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USE OF RESTORATION PLANNING TO DETERMINE DIFFERENT RESTORATION MEASURES

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ABSTRACT

The report is on the use of restoration planning of degraded landscape of the Dagverðarnes situated in South Iceland. This was a farm which was abandoned 150 to 200 years ago because of many reasons including land degradation. The restoration planning was done with the information collected by Soil Conservation Service of Iceland staff in 2016. Information was gathered using SPOT imagery supplemented by photographs. The vegetation, soil and erosion maps were developed which categorised the area into different classes based on the level of degradation experienced.

The causes of degradation were revealed by history as well as assessment of the site constraints and problems. The thresholds crossed by each category were discussed and classified according to a conceptual framework model that shows transitions between undegraded and degraded ecosystem states and the presence of biotic and abiotic thresholds. The different measures or modifications were suggested considering the rate of degradation of each area. The implementation plan was done, prioritizing the highly degraded areas. The restoration measures proposed are based on the conditions and experiences from other projects in Iceland. Monitoring and budget were developed for the project as well.

I recommend restoration planning because it provides the preliminary evaluation of the limitations and difficulties influencing the ecosystem and examines potential effects on restoration possibilities. An appropriate plan is tailored for the precise situation, according to the extent and amount of degradation, the resilience and the actions required for restoring such an ecosystem. This is important because focus will be on the causes of degradation rather than the symptoms. It will help with achieving the restoration goals, which is relevant to the current problem in the specific site.

Based on this study, when I get back to Lesotho I will utilize restoration planning skills in different landscapes and to determine different restoration measures for the different disturbances encountered.

Key words: Dagverðarnes, Lesotho, land degradation and restoration planning

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1. INTRODUCTION

Land degradation is a serious problem worldwide caused by pressure from the growing world population resulting in unsustainable use of resources (Bainbridge 2007). This exploitation of land resources is brought about by economic and cultural pressures that result in degradation. However, United Nations conventions (UNCCD, UNCBD) have been developed to combat further land disturbances which lead to desertification and promote instead conservation of biodiversity to sustain human livelihoods (Akhtar-Schuster et al. 2017).

Lesotho and Iceland have both experienced severe degradation of rangelands caused by overgrazing, cutting of trees and land conversion. The study of my project was based in Iceland in Dagverðarnes to undertake a restoration plan which will help me learn the process so as to apply it in my country to restore degraded areas.

In Lesotho, livelihoods depend on agriculture and pastoral activities, which lead to over-exploitation of the soil and serious overstocking of the grazing land resulting in vegetation loss and soil erosion. Agriculture contributes 14% of the country's GDP (Mbata 2001) of which 72% comes from livestock production while 28% is from crop production (Nchemo 2001). Crop production is usually subsistence and low yielding, mostly maize production (60%) (staple crop), sorghum (20%), wheat (10%), mostly mono cropping and vegetable production in homestead gardens (Woodfine 2014).

Rangelands constitute 60% of the country and are located in the mountains and animals depend entirely on them for grazing (Pelser and Letsela 2012). The majority (76%) of the population of Lesotho lives in the rural mountains and keeps livestock for purposes such as draught power, milk, meat, wool and mohair (Woodfine 2014) and to some livestock is a sign of wealth (Kakonge 2002). History has also shown that deforestation by cutting of trees and shrubs for fuel wood as well as wildfires to destroy unwanted species of weeds and unpalatable grasses with the belief of soil enrichment (Rooyani and Schmitz 1987) have greatly contributed to land degradation.

Iceland has experienced degradation of rangelands by traditional sheep grazing as well as cutting and burning of the woodlands (Aradóttir 2013). Natural processes and human activities have resulted in the loss of trees and more than half of the soil cover (Crofts and Olgeirsson 2011). About 40% of the land in Iceland has been affected by severe soil erosion that is still ongoing in many areas (Thorarinsdottir and Arnalds 2012).

However, efforts are being made to reverse the trend of soil degradation which will help to ensure food security and, above all, conserve land for future generations. This can be attained by ecological restoration which means careful management to recover the ecosystems that have been damaged by human activities (Botkin and Keller 2014). Land is required for increased food production, and to support the population increase over the years (Young 1994).

1.1. Land degradation and land rehabilitation in Lesotho and Iceland

Land degradation in Lesotho is weakening the limited resource which people depend on for survival (NES 2000). The country has been damaged by soil erosion, mainly by sheet and wind erosion on uncultivated steep slopes which are overgrazed (Pelser and Letsela 2012). Rill erosion and mass soil movements cause piping and gully formation on gentle slopes in the lowlands (Singh 2000). Land degradation has been experienced since colonialism in the 1800s, which has led to desertification caused by removal of vegetation (Singh 2000).

Based on the literature by the missionaries, Singh (2000) shows that people in Lesotho practiced gentle cultivation of the land, of mixed cropping with rows of maize and beans. Uncultivated grassy areas were left between the cultivated fields to avoid exposure of soil to rain. The plant stalks were left in the field during harvest to feed animals in winter. Grazing by animals was controlled, grasses were preserved to enhance the ability to produce ripe seeds. All this activity maintained the land's tolerance against soil erosion. However, the missionaries introduced extensive commercial farming of wheat for cash, which led to conversion of grazing land to crop land, leading to animals grazing on marginal lands and hence alternatively leaving no protected grazing land for later use. The result of these factors was depletion of indigenous trees and grass species, giving rise to a lower water table and increasing run-off, and hence soil loss. As time passed drought became evident and cultivation was practised on steep slopes. To prevent this, conservation requirements were formulated and an effort was made to construct lateral terraces and plant trees, using poplars and eucalyptus, the reason being to stop sheet erosion. The conservation approaches were then experimental and unfortunately without consultation with the farmers. The effort became unsuccessful and harmful to the environment where the terraces constructed kept concentrating water and later forming gullies (Chakela 1981).

