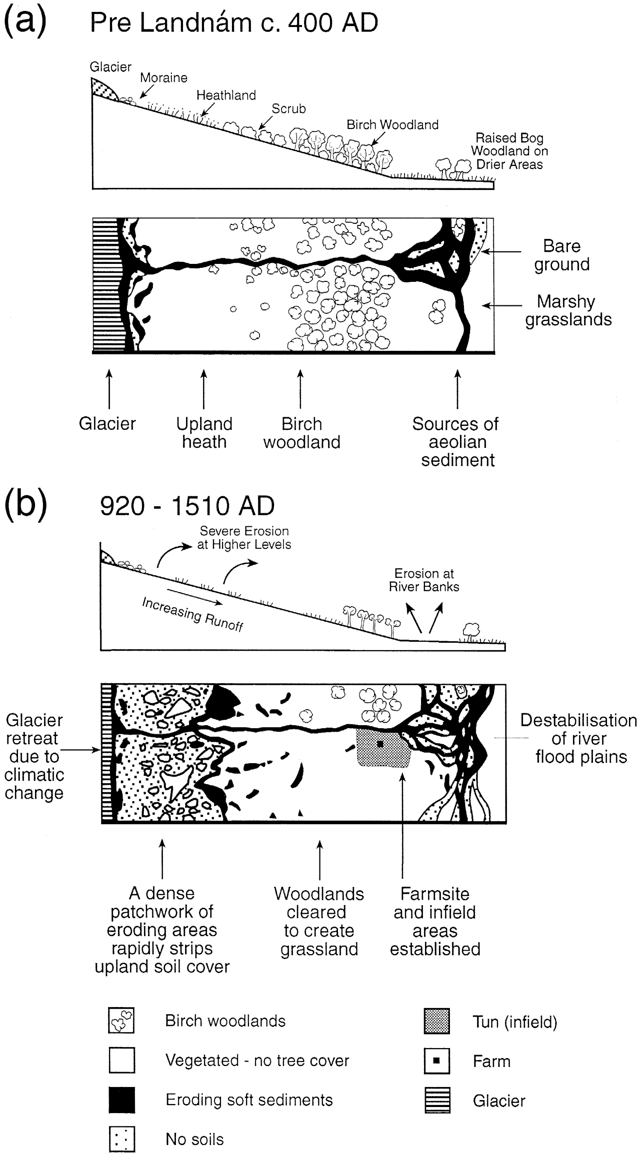

Fig. 2. A general model of soil erosion and land degradation for Southern Iceland, showing three time periods, (a) ca. 400 AD, (b) 920–1510 AD and (c) 1510–1947 AD.

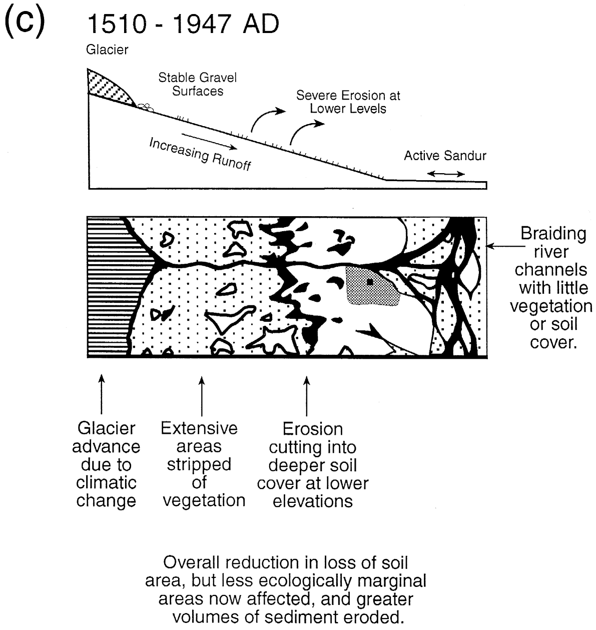

Fig. 2 (*continued*).

