UNITED NATIONS UNIVERSITY
UNU-LRT
Land Restoration Training Programme
Keldnaholt, 112 Reykjavik, Iceland

Final project 2017

EFFECTS OF DIFFERENT GRAZING SYSTEMS ON ECOSYSTEM FUNCTIONS IN LESOTHO AND ICELAND

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ABSTRACT

Excessive livestock grazing has caused extensive land degradation and soil erosion, thereby threatening people's livelihoods. Increased grazing pressure on communal rangelands in Lesotho and Iceland has led to massive amounts of soil being eroded each year causing a tremendous loss in biological diversity and ecosystem goods and services. In response to the above-mentioned effects of unsustainable rangeland management practices, a study on the effects of different grazing systems on ecosystem functions in Lesotho and Iceland was carried out. The two main objectives of the study were to assess the impacts of different grazing systems on Lesotho's rangeland ecosystem functions. Secondly, the study aimed at comparing the similarities or differences on effects of a similar grazing system, seasonal grazing, in the two countries. In addition, this study was aimed at determining and providing guidelines for sustainable rangeland management with grazing systems that are compatible for maintaining and improving rangeland health conditions, sustaining productivity and improving the economy of the countries and the livelihoods of present and future generations.

The study was carried out by investigating types of grazing systems practiced in Lesotho and their impacts on rangeland health, looking at their effects on rangeland site stability, plant species diversity and rangeland productivity.

The results from the two countries coincide with the fact that both countries are experiencing severe rangeland degradation mainly due to poor grazing management. The study concluded that grazing management systems such as rest rotational grazing, deferred grazing and modified seasonal rotational grazing could be suitable for both Lesotho and Iceland for maintaining, conserving and improving rangeland conditions and in enhancing functional ecological processes.

This paper should be cited as:
Rampai R I (2017) Effects of different grazing systems on ecosystem functions in Lesotho and Iceland. United Nations University Land Restoration Training Programme [final project]
http://www.unulrt.is/static/fellows/document/rampai2017.pdf

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1. INTRODUCTION

1.1 Rangelands and land degradation in Lesotho

Inadequate grazing management can lead to extensive land degradation. This is particularly important in areas where rural livelihoods depend on rangelands. In Lesotho, rangeland ecosystems provide goods and services that are essential for supporting the livelihoods of people and the economy of the country. Rangelands play a key role in social, cultural, ecological and economic demands. Rangelands are primarily used for livestock grazing; as such, rangelands provide direct economic benefits from trading livestock and livestock products, such as wool and mohair (Ministry of Forestry and Land Reclamation 2014a).

Rangelands also provide abundant clean water from wetland ecosystems present within them. The water from rangeland ecosystems is used locally in Lesotho for hydropower generation, agricultural and industrial purposes, and it is further exported to the Republic of South Africa through the Lesotho Highlands Water Project. Rangelands are ecologically important for CO_2 sequestration, biodiversity conservation and they provide habitat for both flora and fauna (Ministry of Forestry and Land Reclamation 2014a). Rangelands provide social and cultural goods and services through the provision of food, a variety of different grasses for different purposes, handicrafts, fuel wood, medicinal purposes and traditional ceremonies.

Sustainable grazing management systems should enhance ecosystem functions and ecosystem goods and services for present and future generations. In Lesotho, the rangelands cover about 60% of the total land area. However, Lesotho's rangelands are in poor condition (Ministry of Forestry and Land Reclamation 2014a). According to Nusser (2002), the mountainous Kingdom of Lesotho has been regarded as a prominent example of widespread environmental degradation, since the colonial times of 1884 to 1996. He further stated that poor grazing management practices on communal rangelands leading to overgrazing have primarily caused severe soil erosion and rangeland degradation (Nusser 2002). Lesotho also provides a typical example of the 'tragedy of the commons' (Hardin 1968). According to this scenario, increased livestock numbers to maximise individual benefits from the use of common resources (rangeland) comes at the expense of rangeland health, a cost that is then shared by all rangeland users.

Increased grazing pressure on communal rangelands has led to loss of protective vegetation cover, creating bare ground patches and thus causing loss of massive amounts of soil each year. The Ministry of Forestry and Land Reclamation estimated the rate of soil erosion in Lesotho to be about 40 tonnes per hectare per year (Ministry of Forestry and Land Reclamation 2014a). The exposed soils are compacted and have limited water infiltration, which in turn increases surface water runoff, washing away soil organic matter and nutrients, leading to decreased productivity and loss of biological diversity (Ministry of Forestry and Land Reclamation 2014a). Because of this loss in vegetation cover, soil fertility and reduced water holding and nutrient retention capacity, the rangelands in Lesotho are becoming dysfunctional ecosystems and have lost their potential and capacity to provide sufficient goods and services.

This calls for more research on determining the effects of grazing management on ecological processes to effectively and efficiently address the problem of severe land degradation which threatens the livelihoods of the people and the economy of the country.

1.2 Grazing systems in Lesotho

Grazing systems are specific ways of managing the ecological interactions between grazing animals, plants and soils. Grazing systems are defined by the type and number of grazing animals and the length of grazing and non-grazing periods (Society of Range Management, 1998). Grazing systems, when properly implemented, can help maintain rangeland health while providing valuable ecosystem services. To be sustainable, grazing systems need to be adapted to the local conditions, such as climate, topography, vegetation and soil types. Therefore, there is no single best grazing system, but some grazing systems may be more appropriate than others under specific conditions. To develop sustainable grazing management practices, the focus should be on rangeland health condition rather than livestock condition because it is by improving rangeland health or ecosystem functions that ecosystem goods and services, including grazing, will be enhanced.