The Ministry of Forestry and Land Reclamation emphasized rehabilitating micro catchments for the period of one year (Squires and Heshmati 2013) because of budget constraints. In this case a degraded catchment is assessed and mapped for required intervention, with surface erosion control measures, control of invasive species and afforestation activities employed as per the requirement. The rehabilitation measures employed are physical, which involves building mechanical structures along the gullies, using sand bags, gabions, and loose stones, and biological measures, using trees and grass planted either on the gully banks or in the sediment filled up by the physical structures (Singh 2000). The work is done by the community and individuals are paid daily for carrying out the labour-intensive work with the funding secured by the government. Non-governmental organizations fund some of the projects and the conservation staff supervise the activities undertaken.

Even though there is such an effort to reduce degradation, desertification due to loss of biodiversity and rangelands deteriorating, intensive cultivation and poor animal management still constitute the main problem in Lesotho. An example is the intense rate of soil erosion experienced, where 41 tons of soil is lost per hectare per year (Squires and Heshmati 2013). The Leshoboro plateau is an example of the poor rehabilitation measures employed, where eucalyptus trees were planted and some springs below dried up, indicating that forested catchments have the ability of reducing ground water reserves more than non-forested catchments (Nchemo 2001).

Crofts and Olgeirsson (2011) have discussed the causes of land degradation in Iceland as follows. Weather conditions in Iceland, which are characterized by long cold periods with short warm periods, have brought on a series of freezing, thawing and cryoturbation conditions that result in an unsuitable soil surface leading to erosion when vegetation has been removed by deforestation and overgrazing. Again, global warming has caused glacier retreat and ice cap fronts resulting in exposed sand areas, followed by sand storms at the end and causing soil erosion. An estimated 217 volcanic eruptions since settlement have resulted in deposition of large quantities of ash on vegetated land which has caused dieback and the once productive land has become unsuitable for cropping and livestock grazing. However, human survival needs led to persistent sheep grazing on small plots of weak and fragile land because farmers were not able to make enough hay, and thereby grazing was the only alternative, which later resulted in overgrazing.

As opposed to Lesotho, Iceland has documentation of many successful restoration projects from 1907 to 2010 (Petursdottir et al. 2013). A few of the successful projects are the Hekla Forest Project and Farmers Heal the Land (FHL), even though there are still areas with considerable erosion problems. The Hekla program covers 900 km^2 (Aradóttir 2003); restoration of the area is done by planting native birch trees, willow and dwarf shrubs because they thrive well in tephra, while grasses, legumes and mycorrhizal species were planted with fertilizer application to supplement woody plants (Crofts and Olgeirsson 2011). FHL is a project managed by the Soil Conservation Service of Iceland, responsible for restoring a 150 km^2 area (Aradottir and Hagen 2013). The project involves engagement of 600 farmers working on their own land and SCSI supply them with fertilizer, advice, general management, mapping and grass seed. This promotes direct succession and ecosystem improvement and efficiency, because there is encouragement of native species for reclamation, although exotic species with good qualities may be utilized (Crofts and Olgeirsson 2011).

Both projects used the practice below following research. The planting of grass and trees with fertilizer application is useful in Iceland because of the andisol soils that originate from volcanic eruptions which are deficient in nitrogen for plant growth (Arnalds 2008) and fertilizer improves the vegetation cover, reduces the impact of frost heaving and stabilizes the soil surface (Óskarsson et al. 2006). Stanturf and Madsen (2004) give a reason for planting birch (*Betula pubescens*), which is a native tree to Iceland; it grows up to two to four meters in height at maturity, and is important for rehabilitation purposes and in grazing areas because it survives well on andisols, acting as primary and secondary successor. Lyme grass, red fescue seeds (*Festuca rubra L.*), Bering's tufted hair grass (*Deschampsia beringensis*) and lupine (*Lupinus nootkatensis*) with fertilizer application have shown good results in restoring sand-drifting landscapes (Crofts and Olgeirsson 2011)

1.2. Importance of ecological restoration and having a restoration plan

Aradottir and Hagen (2013) refer to ecological restoration as the next level to implementation of the UN environmental conventions on climate change, United Nations Framework Convention Climate Change (UNFCCC), desertification (UNCCD) and biodiversity (CBD) for the country level as well as for the international level. The Society of Ecological Restoration International explain restoration as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER 2004), while Aradottir and Hagen (2013) describe ecological restoration as an intentional activity to recover the flow of goods and services that ecosystems provide society by initiating ecosystem recovery. Ecological restoration focuses on the reestablishment of native species composition, which ensures sustainability and ecosystem health, but the priority of rehabilitation (reclamation) is to support the soil surface and improve the productivity of the degraded land to return it to a productive state (SER 2004). The aim of ecological restoration is to repair the ecosystem to produce food, fibre, feed, and fuel and secure habitat for wildlife. However, land use must be sustainable, based on ecologically sound principles which are also economically possible and practically achievable to stop ecosystem degradation (Aradottir and Hagen 2013).

Galatowitsch (2012) suggests that a restoration plan can be a narration of several activities to get from the current landscape state to the desirable future by delivering the rationale for each action that needs assistance to happen for creating a self-regenerating ecosystem. In many cases the plan may follow methods that were found to be successful somewhere else, but a restoration plan must be suited to the precise situation at the time. A restoration plan should be based on long-term decisions rather than quick short-term ones which are assumed rather than the reality of the ecological destination. It is therefore necessary to have long-range planning for all types of projects to achieve sustainability in restoration. The restoration plan should be a written formalized plan to keep a record of the restoration target, goals and objectives. It is an important form of communication, as it includes a description of what, where, and by whom the plan of actions will be undertaken (Mcdonald et al. 2016).

For this report the following sections will be discussed in restoration planning:

1. Goals and vision
2. Site description
3. Planned restoration actions
4. Implementation planning (restoration management)
5. Monitoring
6. Cost analysis

1.2.1 Restoration goal/vision

Vision refers to determining developmental goals or the overall objective in project planning. Visioning starts with the development of a common view for the future, and defines common goals and objectives (Terry 2014) .