to have been in existence from at least 1097 AD when tithing was introduced. A *hreppur* (sg.), or commune, was an association of at least 20 farmsteads which could among other things organise the common grazing resource and co-operated in the autumn round-up of sheep (KHL VII, pp. 17–22). While the ownership of the *afréttir* by *hreppar* is not documented until the 15th century, there is much earlier evidence of communal ownership of pastures by two or more farmsteads. This documentary evidence suggests that there was substantial regulation of *afréttir* from an early stage. The earliest evidence comes from the mid-13th century collection of law called *Grágás* (Icelandic: ‘Grey Goose’; Finsen, 1853, 1879), considered to represent legal traditions of the Commonwealth period (AD 930–1262). Following union with Norway in 1262, the Icelanders received a new law code, *Jónsbók* in 1281, subsequently amended in 1294, 1305 and 1314 (Haldórsson, 1970). This made only minor changes to the regulations of *Grágás* in relation to *afréttir* and served as the legal framework for common pasture into the 20th century.

The problem of overgrazing is dealt with as early as *Grágás*. Any insider in an *afréttur* could call for an independent evaluation of the grazing capacity of the pasture. Assessors were instructed to find the maximum number of sheep that could use the pastures without affecting the average weight of the flock and once the maximum number of animals was determined, each user of the *afréttur* was given a quota on the basis of the value of his farm. A farmer who exceeded his quota could face a heavy fine if brought to court by his co-owners of the *afréttur* (Finsen, 1853, pp. 114–115).

Enforcing property rights depended upon the earmarks of the flocks individual to each farmstead (Finsen, 1853, 154–55; 1879, 479–80). *Grágás* and *Jónsbók* required the farmers to drive their flocks to the *afréttur* in a given week in June; to overcome the problem of sheep crossing into another *afréttir* and home pastures the law books required that flocks be driven into the middle of the *afréttur* and not left near the borders. Before the sheep were taken into the *afréttur*, it was to be fallow for 2 weeks but those who owned land bordering on the common land were allowed to use it for grazing in winter. Sheep were to be rounded up before a specific week in September and driven back to the farmstead areas (Finsen, 1853, p. 113). In 1281, when the law code of *Jónsbók* was confirmed by the General Assembly (*Alþing*), demands were made that each district be allowed to set its own conditions on the basis of local circumstances. These demands were met in the Amendments of 1294 and the right to set the dates was given to the overseers of the *hreppar*. *Grágás* further established the exclusive rights of a group of individuals to an *afréttur* and stated that outsiders require permission from all the owners of an *afréttur* before they could use it for grazing (Finsen, 1853, p. 113).

The documentary sources thus suggest that there were mechanisms in place to regulate the *afréttir* grazing areas in relation to sheep numbers. Furthermore, such tightly defined regulation which includes defined boundaries and memberships, congruent rules, conflict resolution mechanisms and graduated sanctions are characteristic of successful management of common resources in other areas of the world (Olstrom, 1990). It is therefore possible to draw the conclusion from Icelandic documentary sources that a ‘tragedy of the commons’ on *afréttir* was an unlikely scenario to the extent that it would result in land degradation. The pressure of sheep numbers in these areas was unlikely of itself to have been primarily responsible for soil erosion and land degradation in Southern Iceland. Such a conclusion can be assessed further through the development and application of grazing models to historic landscapes, which may begin to demonstrate with more precision the characteristics of grazing regimes that contributed to the onset and continuation of land degradation.

4. Landscape reconstruction and modeling of grazing pressure

Landscape reconstructions for the study area have been derived from existing and chronologically well defined paleoenvironmental data for vegetation, together with known altitudinal and vegetation relationships (Hallsdóttir, 1987; Pálsson, 1981), for climate (Ogilvie, 1984, 1991, 1992) and for known geomorphological change (see above). Settlement sites were identified through archaeological excavations and from documentary sources. These data were developed as a Geographical Information System (GIS-ARC Info) database and their integration permitted landscape reconstruction for ca. 900–1000 AD, ca. 1550 AD and ca. 1750 AD (Fig. 3). The reconstructed landscape for ca. 900–1000 AD suggest gradients of vegetation cover with sands adjacent to the coast, marshy grassland in the lower areas of the *hreppur*, areas of woodland, scrub woodland between 300 and 400 m, broad-leaved grasslands between 400 and 500 m, fine-leaved grassland between 500 and 700 m and moss heath (30% cover) above 700 m. Areas lacking accessible vegetation cover include cliffs and cinder cone. The earliest settle-