Livestock are usually classified according to the size of the animals into two main groups, large and small stock. In Lesotho, large stock includes cattle, horses and donkeys, while small stock refers to sheep and goats.

The key to improving rangeland health lies in sustainable rangeland management practices that allow rangelands enough time to recover after grazing and ensure the functioning of main ecosystem processes: primary production and energy flow, nutrient and hydrologic cycling. Depending on the amount of "rest" time, there are two commonly used grazing systems: continuous grazing and rotational grazing. Continuous grazing systems involve grazing a specific range unit or grazing area continuously throughout the year. In contrast, rotational grazing systems involve the movement of animals from one grazing area to another on a scheduled basis. Depending on the duration and sequence of rotation among different grazing areas, rotational grazing can either be: seasonal rotation (transhumance), rest rotation, deferred rotation, short-duration rotation (Savory), high-intensity/low-frequency rotation, and many more (Holechek et al. 2011). In Lesotho about five grazing systems are typically used (Table 1).

It is a customary practice in Lesotho that in summer mixed herds of animals (cattle, horses, donkeys, sheep and goats) are moved to the high-elevation grazing areas and to low laying areas in winter. Since this type of grazing is influenced by seasonal change, it can be classified as seasonal rotational grazing or transhumance. This type of grazing system is also common in other seasonal environments with extensive grazing, like Iceland and other Nordic countries (Ross et al. 2016).

In 2013, an alternative grazing system, short-duration (Savory) grazing method was introduced and piloted in Lesotho (Ministry of Forestry and Land Reclamation 2013, 2014b, 2015). In this method, grazing is carried out by a relatively large number of animals in a relatively small area (i.e. at a high stocking rate) for a short period of time; herds are then moved to a different area, mimicking the natural migration of large herbivores. This method has been called "holistic management". However, the applicability of this method to communal rangelands has been questioned (Briske et al. 2008; Briske et al. 2013).

On other rangelands in Lesotho, different systems like rest-rotation and deferred-rotation have been used (Ministry of Forestry and Land Reclamation 2016c, Ministry of Forestry, Range and Soil Conservation 2010). Rest-rotation grazing involves a recovery period of 12 months, while deferred-rotation grazing involves a longer recovery period of 2 to 4 years (Holechek et al. 2011).

Table 1. Five different grazing systems that are currently practiced in Lesotho, short details of each grazing system, examples of areas where each system was practiced and type of livestock used for each grazing area.

Grazing system	Description	Examples	Type of livestock used
Continuous grazing	Grazing throughout the year	Ts'ehlanyane National Park[1]	Elands (wild animals)
Seasonal rotational grazing (transhumance)	4 months on summer rangelands, 8 months in winter grazing areas	Quthing Sheep-stud[2]	Cattle, sheep, goats and horses
Short-duration (Savory)	relatively large number of animals at a high stocking density for a short period of time on a specific area	Khubelu Sponge Project[3]	Cattle, sheep and goats
Deferred rotation grazing	Recovery period of 2 to 4 years	Semonkong SLM Project[4]	Cattle, sheep, goats and horses
Rest rotation grazing	Recovery period of 12 months	Mots'eremeli Catchment[5]	Cattle, horses and donkey

References:[1]Ministry of Forestry, Range and Soil Conservation (2016a), [2]Ministry of Forestry, Range and Soil Conservation (2016b) [3]Ministry of Forestry and Land Reclamation (2013), [4]Ministry of Forestry and Land Reclamation (2014b), [5]Ministry of Forestry, Range and Soil Conservation (2016c).

1.3 Two different countries facing similar problems

Both the mountainous Kingdom of Lesotho and Iceland are regarded as prominent examples of widespread environmental degradation due to mountainous topography with steep slopes, shallow and sensitive soils, coupled with poor land management practices and overgrazing. Loss of protective vegetation cover has exposed soils on unstable slopes in both countries to heavy rainfalls and fierce winds, causing loss of massive amounts of soil each year (Ministry of Forestry and Land Reclamation 2014a, Nusser 2002, Nusser and Grab 2002, Arnalds et al. 2001, Arnalds 2015).

Despite the differences between these two countries, in terms of climate, biogeography and geological history, some grazing systems are common to both countries. Seasonal grazing is implemented in both countries, and in both cases rangeland degradation has been associated with overgrazing.

Lesotho is a small mountainous kingdom with a total land surface area of 30,355 square kilometres. It is located in the southern part of Africa, within the borders of the Republic of South Africa, and it is home to a total population of about 2.1 million people (Ministry of Finance and Development Planning 2010). The country has four distinct agro-ecological zones, namely: the lowlands, foothills, mountains and the Senqu river valley. Lesotho has a temperate climate with mean annual temperatures that vary from 25˚C in summer to 15˚C in winter. The mean annual precipitation is between 700 and 800 millimetres. Most of the rainfall is experienced between October and April whilst snow is common between May and September, especially on the higher peaks (Ministry of Forestry and Land Restoration 2014a).

Iceland, on the other hand, is a volcanic island of about 103,000 square kilometres located just south of the Arctic Circle, and surrounded by the Atlantic Ocean (Arnalds 2015). The country has a total population of about 344,000 people (Statistics Iceland 2017). According to the Icelandic Meteorological Office, Iceland has a relatively maritime cold-temperate to sub-arctic climate and the mean annual precipitation is about 500 mm in the north and 2000 mm in the south. Iceland has two geographic areas; the lowlands and the highlands, with mean temperatures of 0 to 4 ^{0}C in the lowlands and 0 to -4 ˚C in the highlands (Icelandic Meteorological Office 2017).