Goal setting is the first crucial step in restoration planning; it takes into account the condition of the ecosystem and target features the project is aiming to achieve in the medium to long term (Galatowitsch 2012). Goals provide information about the desired result, size and time frame for achieving the desired outcome. This makes the project easily evaluated over time, more transparent, manageable and transferable (Mcdonald et al. 2016).

Restoration goals can be discussed in terms of 4 paradigms, which should answer the questions about the restoration aim.

1. Restoration as recovery of a damaged ecosystem; set goals are based on ecosystem processes and features that entail species composition, soil fertility, ecosystem structure and function. The goals are directed on reversing the effects of land degradation and promoting sustainable development (Aradóttir 2003).

2. Restoration as compensation for habitat loss; basically, aims to neutralize the destruction of natural ecosystems by reconstruction of the ecosystems by using development and mitigation programmes, which are important but caution should be taken to discourage quick fixes (fast growing exotic species that tend to be invasive) to meet short-term restoration goals (Galatowitsch 2012).

3. Restoration to deliver ecosystem services; contributes to human well-being, poverty eradication by improving ecological, economical and societal needs (Aradottir and Hagen 2013); examples are food, fibre, water quality, nutrient cycling, as well as aesthetic measures (Millennium Ecosystem Assessment 2001).

4. Restoration to ensure resilience; resilience relies on minimizing the undesirable ecosystem degradation caused by disturbance, i.e. by human and climatic activities. Disturbances are encountered when providing services, i.e. land conversion for crop and livestock production, but often overlooking the cost to other services (Aradottir and Hagen 2013).

1.2.2 Site description

To achieve a project that can be monitored and assessed, a reference site (approximate restoration target), that displays ecosystem integrity (SER 2004) must be identified. It should have various native plants, animals and biota, and abiotic conditions (Mcdonald et al. 2016). The state of the surface evaluation gives helpful details regarding stability (capacity of the land to resist forces by erosion), hydrologic processes (elements of infiltration, runoff and drainage), and nutrient cycling (Perrow and Davy 2002).

The information about the current state of the ecosystem is assembled from field surveys, by mapping vegetation patterns, collecting a list of plant species, estimating water flow and distribution of different soil types (Galatowitsch 2012). The information gathered in field surveys is usually shown on a map as this helps to give an idea of restoration possibilities (Galatowitsch 2012).

a) Drivers of degradation of the landscape

The drivers are the major forces of changes to an ecosystem and can be divided into:

1. **Natural drivers**: may be fires, floods, storms and volcanic eruptions. They can affect the habitat stability by causing vegetation change and waterbody fluctuations. Topography across the landscape can impact by influencing the possibility of erosion or runoff speed as well as water storage capacity (Aradottir and Hagen 2013).
2. **Human/anthropogenic drivers:** they are caused when humans exploit the ecosystem by mining, agriculture, forestry, fishing, infrastructure development (Aradottir and Hagen 2013). On a long time scale, ecosystems can deal with most natural drivers of degradation but when the human drivers are added, the equilibrium is disrupted.

b) Restoration thresholds in the landscape

When the drivers have caused gradual change over a long time, the ecosystem resilience can be exceeded and then a threshold is reached. The threshold is reached when there is no connectivity across areas in the landscape and the ecosystem is no longer expected to give the services required for biodiversity (Mcdonald et al. 2016). It can also be referred to as the state when an ecosystem is prevented from returning to a less-degraded state without external input or effort (Perrow and Davy 2002).

The thresholds can be classified into two categories, depending on the drivers.

1. **Biotic threshold** is the state where there is intrusion by other organisms, which can be weeds, with the intention of preventing native rehabilitation of suitable species (Aradottir and Hagen 2013). In this case, a habitat is modified or degraded due to biotic changes such as grazing or weeds; then action is required to remove the degrading

factor which is herbivory and to control the weeds, or to adjust the biotic composition by planting desirable plant species (Whisenant 1999).

2. **Abiotic threshold** is the state where habitat is degraded because of physical attributes such as soil erosion, indicating broken hydrologic activities and a severe micro-environment (Perrow and Davy 2002). The restoration priority needs are to eradicate the degrading factor and then put more effort on repairing the affected site (Whisenant 1999). The habitat in this case needs priority treatment for improving the landscape state.

A conceptual model is usually used for this, that shows the transition between states of varying levels of function, that illustrates the presence of two types of restoration thresholds, controlled by either biotic or abiotic limitations (Whisenant 1999). Such illustrations indicate that an intact ecosystem is reached when primary processes are fully functional and the landscape can then recover on its own, without any assistance. The biotic threshold is crossed when primary functions are functional but recovery requires vegetative intervention. The abiotic threshold is indicated by the dysfunctional ecosystem, where primary succession processes are non-functional, therefore recovery being in need of physical modifications of the environment (Perrow and Davy 2002).

1.2.3 Planned restoration actions

Suitable restoration approaches are determined by project goals, disturbance condition, resilience state, socioeconomic resources, and availability of restoration inputs as well as environmental factors (Aradottir and Hagen 2013); they must be tailor-made for each site. When the ecosystem has high resilience because of comparatively low disturbance, the decision should be to leave the area to natural recovery. This is referred to as passive restoration (Mcdonald et al. 2016).

Biotic control measures can be applied in ecosystems to enhance possible dispersal to initiate growth by preferred plant species, with little effort by humans. Biotic limiting agents can be eradicated, by weeding, reducing herbivory (use of exclosures) and controlling fire (Aradottir and Hagen 2013). This treatment can cover a wide area or cover deliberate patches on the disturbed land.

However, intervention by autogenic processes can be implemented where disturbances are causing an unstable soil surface by erosion, either by water or wind, making the soil lose moisture and nutrients thereby resisting seedling growth (Aradottir and Hagen 2013). Depending on the limitations of the ecosystem, different treatments will be suggested. In most cases the possible actions to employ must provide the improvement by providing surface roughness and improvement of surface stability (Bainbridge 2007).