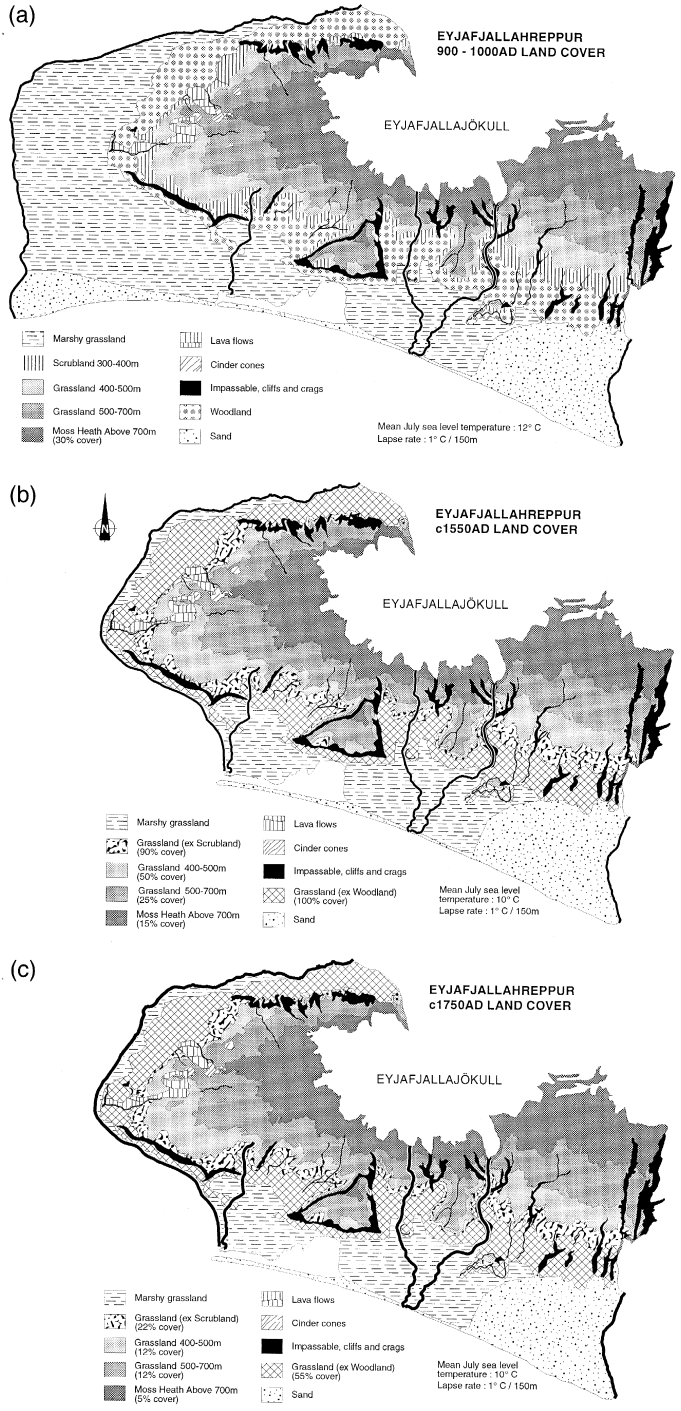

Fig. 3. Landscape reconstructions for Eyjafjallahreppur, (a) ca. 1000 AD, (b) ca. 1550 AD and (c) ca. 1750 AD.

ment sites were located on or adjacent the marshy grasslands, reflecting the need for winter fodder (Vésteinsson, 1998), with secondary settlements more generally evident adjacent to woodland areas. Mean July sea temperature was estimated as being 12°C. Changes in the landscape by ca. 1550 AD include woodland and scrub woodland loss, together with a reduction in the area of grassland cover as a result of land degradation. Furthermore, changes in the Markarfljót channel meant that pasture on the western side of the river became less accessible, although it continued to be used. Mean July temperature is estimated as being 10°C. By 1750 AD, further significant reductions in vegetation cover had taken place. Historic domestic livestock numbers for the *hreppur* were obtained from the farm survey of Iceland undertaken by Árni Magnússon and Páll Vídalín between 1703 and 1714 on behalf of the Danish crown (Melstað et al., 1990). This survey recorded all farms, both working and abandoned, and listed rents, numbers and type of livestock and other available resources. Some caution in using this data is required as it is possible that farmers may have downplayed livestock numbers so as not to appear too prosperous and thereby have their taxes raised; however, the figures given are held to be broadly accurate. For the purposes of calculating historic grazing pressures, the estimate of one cow having the grazing requirement of six sheep was used, giving a sheep-based grazing livestock total of 15,106 for the Eyjafjallahreppur.