Arnalds and colleagues (2001) in their book, *Soil Erosion in Iceland*, stated that research has showed widespread soil erosion in Iceland and the rangelands are no longer suitable for grazing, especially in the highlands with loss in vegetated land by 232 ha/year. They further concluded that land degradation and soil erosion are considered to be major environmental problems in Iceland and therefore there is a dire need for more research, knowledge and information to guide proper grazing management plans which favour maintaining rangeland capacity and the land potential on a long-term basis.

1.4 Aims of the study

The general objective of this project was to investigate the effects of different grazing management systems on ecosystem functions in Lesotho, and to assess how these compare to Iceland. The ultimate goal is to derive recommendations for sustainable grazing management that are applicable to Lesotho and to areas with similar environmental conditions.

The specific objectives of the study were to:

1. Investigate what types of grazing systems are practiced in Lesotho, and determine what are their impacts on rangeland health, with especial attention to their effects on:
    a. Rangeland site stability
    b. Plant species diversity
    c. Rangeland productivity

2. Compare the similarities and differences of the effects on ecosystem functions of the grazing systems common to Lesotho and Iceland, based on expert opinion.

2. METHODS

2.1 Effects of different grazing systems on ecosystem functions in Lesotho

To review the available knowledge on the effects of different grazing systems on ecosystem functions in Lesotho, relevant published and unpublished rangeland inventory and assessment reports from the Department of Range Resources Management were identified by consulting two range technical officers. These experts identified nine relevant reports that could be used in this research project. The information was compiled and synthesised.

From the rangeland assessment reports from Lesotho, I extracted information on indicators relevant to rangeland health attributes that are related to different ecosystem functions (Table 2). The Department of Range Resources Management estimated rangeland health status by measuring the following groups of attributes: rangeland site stability (vegetation cover, litter, bare soil, rock), plant species diversity (species composition and species richness, plant life form, ecological status), and rangeland productivity (forage yield, grazing capacity; Table 2).

Table 2. Rangeland health attributes and indicators considered in this study, and processes and ecosystem functions (primary production, nutrient cycle and hydrologic cycle) they represent. Checkmarks indicate the contribution of each indicator to one or several ecosystem functions.

Attributes	**Indicators**	**Process**	**Ecosystem functions**		
			Primary production	**Nutrient cycle**	**Hydrologic cycle**
Rangeland site stability	Vegetation cover	Increased vegetation cover implies more photosynthetic activity and thus, more production. Vegetation acts as a buffer for soil erosion and provides more resources/plant materials to be decomposed.	✓	✓	✓
	Bare soil	More bare soil means less vegetation cover and less production. It also means reduced supply of raw materials for nutrients and minerals. Bare soil has increased compaction, and accelerates soil and water erosion, as it promotes surface runoff and reduces water infiltration	✓	✓	✓
	Amount of litter	Litter adds value to nutrient cycles through decomposition. Litter also provides habitat and food for micro-organisms, converted into organic matter through decomposition. Litter also prevents surface crusting/ compaction increasing infiltration rate, reducing surface runoff, increasing water holding capacity, thus contributing to the hydrological cycle		✓	✓
	Rock	Promotes surface runoff and reduces water infiltration			✓
Plant species diversity	Species composition and richness	More species count healthier rangelands and increased productivity	✓		
	Plant life form	Grass/grass-like, forbs and herbs, shrubs. More grass species more production	✓		
	Ecological status	Decreasers, increasers and invaders. More decreasers mean healthier range conditions	✓		
Rangeland productivity	Forage yield	Healthier rangelands produce more yield, which in turn enhances ecosystem functions	✓	✓	✓
	Grazing capacity	Good, healthy rangelands have high grazing capacity and high grazing capacity means healthier ecosystem functions	✓	✓	✓

For grazing systems to be sustainable, the functioning of the main ecosystem functions of primary production, nutrient and hydrologic cycling, should be maintained. Primary production is responsible for biomass production through plant growth and reproduction, the nutrient cycle involves the decomposition of organic matter into minerals and nutrients which are essential for plant growth, and the hydrologic cycle should be kept functioning by promoting the water infiltration rate and reducing surface water runoff. The attributes of rangeland health measured by the Department of Range Resources Management are related to these ecosystem functions, as illustrated in Table 2.

2.2 Comparison between Iceland and Lesotho: Are the effects of grazing similar in both countries?

Based on the patterns identified in Lesotho, I designed a questionnaire to investigate if similar trends are observed in Iceland (Appendix 1). I conducted an interview with a subject expert on sustainable land management and natural resources from the Soil Conservation Service of Iceland. The questions were delivered via email followed by a one-on-one interview. The information obtained through the interview was summarised.

3. RESULTS AND DISCUSSION

3.1 Effects of different grazing systems on ecosystem functions in Lesotho

All the reports on rangeland inventory and assessment identified in this study were produced by the same institute, the Department of Range Resources Management, from the Ministry of Forestry, Range and Soil Conservation. The reports estimated rangeland health status by measuring rangeland site stability, plant species diversity and rangeland productivity on grazing areas where different grazing systems were practised, as illustrated in Table 3.

According to Alberta Agriculture and Forestry (2016), range plants can be classified or grouped on the basis of growth form, life span, origin, response to grazing and forage value. Van Oudtshoorn (2012) categorized plants based on their response to grazing, and their nutritive value as *Decreasers, Increaser I, Increaser II, Increaser III, and Invaders.* Decreasers were described as palatable, nutritious grass species that dominate rangelands under good conditions and decline in abundance when the rangeland deteriorates in condition through overgrazing or undergrazing. Increaser I consists of grass species that are abundant in underutilized rangelands due to selective grazing. They are unpalatable grass species that can grow without any defoliation. Increaser II consists of unpalatable grass species that dominate overgrazed rangelands. They increase with increase in grazing pressure. Increaser III consists of grass species that have high frequency count on overgrazed rangelands. They are usually unpalatable with low nutritive value. They multiply in rangelands experiencing excessive grazing because of their strong competitive ability towards other grass species. Invaders are all plants that are not indigenous to an area. They are commonly pioneer plants that invade the habitat of indigenous species and are difficult to eradicate.

