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Short Communication

Complexity in Effects of Climate Change; an Example from Treeline Areas in Northernmost Europe

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- Lichen heaths
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Abstract

This short communication shows an example from northernmost Europe of possible cascading effects of land use and climate changes. It is suggested that complexities of effects may be common also in other biomes and thus important both for man and all biology in general.

INTRODUCTION

Background

The rock conditions of northernmost Europe are complex [1], mainly with Precambrian, normally "acid" and poor gneisses and granites east of the Caledonian north-south mountain chain. In northern Fennoscandia podzolic soils are well developed in the forests, but the raw humus and bleaching layers become thinner in the upper treeline. These acid soils contain only small amounts of plant available nutrients as P and K, which causes poor plant development and biodiversity. In drier districts, particularly in somewhat elevated (300-500 m a.s.l.) inner parts of the region, the main plant communities of the ground layer are low productive [2] reindeer lichens (mostly *Cladonia* sp.) dominated heaths [3,4], with relatively slow growing, multi-stemmed, low (3-5 m tall) and sparse mountain birch (*Betula pubescens tortuosa)* forests in the tree layer of a typical northern European treeline vegetation [5,6].

These heaths have been important forage for native reindeer-caribou animals in Arctic-Sub-Arctic regions of the world for thousands of years. The animals have been used by man for meat, first by hunting as known from Archeological sources, later through domestication and nomadic herding of semi-domesticated animals, to some degree back to the 800's, but in particular from the 17th century [7].

Climate change

Climate change has been a worldwide fact at least since the last decades of the last century, although with different effects in various parts. The temperatures have several times been said to being mostly increasing towards the poles [8,9], and also the precipitation seems to increase in these areas. According to statistics in Norway temperature has most strongly increased, particularly during Spring, in the northern most county Finnmark (at about 70°N) since 1900 [10]. That region is also projected to get the highest temperature increment further to the next century throughout all seasons, but particularly during the coldest part of the year.

Precipitation is generally low in the inner parts of northern Fennoscandia, down to below 400 mm per year in some places [11], but has had an increasing trend during the whole year in the last 100 years. This has, however, particularly been true during spring (2.4% per decade, 10), and is projected to increase mostly, by 25% in the inner, northern districts during spring and summer, to the end of this century [11].

Reindeer grazing at present and by projected socio-ecological and environmental conditions in the future

Today, reindeer husbandry in northern Europe is a small industry on a national scale, but in Sámi and local context it has great importance [12], both economically and as part of the Sámi culture. Reindeer husbandry depends on the diversity of accessible natural pastures [13], and therefore, the herds are very often moved to different regions during the year. During the summer season reindeer strongly use high quality pastures at slopes and depressions (Figure 1) [14], and are herded to such areas, particularly near the coast. During winter, however, reindeer forage is strongly dominated by the nutrient poor reindeer lichens [8] on the dry heaths in inland with shallow snow cover, to more than 50% and even up to 80% [15] of the total intake.

In northern Fennoscandia there have been strong variations in the semi-domestic reindeer grazing densities throughout different districts and time, both due to traditions, governmental policies, weather conditions and facilities for the herding [9,14,16]. From the late 1960's the use of snowmobiles and later

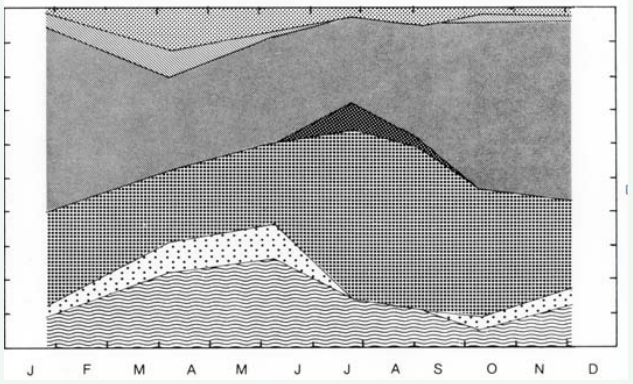

Figure 1 Reindeer diet based on 82 rumen content samples. From top to bottom of the figure percentage score of the following groups of organisms is shown: Mosses, Epilithic lichens, Epigeic lichens, Forbs, Graminids, Litter, Woody plants.

all-terrain vehicles strongly facilitated reindeer herding from an area to another, and stimulated far more intensive pasture utilization [4] and also contributed to herd growth until the 1980's. Then some severe winters caused reduced reindeer herds until around year 2000, after which they have increased again [9,17].