Restoration approaches normally used in ecological restoration are: revegetation, planting of trees, mulching, fertilizing, removal of invasive species, channel reconstruction and many other treatments. Although they are all important, it is always advisable to first consider the level of disturbance and site characteristics, as well as the cost of the intended approach for the restoration project to be successful (Mcdonald et al. 2016).

Examples of interventions, include:

1. **Imbalance in species availability (natural regeneration approach)**; the aim should be to encourage seed dispersal actions which can be artificial seeding or transplanting, or encouraging dispersal by introducing wild or domestic animals or design the landscape to improve seed dispersal or reduce predation (Perrow and Davy 2002).

2. **Imbalance in species performance (assisted regeneration approach)**; according to Perrow and Davy (2002) to stabilize soil, increase infiltration capacity that will retain soil, nutrients, organic matter and seed by improving surface roughness and hence attracting water retention, later giving way to vegetation development and reducing effects of soil erosion. Examples of actions can be pits, contour furrows and basins in addition to the use of rocks, litter and woody debris increasing above-ground barriers which, after the establishment of vegetation, will ensure self-assistance for site development.

3. **Imbalance in site availability (reconstruction approach)**; the above actions are applicable in this case, but for severe conditions like mining, the whole landscape requires reshaping, and it is valuable to consider reducing the slope length, and having less-steep or concave slopes which will improve stability and erosion resistance (Perrow and Davy 2002).

In some cases, all three approaches may be applicable, when there is a mixture of all the disturbances across the site. In this regard some areas may demand natural regeneration, while others need a regeneration approach and of even reconstruction (Mcdonald et al. 2016).

Short-term solutions such as seeding can be helpful because it provides a nurse crop, while long-term solutions improve soil stability, providing establishment of permanent vegetation cover (Aradottir and Hagen 2013). It is important to select appropriate species to avoid invasive plants when introducing exotic species (Bainbridge 2007).

1.2.4 Restoration management (implementation plan)

According to Bainbridge (2007), restoration management involves straightforward plans, schedules, record keeping and budgeting. A timeline must be developed for important activities such as site preparation, seed collection and plant production suitable for specific seasons. Organization of equipment requires time as well as labour to do the work. There must always be records to make sure that time, money and other resources are spent effectively and to include new strategies for corrections. It is important to plan for maintenance of the project for failed activities (adaptive management). Based on the baseline surveys it is of importance to measure the properties considering the parameters based on specific goals and actions of the restoration plan.

a) Involvement of stakeholders in restoration

The most degraded landscape sites are often the communally used areas; thus, it is important to include community participation in environmental problem solving. Involvement of the community from the planning stage of the project provides information about the history of the land use and provides local knowledge (Mcdonald et al. 2016). It is very important to educate local people so that they understand the overall details about the project and its importance.

a) Influence of climate change on land restoration

Ecological restoration activities can basically fail if climate change effects continue increasing, such as rainfall scarcity coupled with rising temperatures that result in a decrease in water tables, reservoirs, wetlands and river flow (Ragab and Prudhomme 2002). Damaged ecosystems cannot be functional when extreme climatic conditions prevail by increasing unfavourable climate change conditions (Perrow and Davy 2002). It is required to include different assumptions about coping with climate change (climate change adaptation planning), thus bringing about the state of the land that could be experienced in the alternative future (Galatowitsch 2012).

b) Incorporating Sustainable Development Goals (SDGs) into the restoration plan

Ecological restoration is aimed at enhancing the recovery of the degraded landscape so that the ecosystem ability and functions are restored and reducing the occurrence of natural disasters. Functional landscape contributes to local needs as well as national commitments such as reducing greenhouse gas emissions, providing rural employment and reducing the possibilities of illness and diseases (Hagger et al. 2017). Therefore, by engaging in ecological restoration planning Sustainable Development Goals will be met to tackle climate change and provide access to a stable environment. The goals depend on each other, so positive progress or negative impact on one goal may affect the outcome of the other goals.

1.2.5 Monitoring

The ecological elements to monitor include species composition, the physical environment, ecosystem functions and structure; however, the variables selected for monitoring depend on the restoration goals (Aradottir and Hagen 2013). Monitoring aims at informing the stakeholders about restoration with feedback during and after the implementation, whether measures taken are up to date with set goals and standards of the project, and tracking the success and incorporating modifications where necessary. Monitoring helps to keep a record of restoration outcomes at the site. Effective monitoring should be undertaken, as the success of the project will have to be maintained. To observe the changes, comparison must be made between the project site and the reference site (Galatowitsch 2012).

During monitoring the following should be taken into consideration to decrease the variability of results that will show what is going to be monitored, why it is monitored, who is going to monitor it and how often.

1. **Data collection** is done on sample plots or transects which can adequately illustrate the whole restoration site. The methods used may be random sampling and straight line or transect sampling (Galatowitsch 2012). Collected data will be of plant populations, species composition and richness, as well as plant cover, soil stability, water processes, etc.

2. **Photo points**: Use of visual evidence such as taking photos of the landscape from the precise photo points before and at intervals after treatments to show changes occurring over time. This is appropriate for noticeable species, such as invasive plants, regeneration and dieback (Galatowitsch 2012). The photo point is a qualitative monitoring tool that can be used together with the quantitative methods (data collection)

to give more clarity on the observable characters when reporting about the restoration project (Mcdonald et al. 2016).

3. **Participatory monitoring** gives the community a chance to observe the direction of the project, to see whether it is relevant to the goals. It informs and provides feedback such that if problems are encountered then solutions can be sought in time and effectively. The information gathered is realistic because it shows trends which are observed by all stakeholders.

Project evaluation will rely on the results given by the monitoring report. This will show whether the project is successful or not, which will then inform about possible interventions.