Table 3. Summary of nine rangeland assessment reports from Lesotho showing rangeland site stability, plant species and rangeland productivity measured for each grazing system on nine different grazing areas. The table includes additional interventions that were put in place to speed up the recovery of rangelands. The time when rangeland assessment and reporting were carried out is also shown in the table.

GRAZING SYSTEM	RANGELAND SITE STABILITY	PLANT SPECIES DIVERSITY	RANGELAND PRODUCTIVITY	STUDY / REPORT	ADDITIONAL INTERVENTION	DATE
SEASONAL/ TRANSHUMANCE	The area seemed to be stable	High number and percentage	Productivity is notably high	QUTHING SHEEP-STUD[1]	Fencing	Aug-2016
SEASONAL/ TRANSHUMANCE	High erosion potential – unstable	Variety of grass species	Low yields	FAO PROJECT[2]	Removal of shrubs Fodder production	Oct-2016
SEASONAL/ TRANSHUMANCE	Stable	Fair amount of species	High productivity	HA MASITA GRAZING ASSOCIATION[3]	None	Jul-2012
SEASONAL/ TRANSHUMANCE	Stable	Low species diversity	Low productivity	MAFETENG[4]	None	2016
SHORT DURATION GRAZING (SAVORY)	Improvement in site stability	Undesirable grass species and shrubs with high frequency	Productivity has improved by 10 – 25%	KHUBELU SPONGE PROJECT[5]	Mobile kraaling	Sep-2013, Apr-2014, Mar-2015
REST ROTATION	Stable, excellent	Improved plant diversity mostly grass species	Productivity has improved	MOTS'EREMELI CATCHMENT[6]	Removal of shrubs	2016
LOW INTENSITY CONTINUOUS GRAZING	Stable	Variety of plants, mostly grass species	High yield	TS'EHLANYANE NATIONAL PARK[7]	Fencing, conserved for wildlife only	Nov-2016
DEFERRED ROTATION	Stable as compared to reference sites	Grass species on rehabilitated sites, while shrubs on reference sites	Improved rangeland productivity	MT MOOROSI[8]	Removal of shrubs, Construction of stone-line	Aug-2010
DEFERRED ROTATION	Improvement	Species diversity is satisfactory, with high frequency count of invaders	Production improved by 5-10%	SEMONKONG SLM PROJECT[9]	Removal of shrubs	Sep-2010, Mar-2014

References: [1]Ministry of Forestry, Range and Soil Conservation (2016b), [2]Ministry of Forestry, Range and Soil Conservation (2016d), [3]Ministry of Forestry and Land Reclamation (2012), [4]Ministry of Forestry, Range and Soil Conservation (2016e), [5]Ministry of Forestry and Land Reclamation (2013, 2014c,2015), [6]Ministry of Forestry, Range and Soil Conservation (2016c), [7]Ministry of Forestry, Range and Soil Conservation (2016a), [8]Ministry of Forestry and Land Reclamation (2010), [9]Ministry of Forestry and Land Reclamation (2014b).

Most reports (4 out of 9) focussed on the effects of seasonal grazing systems, the most common grazing system in Lesotho. The results in Table 3 show some variation on the impacts of seasonal grazing systems on site stability, species diversity and rangeland production for different grazing areas. Sites were stable and species diversity for three out of four grazing areas seemed to be high, while rangeland productivity was high for only two of the areas. The reasons for this variability, the stability of sites and the more diverse plant communities with relatively satisfactory productivity, might be the ownership of the land or the control of grazing areas and some form of rotational grazing among other factors. The Quthing sheep stud farm is a fenced area owned by the Government of Lesotho through the Ministry of Agriculture and Food Security with the purpose of producing improved breeds of sheep and goats and promoting wool and mohair production. Some areas might be experiencing undergrazing and selective grazing (by grazing and overgrazing the most palatable species and undergrazing the rest), thus resulting in dominance of undesirable grass species due to underutilisation.

At Ha Masita, even though the rangelands are communal, they are managed by a grazing association and this might be the reason why the area is stable and with relatively good productivity. The association is managing the daily routines of grazing management and they have developed some strategies amending the traditional seasonal grazing into modified seasonal grazing by incorporating some form of rotation in their rangelands. The Mafeteng grazing area reflects a typical example of a seasonal grazing area with no rehabilitation programme or management modification. The results in Table 3 give a clear picture of the impacts of the traditional seasonal grazing system with both the plant species diversity and rangeland production being low. However, the site was considered to be stable only because rock is considered a form of surface cover (Fig. 1). Vegetation cover, litter and rock are considered as total cover.

Figure 1: Example showing a grazing area which is considered stable because of the dominance of rock, since rangeland site stability is determined by measuring the amount of vegetation cover, amount of litter, amount of rock and amount of bare soil (photo: Teboho Sebatli).

Short-duration grazing has improved site stability and productivity with high frequency of unpalatable grass species and shrubs, while rest-rotation shows only positive results on site stability and species diversity which are stable and excellent, with high rangeland productivity.

