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Impacts of livestock on vegetation communities and structure in Iceland

Karjanhoidon vaikutus Islannin kasviyhteisöihin ja niiden rakenteeseen

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Many ecosystems in Iceland are fragile and vulnerable as the effect of large herbivores has started only after the human settlement in 870's. Before human influence – meaning also the influence caused by domestic animals i.e., sheep, cattle, and horses – birch woodlands were the dominating ecosystems. Cutting of these woodlands and the grazing of domestic animals have caused large-scale soil erosion leading to soil degradation and even desertification. Even though domestic animals are vital for food security, human livelihood and economic growth, it is important to minimize the negative impacts of livestock farming on the ecosystems. Livestock can be controlled and manipulated through different grazing systems. Therefore, it is important to determine past and present vegetation structure and compositions and the causes of changes to determine a sustainable management practice that serves the local environmental, societal, and economic objectives.

Introduction

Livestock were introduced into Iceland along with the arrival of the first settlers in 870s (Thorsteinsson et al. 1971). Settlers brought cows, horses, and sheep into the country mainly for dairy products, means of transportation and meat production. Further, reindeer were brought into the country from Norway between 1771 and 1787 by the Danish authority initially to experiment if they can survive and thrive in the country (Karlsdóttir 2021). This could have provided an alternative to sheep meat in case of climate severity when sheep cannot survive. Before the human settlement, low-growing birch trees with dense ground vegetation cover of forbs and grasses had dominated the large parts of the lowlands of Iceland (Fig. 1). Human settlement, however, caused the destruction and loss of natural forest cover due to cutting and burning as well as uncontrolled and intensive grazing of livestock (Thorsteinsson et al. 1971; Aradóttir et al. 2013).

Livestock can have both direct and indirect effects on the terrestrial ecosystem. Grazing, trampling and release of excreta are some of the direct effects while alteration in the rate of nutrient cycling and nutrient availability are some indirect effects (Harrison & Bardgett 2008). Grazing pressure and intensity affect vegetation composition, diversity, and structure. Due to technological advancement, globalization, and access to commercial fertilizers the number of domestic animals increased hugely by the end of the 19th century (Marteinsdóttir et al. 2017). For example, the number of sheep almost tripled from the mid-19th century to 900 000 by the end of the 19th century (Marteinsdóttir et al. 2017). This may have caused overgrazing of both highland and lowland pastures. Extensive cutting down of mountain birch woodlands and overgrazing by livestock might have played a major part in the process that transformed these woodlands into presently found open grasslands and heathlands. Such an extensive land management practice, in

many instances have caused soil erosion resulting in soil degradation or even desertification (Arnalds 2015).

Plants are the bases of an ecosystem that empowers higher-level communities and individuals of the food web inhabiting the system by providing them with food and shelter (Maron & Crone 2006). In Iceland, land degradation and soil erosion have been recognized as the consequences of sheep grazing (Arnalds 2015). However, a study by Mörsdorf et al. (2021) on the Icelandic tundra landscape found insignificant effects of exclusion of grazing on plant diversity. Therefore, it is vital to understand the impacts of grazing on vegetation and vegetation responses to grazing to ensure long-term productivity and other ecosystem services of land. The study of plant-herbivores interactions might also help us to understand the past, current, and future state of vegetation structure, cover and composition with herbivores as main controlling factors.

Past and present vegetation cover and types

At the beginning of human settlement, approximately 65% of land cover was thought to be covered with vegetation of birch at lower elevations and willows and other dwarf shrubs above 300 to 400 m elevation (Andrés 1987). These past vegetation cover and distribution scenarios of Iceland are determined based on the study of remnant vegetation found on islands on lakes and rivers as well as some other methods such as tephrochronology and pollen analysis. Since the arrival of settlers, birch woodland covers have been cleared for farmlands, fuel, hayfield, and lumber. Woods were extensively used as fuel and for charcoal production. Moreover, uncontrolled grazing by livestock might have disturbed or ceased the process of natural regeneration of woody species such as birch (Andrés 1987). It seems that birch trees in the past were mostly single stem and much larger as compared to present birch trees in Iceland (Fig. 1).

The most noticeable and striking fact regarding the current vegetation cover of Iceland is the absence of trees and openness of the landscape.

Fig. 1. Dry lowlands of Iceland most likely looked like this at the time of settlement A (Thorsteinsson et al. 1971) and present vegetation cover B (a photograph taken during the fieldwork on 12th June 2022. Photo: Gopal Adhikari).

Kuva 1.A Luultavasti tällaiselta näyttivät Islannin kuivat alangot ensimmäisten siirtolaisten sinne saapuessa (Thorsteinsson ym. 1971). B. Tällaiselta nuo alueet näyttävät nyt (Kuva Gopal Adhikari, 12.6.2022).