The increment of reindeer herds in many areas of northern Fennoscandia in recent times may partly explain an overexploitation of some grazing areas, particularly by a reduction of the main winter forage, the slow growing and low competitive reindeer lichens [4]. These lichens may be seen as a "bottleneck" for survival of the reindeer. They have a specialized microbial flora in their rumen to digest the nutrient poor and carbohydrate rich lichens [18]. Despite the low daily intake by the lichens, they are vital for these animals in winter.

There are several reasons for the destruction of the lichens by too many reindeer. These animals are not only eating the lichens. They are also trampling the areas and try to dig through the often shallow snow cover to get to their lichen food [4]. By that a strong destruction of the lichen mat may occur. When we know that lichens have a low growth rate, it may be difficult to get a sustainable re growth before the next visit of the animals.

But overgrazing is far from the only reason for difficulties in recovery of the lichen mats, and for the reindeer to find what is left. The climate change with increasing temperatures, particularly in the winter season, often causes melting and freezing periods of snow, leading to ice layers in the snow, which may be very difficult for the reindeer to penetrate [9,19]. Although the annual precipitation generally is low in the inner northern Fennoscandia, recent and projected further increment of precipitation [10] will probably increase this ice crust problem. On the other hand, it is found that lichen growth in summer strongly increase by increased precipitation [20,21], but anyhow it may take 4-7 years without disturbance for a recovery of a lichen mat to be somewhat like a sustainable new reindeer forage.

Overgrazing, trampling and digging by reindeer will of course result in much open soil, which facilitate germination of many plant species growing faster than the reindeer lichens. This again results in strong competition with the lichens. It may also be important for plant growth that more nutrients may be available for them by faster decomposition rate and mineralization at the climate change with higher temperatures and precipitation, although some CO_2 may be lost to the atmosphere at increased decomposition. On the other hand, more nutrients are supplied to the ground by the increased precipitation, particularly due to increased airborne CO_2 and NO_x by e.g. pollution brought even to the less populated areas often with poor soil in the far North.

A model from Scandinavia [22] has shown that doubling the ambient CO_2 concentration increased net primary production by 36%. A scenario with both elevated temperature and higher CO_2 caused an increment in the production of nearly 50%. Similarly, it is found that at a fixed increase in CO_2, biomass also increases proportionally to increased nitrogen availability [8].

In these ways nutrient demanding plants may out-compete lichens, and the reindeer herds have to change their diet to these plants. Even in winter they have to change to young shoots of birch saplings surviving the first years of growth, and mountain birch forests are predicted to have a strong increment in the heaths of northernmost Fennoscandia in the future [23].

However, at increased temperature in winter more birch moth eggs could survive [24,25], and then there may also be arrival of new defoliating insect species to the area [26], using e.g. mountain birch forests as a host species. The larvae of the birch moth may totally browse all leaves off the trees. This often happens more years after each other, and the mountain birches may then die. The quality of the reindeer lichen-mountain birch heaths is further diminished, and the semi-domestic reindeer herds will have access to less food. The reindeer owners will then "have to reduce the number of animals using the area or to keep the herds in summer grazing areas for prolonged periods. This will however, cause other cascading effects" [6].

CONCLUSION

This paper is written to show that although grazing by too many semi-domesticated reindeer in a herd within a given area may destroy the grazing habitat, also many aspects by climate change will influence the area. In the mountain treeline areas in northern Europe it is essential to find the socio-ecological sustainable use of the vegetation [27,28]. The author of the present paper is of the opinion that changes in the use of an area may have one main effect but, particularly at the present climate change, there will be also be several other effects. Therefore, all bio-ecological and socio-ecological studies have to be interdisciplinary collaboration!

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