The short-duration grazing system or the Savory method, commonly known as holistic range management, included rotational high density grazing and temporal or mobile kraaling. This method was introduced and piloted in Lesotho in 2013 (Ministry of Forestry and Land Reclamation 2013, 2014c, 2015, GOPA et al. 2015). The ultimate goal was to demonstrate high animal impact through temporal or mobile kraaling (GOPA et al. 2015, Ministry of Forestry and Land Reclamation 2015). The method required large herds of animals to be bunched together while grazing and at night they were kraaled for three consecutive nights, and then the kraals were shifted after every three nights. According to GOPA et al. (2015), the results were promising as they increased the percentage cover of litter and dead grass on the soil surface through trampling, fertilising the soil through bunched herding and kraaling, enhancing nutrient recycling and decomposition through incorporation of litter, dung and urine, which also increases re-seeding and reduces the dominance of shrubs, mostly *Chrysocoma cilliata* and *Helychrisum trilineatum*, that have encroached and dominated the rangelands as a result of extensive degradation (Fig. 2).

Generally, the results from the Ministry of Forestry and Land Reclamation for the Savory methods show an increase in total cover and a decrease in bare soil. However, the increase in vegetation cover is mostly dominated by unpalatable species and shrubs. In two vegetation assessments of 2013 and 2014, increaser I and invaders species were observed to dominate the rangeland vegetation with frequencies ranging between 30.2% - 62.3% and 32.7% - 64.6%, respectively, in 2013, while in 2014, the frequencies of increaser I and invaders ranged between 31.3% - 63.7% and 30.3% - 58.2% respectively. The most preferred, palatable and nutritious species in 2013 and 2014 vegetation assessments ranged between 0% - 9.4% and 0% - 9.3%, respectively.

Plants with same growth form are grouped or classified into grasses/ grass-like, forb and shrubs (Alberta Agriculture and Forestry 2016). According to the reports from the Ministry of Forestry and Land Reclamation (2014c, 2015), the Savory method increased both grass/ grass-like species and shrubs. The baseline vegetation assessment of 2013 and 2014 showed an increase in grass/ grass-like species with ranges between 44.5% - 67.3% and 40.7% - 70.7%, respectively, and the range for shrubs was between 17.5% - 44.5% in 2013, and 20.6% - 47.1% in 2014.

This shows that even though there were some slight positive results of the Savory methods in terms of the impact on invaders, there is still a long way to go in order to achieve the desired goal of maintaining healthy rangeland ecosystems.

Low intensity continuous grazing is practiced in the Ts'ehlanyane National Park, whereby only a low number of wild animals, elands (*Taurotragus oryx*), are kept in the park to utilize available vegetation (Table 3). Even though the park is under continuous grazing, the intensity is low, as there are only 26 wild elands in the park. The area is subject to underutilisation and selective grazing by grazing plants in order of their preference, starting with the most preferred plant species. According to the report from the Ministry of Forestry, Range and Soil Conservation (2016a), the diversity of plant species (49 species) in the park promoted stability with a high percentage of vegetation cover (71%), which in turn has resulted in a higher amount of litter accumulation (18%) as compared to bare soil (8%) and rock (3%).

The park is doing well in terms of ecosystem functionality; rangeland conditions are suitable for primary production and energy flow, and there is sufficient vegetation cover. The conditions are also conducive for nutrient recycling due to litter accumulation. The total cover of both vegetation cover and litter was up to 79%. The higher percentage cover of both vegetation and litter implies enhanced hydrologic functioning, and the capacity of the area to capture and store water is improved (Frame and Laidlaw 2011). However, an excessive amount of litter has harmful effects on the plant species diversity by suppressing tillers, destroying parent plants, and reducing the quality of forage. The results from Ts'ehlanyane National Park show the area being dominated by a high species diversity of palatable, nutritious plant species, decreasers. Decreasers, according to Oudtshoorn (2012), dominate rangelands that are in good conditions, neither underutilized nor overutilized. Therefore, the results from an assessment exercise are contrary to theory, which states that areas that are subject to underutilization like this park, are mostly dominated by unpalatable plant species that can grow without any defoliation.

Figure 2: Typical example of a rangeland which is densely populated and encroached by shrub species, *Chrysocoma cilliata* and *Helychrisum trilineatum*, which have a very aggressive invasive nature and tend to dominate over all other plant species (photo: Teboho Sebatli).