1.2.6 Cost analysis

Restoration activities require budgeting for support of equipment, supplies as well as materials, travel and sometimes contracted services. It is important for the plan to show how the project will be administered and who will be responsible for the resource management (Mcdonald et al. 2016). The specific time frame for each activity and approximate cost for each stage should be specified in the budget (Galatowitsch 2012).

2. METHODOLOGY

For this report a restoration plan for a landscape in Dagverðarnes was developed from a document by FE Thorarinsdóttir at the Soil Conservation Service (2016). The information was gathered using the mapping procedure for land assessment of new restoration areas used by the Soil Conservation Service of Iceland.

2.1. Site description

The study area is Dagverðarnes, 10 km from Gunnarsholt, in Hekla which is located in South Iceland, and covers about 145 ha. It was a farm considered good for sheep farming 100 to 150 years ago, until scarcity of water, severe land degradation and an earthquake led to the owners abandoning it (Gudmundsson 1952). It was later bought by the Soil Conservation Service (SCS) and is under its supervision. The plan is to restore the area and maintain it as a rangeland.

2.2. Land assessment

Mapping of the area was done on 2 June 2016, based on the SCS mapping procedure, the SPOT satellite imagery, and the area was reviewed and evaluated with visualization and photographs captured with GPS location at a scale of 1:10,000. The mapping procedure used was adopted from the SCS of Iceland. The site was surveyed and information about condition and disturbances of the area was recorded. The landscape was divided into four categories according to the erosion type and severity. Maps of vegetation, sand and erosion classes were made using ArcGIS.

The field trip to Dagverðarnes was conducted on the 21st June 2017 with my supervisor, where the site was viewed in order to develop an understanding of the area. All the four categories of different land classes were investigated so as to be familiar with the site characteristics and information in the main report by SCS. Restoration methods and the cost analysis were then developed using the Soil Conservation Service (2016) report with the help of my supervisor who is a Soil Conservation Service officer (G Asbjornsson).

Table 1 to 3 were extracted from Stadlarad Islands (2007) to show different vegetation, sand and soil erosion classes used for land assessment and the land classification system by SCS Iceland.

Table 1. Vegetation cover classes as part of the land classification system by SCS (source: Stadlarad Islands 2007).

Vegetation cover class	**% cover**
Very sparse or no vegetation	0-10
Sparsely vegetated	11-33
Half vegetated	34-66
Mostly vegetated	67-90
Fully vegetated	91-100

Table 2. Sand / tephra on the surface as part of the land classification system by SCS (Source: Stadlarad Islands 2007).

Sand on surface	**% cover**
No sand on surface	0
Very little sand on surface	0-10
Some sand on surface	11-33
Considerable sand on surface	34-66
A lot of sand on surface	67-90
Mostly sand on surface	91-100

Table 3. Erosion class and grade (kind of erosion involved) as part of the land classification system (Source: Stadlarad Islands 2007).

Class	**Erosion grade**
0	No erosion
1	Little erosion
2	Slight erosion
3	Considerable erosion
4	Severe erosion
5	Extremely severe erosion

3. RESULTS AND DISCUSSION

3.1. Site properties

The area was classified into four classes, considering vegetation, sand and erosion on site. The landscape was categorised according to the following findings: 28 ha located on the east were uninhabited land found on the edge and were fully vegetated; a half-vegetated area of 56 ha was on the west; while 45 ha were covered with the least vegetation and in the centre; and 16 ha in the east were classified with little or no vegetation. The key species found were lyme grass and single birch plants. The condition of the landscape is shown in the photographs in **Figure 1** to 4.

Figure 1. Photograph taken looking towards the north-west. The area is characterised by tephra, where neither vegetation nor rocks bind the surface, and there is a lot of loose sand and visible erosion escarpments but no activity found at the boundaries. (Source: Soil Conservation Service 2016).

Figure 2. Shows the erosion escarpments at the edge on the east side of the landscape showing erosion escarpments and land with loose sand. (Source: Soil Conservation Service 2016).

Figure 3. Centre of the landscape with lava rocks and a lot of loose sand, but no vegetation. (Source: Soil Conservation Service 2016).

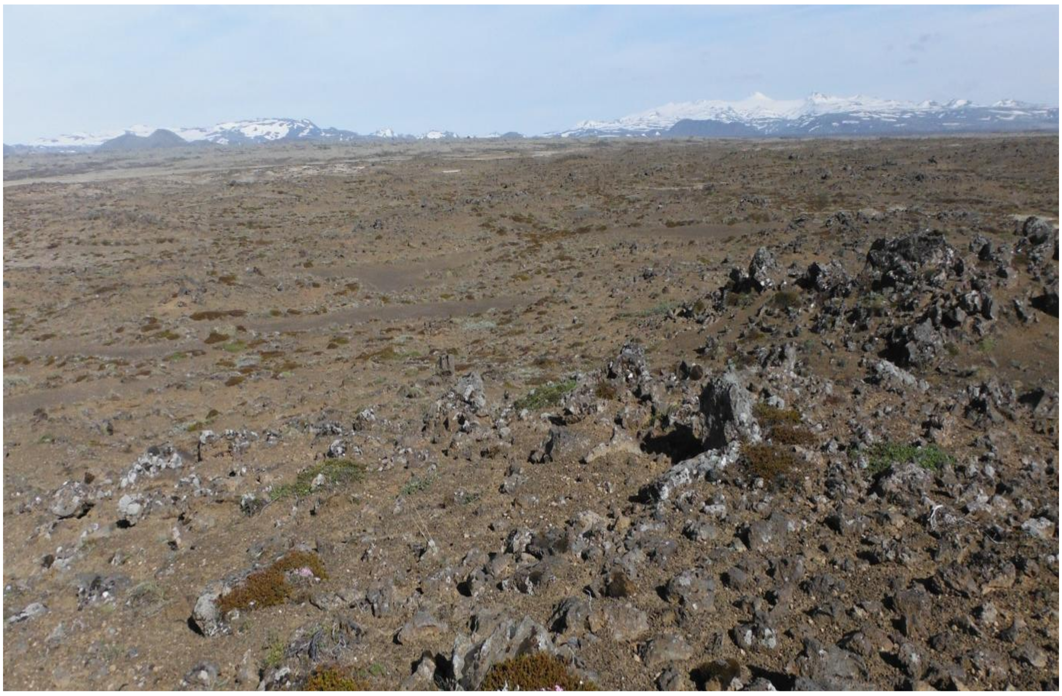

Figure 4. West of the area, showing sparsely vegetated land in sandy lava. (Source: Soil Conservation Service 2016).