This data was then used to empirically estimate biomass production and off-takes by domestic livestock off-takes based on established relationships between vegetation type and biomass production. Our first approach to estimate the relationship between biomass production and off-take by sheep in *afréttur* has been to utilise existing published data of average annual yields (kg/ha, dry matter) of plant communities in Iceland and estimated sheep off-takes (Friðriksson, 1972; Thorsteinsson et al., 1971). In these studies, a 40% utilisation rate has been regarded as 'proper use' of the pasture and it is assumed that the livestock are on the *afréttur* from June to September. Calculations based on these data indicate a decline in available biomass as a result of climatic change and erosion over the three time periods under consideration (Table 1). Estimates suggest that livestock would require 393×10^4 kg of dry matter for a 4-month summer grazing period. For the 1000 AD landscape, modeling suggests that the common grazing area above 400 m could have provided this amount. By ca. 1500 AD previously wooded land at lower altitudes would have to be exploited to maintain the historic numbers of livestock. By ca. 1750, lowland wet grasslands would also have to be used over the

Table 1
Estimates of utilised biomass in Eyjafjallahreppur, 1000 AD, 1550 AD and 1750 AD (calculations from existing data)

Available kg dry matter	1000 AD	1550 AD	1750 AD
Moss heath: >700 m	21×10^4	10×10^4	21×10^4
Grassland: 500–700 m	199×10^4	49×10^4	24×10^4
Grassland: 400–500 m	263×10^4	131×10^4	32×10^4
Grassland (ex scrub)		102×10^4	25×10^4
Grassland (ex woodland)		320×10^4	176×10^4
Marshy grassland			274×10^4

summer months, putting inevitable pressure on the area harvested for winter hay. Despite this obviously deteriorating situation, the analyses suggest that there was sufficient biomass across the Eyjafjallahreppur as a whole to support the historical numbers of livestock. While there was little margin for error, livestock numbers could have been maintained with careful timing of the period livestock were kept on common grazing areas.

A second approach to the assessment of grazing pressure is through application of grazing models as a means of providing indicators of grazing pressure. In the absence of a grazing model specific to Iceland, a grazing model developed for UK upland environments, and which has successfully been applied to the Northern Isles of Orkney