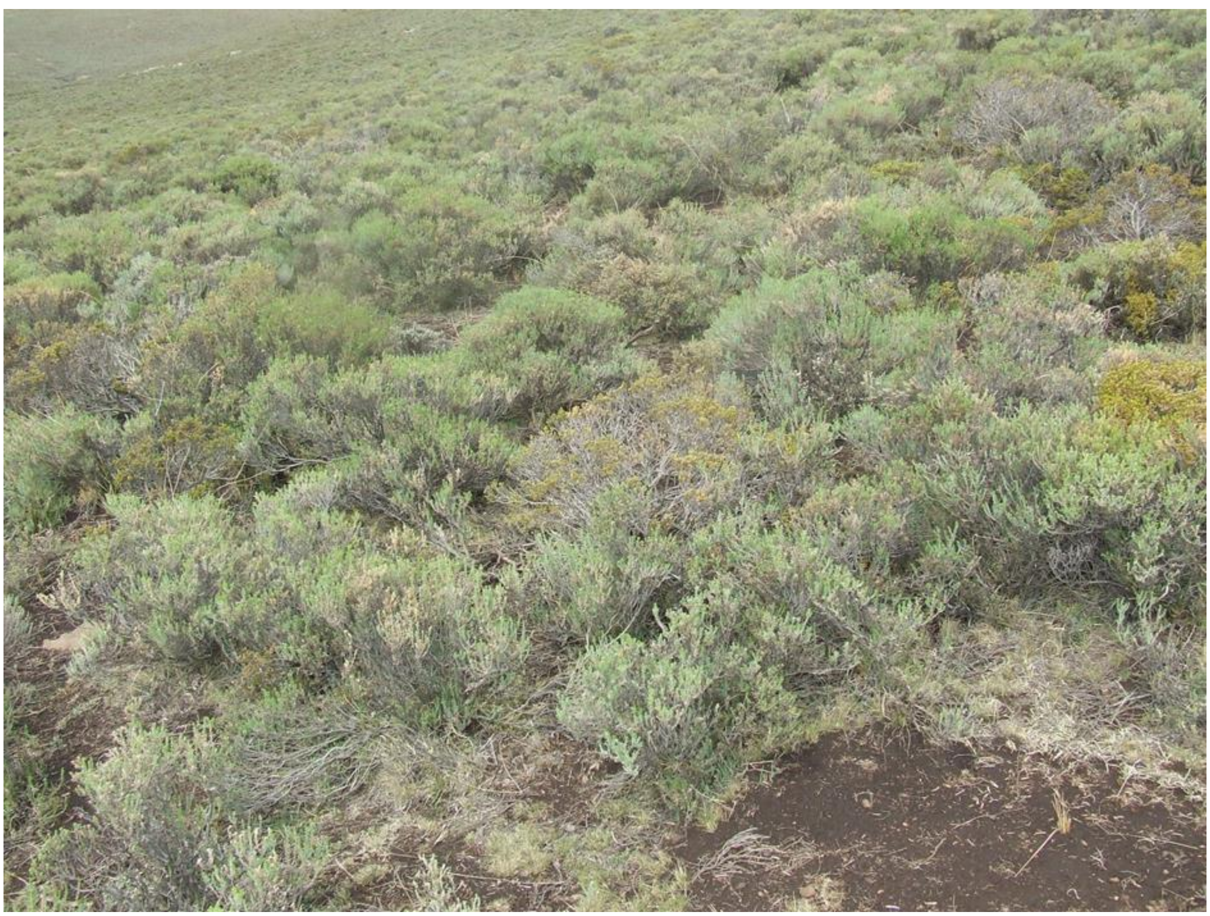

Figure 3: Removal of shrubs at Mots'eremeli catchment as one of the restoration measures in response to encroachment of shrubs through the Ministry of Forestry, Range and Soil Conservation (photo: Teboho Sebatli).

On the other hand, a deferred grazing system seemed to be doing quite well. From two studies on this type of grazing system there are similarities on the impacts on rangeland site stability, plant species diversity and rangeland productivity. Sites were stable for both the Mt Moorosi and Semonkong SLM Project grazing areas, and the plant communities are diverse. Mt Moorosi is dominated by grass species while the Semonkong SLM Project area is dominated by an increasing number of invader species. In both areas, rangeland productivity seemed to be improving. According to Bell (1973), a study conducted in Texas demonstrated deferred grazing as the most practical and feasible system for managing rangelands. He further pointed out that non-use of rangeland for a longer time gives plants enough recovery period to develop, mature and produce seeds.

However, it must be noted that most of these rangeland assessments were conducted in areas where other interventions were being implemented or in places of particular interest (Table 3), rather than with the aim of assessing rangeland condition in relation to grazing systems per se, for example, to determine the impact of restoration activities on rangelands such as Mots'eremeli, Mt. Moorosi and Semonkong or in areas like the National Park and the Sheep Stud Farm. Restoration activities included reseeding of denuded areas and mostly removal of shrubs, among others (Figs. 2, 3 and 4). The restoration interventions greatly influenced some improvements on rangeland health conditions and their effect is confounded with that of the grazing system used. Livestock grazing was then restricted to give the rangeland a sufficient rest and recovery period of one to three years, depending on the local conditions of each area. Systems such as rest-rotation and deferred-rotation were then introduced as replacement for traditional seasonal grazing to avoid further rangeland degradation in such areas.

Figure 4: A fully rehabilitated and healthy Mots'eremeli catchment after the removal of shrubs and recovery period. The rangeland is now completely covered by fully mature grass species. The current grazing management practice is rest-rotation (photo: Teboho Sebatli).

3.2 Comparison between Iceland and Lesotho: Are the effects of grazing similar in the two countries?

Transhumance has been a traditional way of managing rangelands in Lesotho, specifically driven by seasonal change. In summer, livestock are moved to grazing areas in the highlands, while in winter livestock are moved to low-lying grazing areas (Nusser 2002). According to Arnalds et al. (2001), the same management system is practiced in Iceland. In both countries (Table 4), livestock are grazed on the commons or communal rangelands. The main difference is the type of livestock grazed. In Lesotho, there is a mixed herding of animals; cattle, horses, sheep, goats and donkeys, while in Iceland it is sheep, and to a very limited extent horses.

According to the rangeland expert from the Soil Conservation Service of Iceland (SCSI), there is a direct relationship between livestock grazing and land degradation in Iceland. The expert mentioned that there is currently about 50% of degradation in vegetation cover and overgrazing has been the main contributing factor to rangeland degradation. The expert further mentioned that even though there is no active national monitoring scheme yet, SCSI district consultants do make annual visits to the rangelands but there are no available data for comparison. However, according to his experience in this field of study, there is a decline in vegetation cover and amount of litter. There are tremendous amounts of bare soil and rock in rangelands with a decrease in forbs and woody species (shrubs) and a general increase in unpalatable grass and grass-like species which have replaced palatable plant species that are almost extirpated. The expert concluded by saying that in general there is a decline in rangeland productivity due to nutrient losses from soil erosion.

Table 4: Comparison of effects of seasonal grazing system on rangeland health in Lesotho and Iceland. The table shows a summary of findings looking at attributes and indicators of rangeland health conditions from the rangeland assessment reports received from Lesotho and findings received from a personal interview with an expert from the Soil Conservation Service of Iceland.