Table 4 to 6 give information about the classes used to develop the maps in Figure 5 to 7.

Table 4. Vegetation cover classes represented by landscape condition (see **Figure 5** for map).

Vegetation class	Surface area covered	% of surface
Fully vegetated – 91-100%	28 ha	19
Half vegetated – 34-66%	45 ha	31
Sparsely vegetated – 11-33%	56 ha	39
Very sparse/no vegetation – 0-10%	15 ha	11

Table 5. Sand / tephra classes found on the surface of the landscape (see **Figure 6** for map)

Sand class	Surface area covered	% of surface
Very little sand on surface 1-10%	16 ha	11%
Considerable sand on surface 34-66%	75 ha	52%
A lot of sand on the surface 67-90%	54 ha	37%

Table 6. Soil erosion classes found in landscape (see **Figure 7** for map)

Soil erosion class	Soil erosion grade	% surface area
1	Little erosion	19
2	Slight erosion	31
3	Considerable erosion	39
4	Severe erosion	11

See Figure 5, Figure 6, and Figure 7 for maps developed with ArcGIS to show the information in Table 4, Table 5, and Table 6.

According to the information provided in Table 4, to 6 and Figure 1 to 7, the surface of the area of Dagverðarnes is generally very unstable and has a large amount of loose soil material on the surface and is hence highly degraded. The most degraded areas are the northernmost and middle where the loose soil material on the surface is greatest.

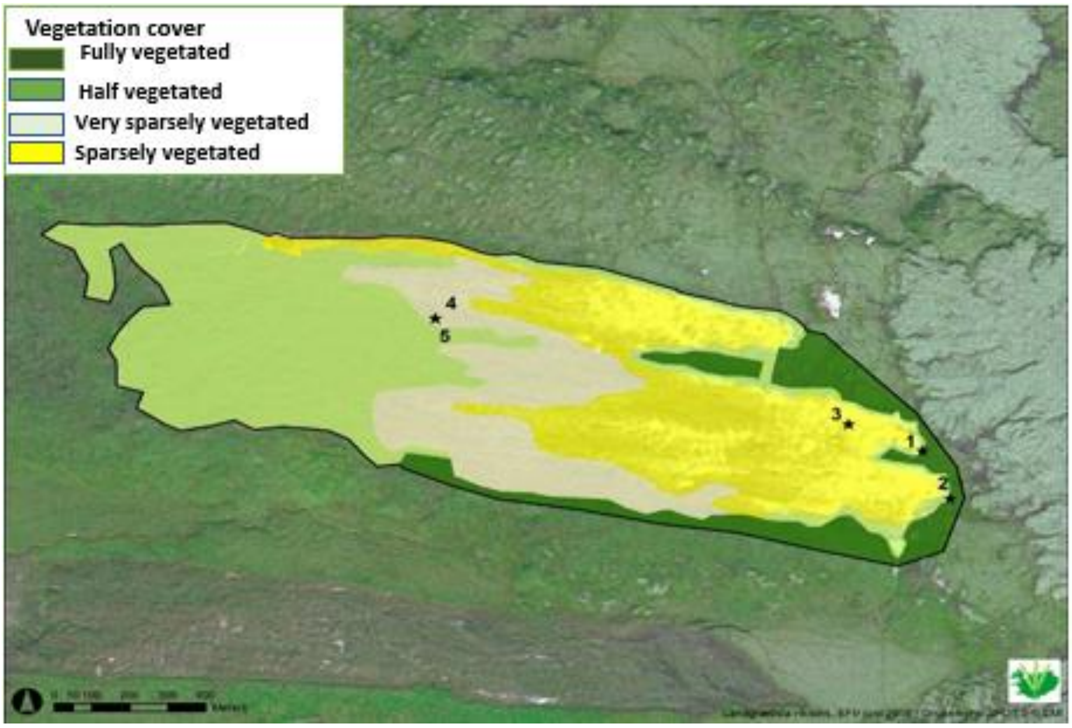

Figure 5. Vegetation cover classes in the study area (Source: Soil Conservation Service 2016).