Presently only 25% of Iceland is covered with vegetation whereas birch cover accounts for 1% only (Arnalds 2008). The majority of today's birches are multi-stemmed with an average height of less than 2 m. Yet, in some grazing-restricted areas, birches with a height of more than 12 m are also found (Andrés 1987). There are plenty of well-drained lands that are covered with low-growing shrubs, mosses, and sedges. The poorly drained areas that have approximately 40% share of the total area of the vegetated lands, are mainly dominated by sedges. However, there are also undrained or restored peatlands with dense carpets of *Sphagnum* mosses, sedges and shrubs. Further, *Racomitrium* moss has extensive cover mainly in unfavourable growth conditions

areas in the highlands of Iceland and on lowland lava fields. Currently, the remaining native birch woodlands under the national forest are protected and promoted.

The Iceland Forest Service (IFS) is a governmental agency established in 1908 mainly to manage the national forests (IFS, 2016). In addition to the protection and promotion of remaining birch woodlands, IFS activities also include finding suitable areas and species for afforestation. Farm afforestation supported by the Regional Afforestation Projects accounts for 70–80% of the afforested areas in Iceland. From 2000 to 2015, the annual plantation of seedlings peaked in 2008 with a gradual decline until 2013. Birch, larch, and spruce seedling planting has decreased considerably as compared to pine and poplar (IFS 2016). The lower seedling planting might be due to the protection and management of existing woodlands to promote natural regeneration. Natural regeneration could be a better alternative in some cases as seedling production and plantation of certain tree species might be costly and highly labour demanding. However, FAO global forest resources assessment report (2020) showed that the naturally regenerating forest area remained nearly stable between 1990 and 2020 (Fig. 2). In comparison, the area of plantation forests has increased nearly by factor of seven between 1990 to 2010 with further increases towards 2020.

For the same period (1990–2020), in addition to forests, the area or grasslands also increased considerably (Fig. 3). This increase of grassland area might help to protect and promote forests development as it may deliver an alternative for sheep grazing in wooded areas. Simultaneously, the expansion of forests and grasslands is seen as the decline in the area of wetlands and arid lands.

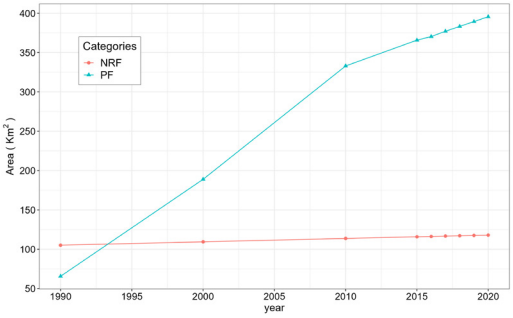

Fig. 2. Areas of Naturally regenerating forest (NRF) and plantation forest (PF) of Iceland from 1990 to 2020 (FAO 2020).

Kuva 2. Luontaisesti uudistuvien ja istutusmetsien pinta-alakehitys 1990–2020 (FAO 2020).

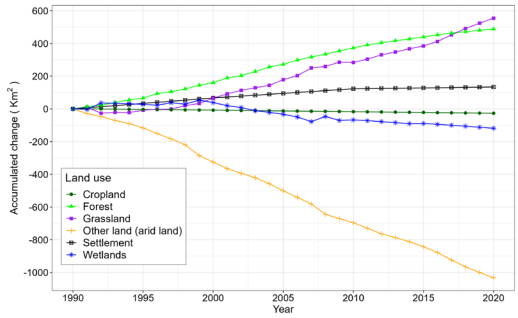

Fig. 3. Land use change for Iceland from 1990 to 2020 (Statistics Iceland 2022).

Kuva 3. Maankäytön muutos Islannissa 1990–2020 (Statistics Iceland 2022).

Plant herbivore interaction

The ability of different plants to counter or tolerate the impacts of herbivory grazing depends partly on the evolutionary history of grazing (Marteinsdóttir et al. 2017). Yet, Icelandic vegetation evolved in the absence of livestock which made it extremely prone to grazing stress. Furthermore, the impacts of grazing on the abundance, distribution, and composition of vegetation might also depend on the intensity of grazing, the feeding nature of herbivores, timing of grazing and soil properties. For example, grazing might cause severe consequences in vegetation survival and regeneration if the vegetation is performing already under some other stresses such as low nutrient availability and poor carrying capacity. The number of livestock increased considerably after the settlement. Thorsteinson et al. (1971) had pointed the issue of overgazing and its consequences already in seventies. Even at present, livestock grazing is one of the most pronounced disturbance factors to the remaining woodlands (Arnalds et al. 2023).

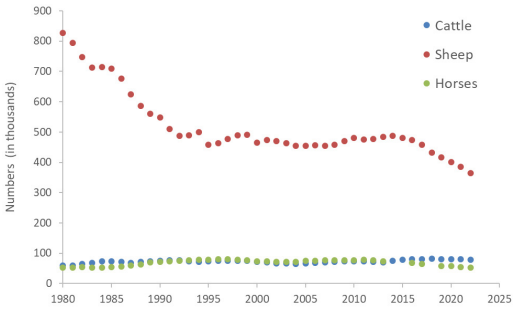

Fig. 4. The number of sheep, cattle, and horses from the year 1980 to 2022 in Iceland (Farmers' Association of Iceland 2019).

Kuva 4. Lampaiden, nautojen ja hevosten lukumäärät vuosina 1980–2022 (Farmers' Association of Iceland 2019).