Attributes	**Indicators**	**Lesotho**	**Iceland**
Rangeland site stability	Vegetation cover	Decline	Decline
	Amount of litter	Less amount	Almost absent
	Bare soil	Common	Common
	Rock	Common	Common
Plant species diversity	Species composition and richness	Mostly shrubs	Woody species disappear
	Plant life forms	Increase in shrubs	Increase in grass/grass-like species
	Ecological status	Increase in invaders and increaser II and III	Not known
Rangeland productivity	Forage yield	Decline	Decline
	Grazing capacity	Decline	Decline

Table 4 gives an overview of prevailing conditions of rangelands in Lesotho and Iceland because of poor management practices, over past decades. Rangeland site stability for both Lesotho and Iceland seemed to be unstable and very poor, which is reflected by the decrease in vegetation cover and amount of litter, with increases in bare soils and rock. The decrease in vegetation cover has entailed a decline in primary production, driven by less vegetative material to capture enough solar energy from the sun to produce food through photosynthetic processes (Frame et al. 2011). The negative impacts on vegetation cover also mean there is less plant material to be later converted into organic matter and later nutrients and minerals essential for plant growth through the process of decomposition, leading to dysfunctionality of nutrient recycling processes (Frame et al. 2011). Minimal vegetation cover also leads to an increase in land degradation and soil erosion by exposing soil surface to agents of erosion, nutrient loss and soil compaction. Insufficient vegetative cover further retards the hydrologic cycling process because vegetation cover has the ability to capture, absorb and store water during wet periods (Bainbridge 2007; Frame et al. 2011). This implies a serious threat to the sustainability and the health of rangeland ecosystems.

A low amount of plant litter means negative feedback in primary production, hydrologic function, as well as the nutrient recycling process because all essential benefits associated with accumulation of plant litter are negatively affected. Litter accumulation influences plant growth and regeneration. Litter acts as a mulch and retards surface water runoff, and by so doing, it enhances water infiltration and storage in the soil through the hydrologic functioning process. Litter provides habitat for micro-organisms and boosts microbial activities through the process of decomposition. Litter is also an important source of nutrients essential for plant growth and hence rangeland productivity (Bainbridge 2007). More bare soil and rock pose a serious threat to both primary production, and hydrologic and nutrient cycling because more bare soil on the rangeland means loss of vegetation cover, soil compaction and increased surface water runoff, and loss in soil fertility for plants.

In Lesotho, there is a drastic shift in plant species diversity whereby some palatable nutritious plant species are diminishing and being replaced by unpalatable plant species. The unpalatable plant species have less or low nutritive value and there is a high frequency of shrub species, such as *Chrysocoma cilliata* and *Helychrisum trilineatum*, which have a very aggressive invasive nature. On the other hand, in Iceland the situation is the opposite to what is happening in Lesotho, where there is an increase in unpalatable grass species replacing woody species which used to dominate in the past. However, it is not yet known whether the increasing grass species in Icelandic rangelands are decreasers, increasers, palatable or unpalatable because the ecological status of Iceland grass species is not yet known.

What is common in both Lesotho and Iceland is the fact that rangeland conditions are in some degraded state. There is a general decline in rangeland productivity and grazing capacities in both countries. The prevailing conditions of land degradation and soil erosion due to excessive grazing by livestock might cause irreversible negative effects in the long run if drastic measures and practices such as rest and deferment of rangelands are not taken into consideration to address the situation (Ministry of Forestry and Land Reclamation 2014a). A research of this kind is therefore essential, as a basis for development of sound and effective rangeland management strategies that can help in maintain healthy rangeland ecosystems.

In addition, a modified seasonal grazing system could be piloted in both countries. In a traditional seasonal grazing system, during the summer growing season, animals are taken to the highlands or summer grazing areas and they spend the whole time grazing in those areas. Continuous grazing during the whole growing season at high grazing pressure may compromise the ability of plants to fully grow and develop (Arnalds et al. 2001, Bell 1973, Nusser 2002). Plants need recovery time during the growing season to grow, mature and produce seeds. In order words, a seasonal grazing system can be classified as summer continuous grazing because it does not allow plants recovery time during the whole period of the growing season; this could be the reason why it contributes to the problem of overgrazing, land degradation and soil erosion. This further negatively affects primary production, nutrient recycling and hydrologic functioning of rangeland ecosystem.

Traditional seasonal grazing systems could be modified. Instead of grazing the whole area continuously, the animals could be moved between subdivisions of the grazing area (Bell 1973). This could be achieved by dividing the vast commons into two, three or four smaller areas, making some rotations within a period of a month, two months or even three months per area depending on the size of the area, condition of the rangeland, and number of animals (Bell 1973). For Lesotho, a modified seasonal grazing system can be more viable because of the herding system in place;

through herders, the mobility of livestock can easily be controlled. Through proper collaboration between all relevant stakeholders such as extension officers, local authorities, farmers and herders the system can be piloted to meet the needs of both the rangeland and livestock, taking into account the local conditions.

Depending on the size of the rangeland and livestock numbers, the rangeland can be divided into four or three grazing areas, then followed by a one- or two-month rotation or cycle, and by so doing, each grazing area can have at least two months of recovery during the growing season. According to Bell (1973), this will provide necessary requirements for plant growth. Then the end products will be improved rangeland site stability, plant species diversity, rangeland productivity and functional rangeland ecosystems.