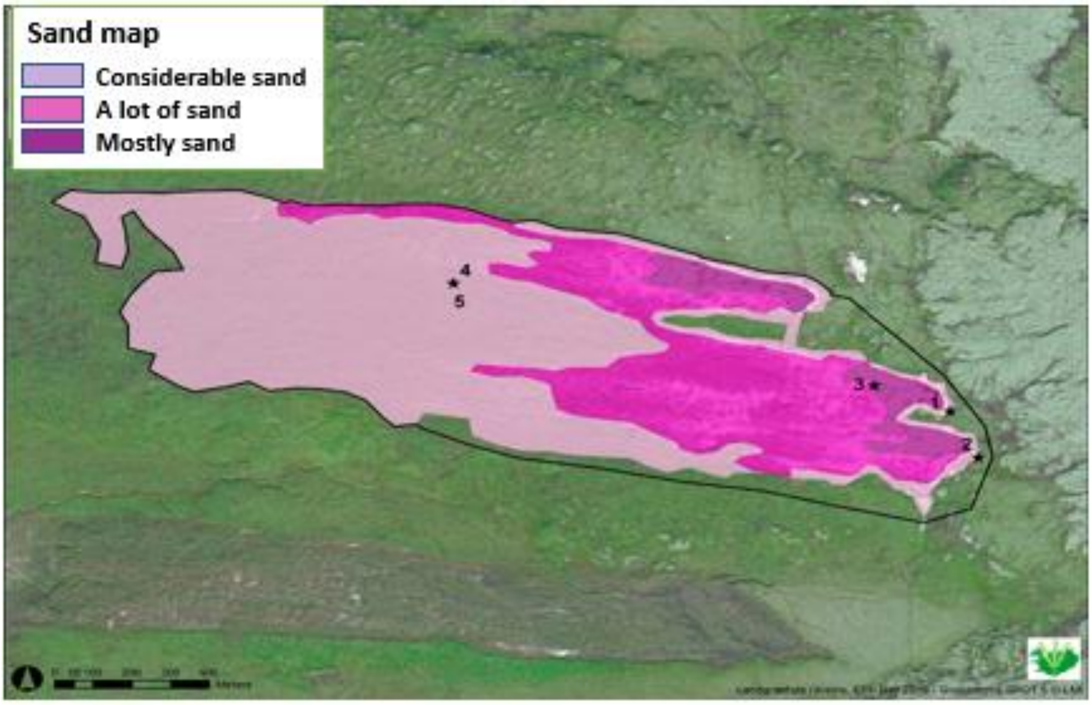

Figure 6. Sand / tephra on the surface in the research area (source: Soil Conservation Service 2016).

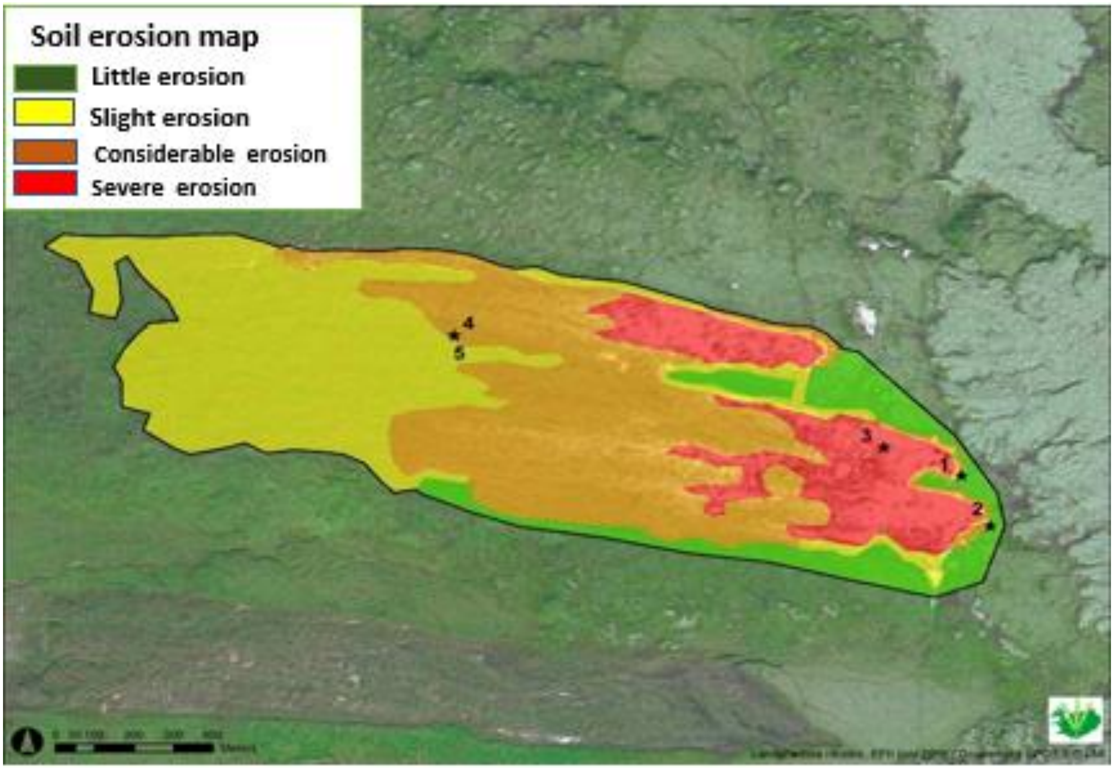

Figure 7. Soil erosion classes in the study area (source: Soil Conservation Service 2016).

3.2. Goals and objectives

In accordance with the projected land use in Dagverðarnes, the vision of the project is to rehabilitate the landscape to be covered by grass, shrubs and trees by 2027 to increase soil stability and the resilience of the site. The goal is to increase 50% of the palatable grass seeding to improve pasture for grazing animals and soil stability by 2022, and again, to increase tree cover by 10% by planting to ensure soil stability by 2027.

3.2.1 Causes of degradation

According to the above information, the causes of the land degradation were found to be loss of vegetation which led to soil erosion. However, history revealed that unsustainable land use, overgrazing by sheep and deforestation added to the harsh climate and volcanic activity resulted in loss of vegetation cover.

3.2.2 Thresholds

A small part on the periphery of the landscape is fully vegetated and with little sand on the surface, making the area more resilient; therefore it will be left to recover on its own. More than one quarter of the landscape is classified as half vegetated, with considerable sand on the surface. In this area soil particles are loose and lack cohesion, making the area susceptible to wind and water erosion. The area has crossed the biotic threshold and requires biological recovery. About half of the area is sparsely vegetated with a lot of sand on the surface in the form of pumice. The surface cannot retain water for absorption, and therefore recovery requires physical modifications because the area is degraded. It has crossed the abiotic threshold, though11% is very sparsely vegetated with mostly sand on the surface. This area is classified with lava rocks, with a lot of sand, and is hence extremely eroded. It has crossed the abiotic threshold, which shows the need for physical modification. In this case physical recovery should help to stabilize the soil and increase infiltration capacity and retention of nutrients and organic matter.