Sheep, horses, and cattle are the major livestock of Iceland. For centuries sheep farming was the main source of meat as well as some other products such as wool and milk. The numbers of sheep have declined almost by half from 1980 to 2022. The numbers of cattle and horses remained nearly stable for the same period with a slight decrease in the number of horses from the year 2015 to 2022 (Fig. 4). This decrease in the number of horses might be due to the development of road networks and the advancement of transportation. Because of livestock quotas introduced in 1985, number of sheep decreased considerably (Ross et al. 2016). A further decrease might be related to the consumption of pork and poultry instead of lamb.

A grazing system is a way of controlling ecological interaction between livestock, soil, and vegetation. There are two main systems for livestock grazing, **continuous** where livestock are allowed to graze throughout the entire season or year with free access within a pasture and **rotation** grazing where access and timing of grazing are controlled. At the time of settlement in Iceland, the access and movement of livestock may not have been regulated, thereby causing unbalanced grazing as animals might favour particular areas which they visit more frequently than other areas. Thus, implementation of appropriate grazing systems that are adapted to the local conditions might assist on maintaining pasture health, forage quality and enhance livestock performance, health, and profitability.

Discussion

In addition to natural disturbances, various factors associated with human settlement have transferred the Icelandic landscape from fairly vegetation covered areas into more open treeless grasslands to barren deserts (Andrés 1987; Thorsteinsson et al. 1971). At present, continuous vegetation cover has nearly 27% of total area of Iceland with 23% of additional cover of non-productive plants where share of barren deserts accounts for around 36% (Arnald 2008). Soil erosion and desertification processes are still noticeable in many parts of the country.

Livestock grazing played an important role in the ecosystem degradation and vegetation composition in Iceland. The impacts of herbivores on Icelandic vegetation might have been acute as the Icelandic vegetation evolved in the absence of livestock and was suddenly exposed to large numbers of animals (Runolfsson 1987). Moreover, the vulnerability could also had been magnified as the Icelandic vegetation lack a defensive mechanism against herbivores. The dominance of grazing tolerant species in most of the Icelandic rangelands reveals that there has been high intensity of sheep grazing (Arnold 2008).

There are various direct effects of livestock grazing on soil and vegetation such as trampling and removal of living biomass. Selective grazing might alter vegetation composition and structure by constantly consuming specific plants while creating competitive benefits for others. Arnolds (2015) suggested that the continuous and intensive grazing by sheep in long-term can cause the loss of birch woodlands by preventing natural regeneration. Trampling increases the extent of bare soil and reduces vegetation cover thereby increasing soil vulnerability to erosion, wind, and heavy rain. Trampling, however, might create a suitable condition for seed germination by allowing easy access to the soil layer for lightweight seed species. Further, the presence of livestock in certain system might improve ground layer light conditions with larger openings and due to the movement and defoliation of shading leaves and branches. Thus, the impacts of grazing vary considerably according to soil conditions, size

and nature of grazing animals and types of grazing system.

To minimize the negative impacts of livestock farming on the ecosystem, livestock can be controlled and manipulated through different grazing systems. In contrast, some other environmental factors such as drought, wind and rain are difficult to control and expensive to manipulate. Therefore, it is important to determine past and present vegetation structure and compositions and the causes of changes to determine a sustainable management practice that serves the local environmental, societal, and economic objectives. The extent of current woodland cover could be much larger if livestock grazing practices were managed in the past.

Conclusions

Livestock are vital for food security, human well-being, and economic growth. Nevertheless, there are severe ecological issues associated with unsustainable livestock management practices. Uncontrolled and extensive livestock grazing in Iceland had interrupted the process of natural regeneration with the continuous removal of seedlings. Furthermore, livestock overgrazing and trampling increased the extent of bare soil making it more vulnerable to soil erosion, flood, and wind. Loss of soil organic layer in both natural and anthropogenic disturbance events might further slowdown the process of natural regeneration due to the unfertile soil condition. These converted or degraded landscapes are of huge potential for restoration, replantation, and rewilding to combat soil erosion and secure woods for the future generation. Thus, sustainable uses of rangelands are inevitable to maintain the long-term productivity of rangelands and tackle deforestation and soil erosion.

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Tiivistelmä

Islannin hauraat ja herkästi haavoittuvat ekosysteemit ovat kärsineet akuutista ekosysteemien rappeutumisesta, mikä on aiheutunut pääasiassa ihmisen toiminnasta. Ihmisasutuksen sekä kotieläimien esim. lampaiden, lehmien ja hevosten saapuminen on muokannut Islannin maisemaa ja luonnon monimuotoisuutta dramaattisesti. Luonnonmetsien laajat avohakkuut ja karjan laiduntaminen ovat monissa tapauksissa aiheuttaneet maaperän eroosiota, joka on johtanut maaperän huononemiseen tai jopa aavikoitumiseen. Vaikka karja on elintärkeä elintarviketurvan, ihmisten hyvinvoinnin ja talouskasvun kannalta, kestävää kehitystä tulisi edistää maatalouden harjoittamisessa.