In the case of Iceland, there are good structures and collaboration in place, namely, institutes dealing with natural resources and sustainable land management practices and farmers associations. The only problem is livestock management, since there is no herding system at the moment. Livestock are allowed to roam around in the rangeland on their own, and they are only rounded up in the autumn and brought back to the farms for the winter season. Fencing of communal rangelands might be costly for both countries.

The results of this study show some inconsistencies on the effects of grazing systems on ecosystem functions, simply because factors such as soil properties, climate, aspect, topography, season/ timing of grazing, duration of grazing, livestock numbers, the time/period when the assessment was carried out and the method of assessment were not taken into consideration while conducting the assessments (Holechek 2011). It is also important to consider making an assessment and continued monitoring before, during and after the grazing periods for better management results/purposes.

4. CONCLUSIONS AND RECOMMENDATIONS

The objective of the study was to investigate the effects of different grazing systems on ecosystem functions in Lesotho and Iceland. The study has shown that excessive grazing has detrimental effects on rangeland site stability and plant species diversity as well as rangeland productivity, and by so doing subsequently affected primary production and hydrological functioning together with nutrient recycling.

Most human activities have caused dramatic land degradation and dysfunctionality of rangeland ecosystems. The most prominent example of human activity that has caused deterioration of rangeland ecosystem is overgrazing. Overgrazing has detrimental effects to rangeland ecosystems resulting in physical, chemical, biological and hydrological degradation which consequently threaten the rangelands by reducing the functionality of ecological processes (Arnalds 2001, Arnalds et al. 2015).

Overgrazing decreases rangeland site stability, plant species diversity and rangeland productivity by reducing the densities of plant species, changing community composition, reducing vegetation cover and exposing soil surfaces to erosion and soil fertility loss/depletion, reducing water infiltration, reducing biomass production and grazing capacity. Overgrazing compromises the resilience and resistance of the rangelands, and hence, their potential (Arnalds 2001).

Healthy rangelands capture energy efficiently through increased primary production; they are also efficient in retaining nutrients and water. Grazing management systems that include relatively long resting periods, like modified seasonal rotation, rest-rotation and deferred-rotation, might be more suitable for the mountainous terrains of both Lesotho and Iceland, by allowing some recovery time between grazing events.

Viable grazing systems should meet the needs of both the livestock and the rangeland, be economically feasible and practical for range users. Grazing systems should also take into consideration factors like climate, topography, soils, vegetation types, timing of grazing and type of livestock to be grazed.

Further research and knowledge of how plants at both community and species level respond to grazing is fundamental for the sustainability of rangeland ecosystems.

ACKNOWLEDGEMENTS

This research project would not have been a success without the boundless support of many individuals and institutions that I sincerely acknowledge below:

First, I thank and dedicate this project to my lovely wife, Sabby and our angels, Tebo and Talia.

Isabel C. Barrio (Supervisor), my deepest gratitude for her competent and proficient guidance throughout this project work.

Hafdís Hanna Ægisdóttir (Project Coordinator and Programme Director), for her constructive comments, adroit guidance and support in this project and programme.

Berglind Orradóttir, Halldóra Traustadóttir and Azfar (UNU-LRT staff), for their hospitality, friendliness and untiring support at all times.

Johann Thorsson (SCSI), for his willingness and support and being conversant in sustainable land management practices.

Brita (AUI), for her encouragement and motivation during this six-month training programme.

UNU-LRT Lecturers, for their valuable skills, knowledge and experiences in land restoration and sustainable land management.

UNU-LRT Fellows, for being part of my family while away from my family.

Teboho Sebatli and Tsilane Mokitjima (Range Department), for their hard work, support, encouragement and provision of data for the success of this project.

Taole Tesele (GIZ), for his immense and untiring support for this research project.

Dr Rats'ele Rats'ele (Director Range Resources Management), for his heart-whelming support.

Agricultural University of Iceland and Soil Conservation Service of Iceland, for a conducive environment and provision of resources during the period of this training programme.

Department of Range Resources Management, for granting me this precious opportunity to attend this six-month training programme.

Ministry of Forestry, Range and Soil Conservation, for granting me this opportunity to undertake this study.

Government of Iceland for financial support and all forms of support.

Above all, I thank, 'God Almighty' for the gift of life.

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APPENDIX

RESEARCH INTERVIEW GUIDELINES

1. What is the current conditions of your rangelands?
    - Are the conditions normal / the same as compared to the previous times? Are they improving or deteriorating?
2. What might be the cause of these changes? If there are any changes!
3. What systems of grazing management are practised in your rangelands?
    - What makes one system different from another?
4. Are livestock numbers regulated using stocking rate or carrying capacity of the rangeland?
5. What methods do you use for rangeland condition assessment and monitoring? How often / frequency? When? (Timing)
6. What effects are your current management systems having on rangeland health? Looking at:
    - ➢ Rangeland Site Stability
        - Vegetation cover
        - Amount litter
        - Bare soil
        - Rock
    - ➢ Plant Species Diversity
        - Species composition
        - Species richness
        - Plant life form
            - o Grass/grass-like
            - o Forb
            - o Shrub
    - ➢ Ecological Status
        - Decreasers
        - Increasers
        - Invaders
    - ➢ Rangeland Productivity
        - Forage yield
        - Grazing capacity
7. Are the same management systems having different effects on rangeland health in other different grazing areas?
8. Are there some areas that are degrading quickly and need to be managed differently to prevent further degradation due to the current management systems?
9. Are there areas that are improving because of different/alternative management systems?
10. According to your own knowledge, skills and experience, what can be the viable options or strategies to maintain and improve rangeland health?
11. What consequences would each of these options have?
12. How would any potential change in management affect the lives of people making living from the rangeland in the short-term and in the long-term?

THANK YOU VERY MUCH FOR YOUR TIME!!!