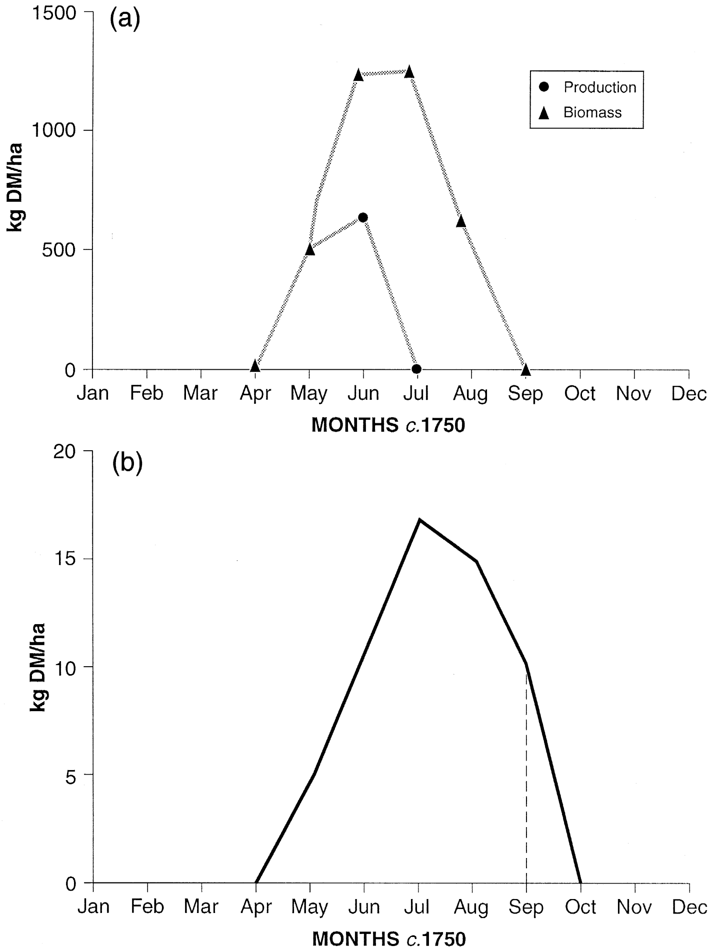

Fig. 4. Grazing model output for Eyjafjallahreppur 1750 AD landscape, showing (a) green biomass, productivity and (b) grazing offtake values (kg dry matter).

and Shetland, was adapted for Icelandic historic landscapes (Armstrong et al., 1997a,b; Simpson et al., 1998). The adaptation required the use of altitudinal lapse rates, given as 1°C/150 m (Bergthórsson et al., 1987), as a proxy for latitude variation. Although this model is only a partial representation of Icelandic conditions, observations from the model again indicate that there was sufficient biomass provision across the Eyjafjallahreppur for the historical numbers of livestock. Green biomass is estimated as 1900 kg/ha/year dry matter production for upland grasslands in the ca. 900–1000 AD landscape, with an estimated off-take of only 5.5 kg/ha/year dry matter. For the ca. 1550 AD and 1750 AD landscapes green biomass is estimated as 1200 kg/ha/year dry matter, with estimated off-takes of 10.5 and 17.5 kg/ha/year dry matter, respectively. These estimates reflect cooler climatic conditions and increased off-take per ha with erosion reducing the available grazing area. A check of these estimates against the available Icelandic data (Friðriksson, 1972; Thorsteinsson et al., 1971) indicates close similarities in biomass production and off-take requirements and suggests that model predictions are providing meaningful approximations.

Potentially of greater significance are the model-predicted patterns of yearly green biomass. For the ca. 900–1000 AD landscape, with comparatively benign climatic conditions, the model suggests that green biomass production in the upland grassland areas, although declining during the winter period, was available all year round, a similar situation to modern day Shetland. In contrast, the model suggests that green biomass production of the upland grasslands (above 400 m) during the more severe climatic conditions of the ca. 1550 AD and ca. 1750 AD landscapes was restricted to a growing season between the months of May and August (Fig. 4). Although off-take of dead biomass by livestock has still to be properly accounted for, these observations indicate that any pre-May and post-August grazing would have resulted in off-take exceeding green biomass production. Thus, livestock brought to the *afréttur* early in the year, perhaps because of failure to harvest sufficient hay for the winter, is a scenario where carrying capacities of *afréttur* could have been exceeded. Similarly, livestock kept on the *afréttur* into the autumn, as indicated by the documentary sources, would also be a situation where *afréttur* carrying capacities could have been exceeded, with the consequent onset of land degradation.

5. Discussion

While grazing of *afréttur* by domestic livestock, and sheep in particular may remain a primary cause of the major soil erosion and land degradation in South Iceland, an integrated historical approach to this issue suggests that a simple ‘tragedy of the commons’ scenario is an inadequate, and even false, explanation. Documentary sources clearly indicate that sheep numbers and management of sheep on the *afréttur* were regulated. Rather than common land, a common pool resource with well-defined conceptual management boundaries is a more accurate definition of these areas, and could have been sufficient to prevent major land degradation problems. Furthermore, landscape reconstruction and grazing modeling suggests that there was sufficient green biomass to support the historical numbers of livestock, even when cooler climatic conditions and land degradation were reducing biomass production. Significantly, despite major land degradation prior to the 19th century, the land was still able to support and sustain the major increases in livestock numbers associated with the agricultural improvements of the late 1800s. Over the study area as a whole it would appear that there were sufficient biological resources to support stocking levels created. There remains therefore a dilemma in how to explain the relationship between soil erosion and sheep grazing in South Iceland when there is strong evidence for sufficient biomass to support the numbers of livestock. The issue of soil erosion and its relation to livestock is clearly of greater subtlety than previously considered.

Based on the grazing modeling approach adopted, we can highlight two possible reasons for land degradation associated with sheep grazing. The first is a lack of adequate shepherding of sheep on *afréttur*. Given that that there was sufficient green biomass to adequately support the historical numbers of sheep in the study area, it is possible that a failure to move sheep across the landscape resulted in localised overgrazing in locations where the vegetation was particularly palatable with subsequent land degradation (Evans, 1998). A second reason for land degradation associated with sheep grazing could be the failure to remove livestock from *afréttur* outwith the growing season when there was a lack of green biomass. The timing of grazing in these areas is emerging as a critical factor, and social or environmental pressures to have livestock on *afréttur* too early or too late would be likely to contribute to land degradation as the margin for error became slimmer.

Social explanations as to why there was a lack of adaptation now need to be sought. One emerging critical determinant of human impact on landscapes and in social responses to landscape change is the notion of cultural knowledge (Crumley, 1994). Applied to landscape sensitivity, cultural knowledge can be regarded as what is known by a social group about the dynamics of a landscape, as well as what is known about landscape responses to the activities of that social group. A typology of cultural knowledge has been derived and includes axiomatic knowledge, which provides a rationale for actions; directory knowledge, defining how actions are to be undertaken; dictionary knowledge, indicating what areas are appropriate for action; and recipe knowledge, indicating whether actions should be undertaken or not (Sackmann, 1991). It is also recognised that the different types of cultural knowledge can be differentially acquired and retained by different subgroups of the social system.

Although Icelandic settlers brought European land management systems, economic strategies and expectations (Amorosi et al., 1997), the evidence of *Grágás* and *Jónsbók* suggests that by the Commonwealth period graziers were well aware of land degradation in a new and different environment, and were taking action to address the issue. A striking feature of the documentary sources however is the lack of any further evolution of land management strategies for *afréttur* in subsequent centuries, suggesting stagnation in cultural knowledge of these sensitive landscapes. Such stagnation may be explained by the onset of short-term but wide fluctuations in climatic conditions, embedded within a long-term decline in temperature, as evidenced by estimated equilibrium line altitude data from Sólheimajökull (Fig. 5; see Fig. 1 for location). While this record is influenced by increasing data resolution from 1600 AD onwards, it does

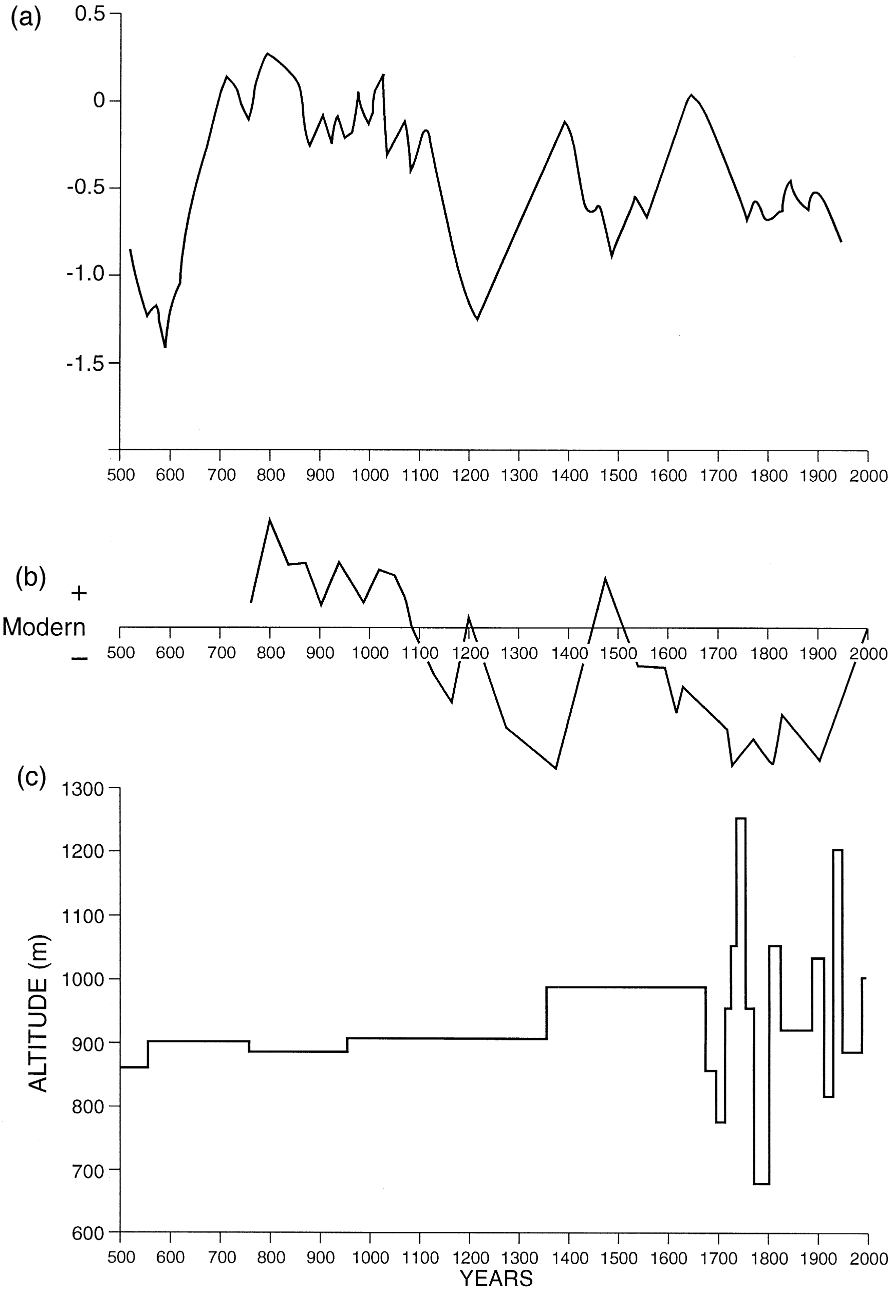

Fig. 5. Climatic change indicators ca. 500–2000 AD. (a) Central Greenland GISP2 EOF, generalised climate proxy record; (b) East Greenland, Nansen Fjord, biostratigraphy climate proxy record; (c) Sólheimajökull, South Iceland, estimated equilibrium line altitude record from 500 AD, a proxy indicator of climatic change.

indicate increasing climatic variability in the 'Little Ice Age'. Such a view is supported by a similar climatic history evident from the biostratigraphic proxy record of climate change from Nansen Fjord, East Greenland and the GISP2 Greenland ice core (Fig. 5; Mayewski et al., 1993; O'Brien et al., 1995). Several years of relatively mild conditions, for which existing management structures were appropriate, may have meant graziers failed to perceive environmental change and induced a sense of security. Milder conditions were followed by several years of more severe conditions including harsh winters and cool summers for which grazing management regimes were poorly adapted and from which graziers may have had difficulty in recovering. Under these uncertain circumstances, the maintenance of existing land management systems could have been regarded as the safest option, a position exacerbated by the very high levels of insecure and annually renewed tenancies — 96% of farms in 1695, slowly reversed to 90% by the start of the 19th century.

6. Conclusions

The detailed analyses of landscape sensitivities carried out by earth scientists and physical geographers have yet to be matched by equivalent attention to causal human factors. In this paper, we have demonstrated that the relationship between land degradation and common land grazing management is more complex than commonly applied models allow. As a general principle we would argue that rigorous assessment of sometimes simplistic models of human impacts on landscapes is an essential starting point. Only then will genuine integration between physical and social scientists begin to be achieved.

Our integrated historical approach has highlighted the need for assessment of documentary sources, environmental reconstruction and appropriate assessment of vegetation productivity and utilisation, and in doing so has demonstrated the enhanced understanding of landscape sensitivity that adopting this approach can bring. Such benefits will not be confined to the fragile landscapes of Iceland. Andosol landscapes with increasingly well defined tephrochronologies are also found in New Zealand, in Central and South America and in Western North America (ISSS Working Group RB, 1998), opening up the possibility of culturally driven landscape sensitivity studies that examine landscape change associated with the colonisation of already occupied regions. As in Iceland, the challenge in these regions is to provide genuinely interdisciplinary methods of analyses to achieve a fuller understanding of the human dimensions of landscape sensitivity.

Acknowledgements

Aspects of this work have been supported by a National Science Foundation Grant (via the North Atlantic Biocultural Organisation), by the National Geographic Society and by the Leverhulme Trust. We are grateful to Tracy Grieve and Bill Jamieson (both from the University of Stirling) for their assistance in developing the GIS data base.

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