3.3. Planned restoration actions and restoration implementation plan

The following are the recommended modifications with the plant species to use on the different degraded land to improve ecosystem recovery. They are specified regarding the extent of degradation found in each category.

The area that has crossed the biotic threshold, with half the vegetation, will be treated with fertilizer to enhance soil fertility and to promote recovery of the available vegetation, whereas the area characterized with severe erosion and considerable erosion classes will have an intervention by grass seeding using *Festuca rubra L*. (red fescue) seeds with fertilizer application. This is because the available vegetation cover is sparse to no vegetation. This will provide stability to the surface faster than applying fertilizer only. Lastly, for building resilience of the area, planting of birch trees will be done along the edges of the landscape to serve as a shield against wind and water erosion.

An estimated application rate is 150-200 kg of fertilizer prepared with 30-50 kg of seed per hectare. Sowing and fertilization should be carried out in the early summer to ensure good grass growth before winter arrives. Fertilizer will provide nitrogen, which is always deficient in bare soils and enhance growth of the grass. The above plan will improve the capability of seed dispersal; it is therefore important to remove herbivory for better results so that plants can produce ripe seeds. Birch trees will be planted in high potential areas for improved establishment to serve as seed sources. The restoration actions proposed are shown in Table 7 and Figure 8, while Table 8 shows the restoration time frame and Table 9 shows the budget for the whole project.

Table 7. The implementation plan for Dagverðarnes for each erosion class category with specific action and area size.

Site	Erosion class	Vegetation cover	Area	Action
1	Severe erosion	0 – 10%	15 ha	Grass Seeding + fertilizer application
2	Considerable	34 – 66%	45 ha	Grass Seeding + fertilizer application
3	Slight erosion	67– 90%	56 ha	Fertilizer application
4	Little erosion	91 -100%	28 ha	No action

Figure 8 shows the proposed restoration actions on the erosion map.

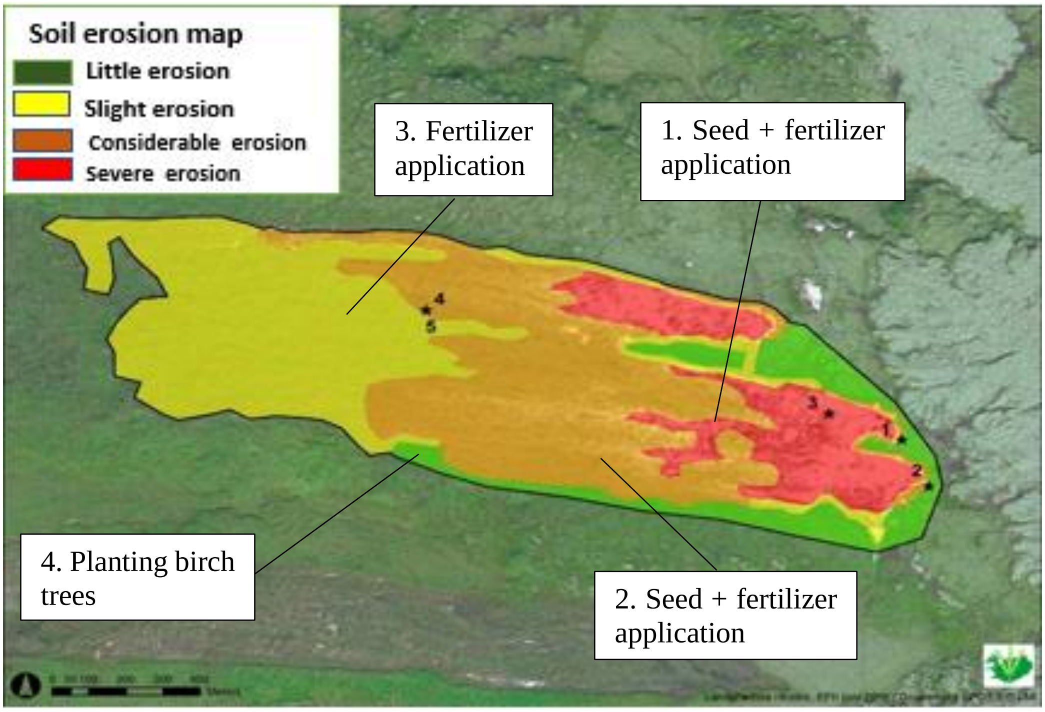

Figure 8. Implementation plan using the erosion map to show how each action will be carried out with priority for the most degraded part.

Table 8. Restoration time frame that specifies when each activity will be undertaken in the specific category, starting with the most degraded part.

Site	Action	Year	Area (Ha)
1 and 2	Seed + fertilizer application	2018	60 ha
3	Fertilizer application	2018	50 ha
4	Planting of birch trees	2018	15 ha
1 and 2	Re seeding + re-fertilizing	2019	10% of the area
3	Re fertilization	2019	50 ha
4	Fertilization on the birch trees	2019	15 ha
	Replanting + re-fertilization trees	2019	10% of the area
1,2 and 3	Re-fertilization	2023	100 ha
4	Re fertilization on trees	2021 or 2022	10 ha
All	Monitoring	2018 to 2027	

3.4. Monitoring

Monitoring of the area will be done using photo points which will show the physical change of vegetation for comparison purposes in the area. An annual inventory method to collect monitoring data using the Gap method (Riginos and Herrick 2010) (vegetation canopy gap size distribution at 10 cm interval) will give detailed data on available vegetation species (palatable species), bare soil, vegetation type, rock, litter and gap between plant bases.

3.5. Project cost

Table 9. Budget cost of the Dagverðarnes project for the period 2018 – 2027.

Year	Activity	Unit cost (ha) isk	Area covered (ha)	Total cost (isk)
2018	Seed + fertilizer	76,000	60	4,560,000
2018	Tree planting	1,500	15	22,500
	Tree seedling (per plant)	47	1,000 trees x 15ha	705,000
2018	Fertilizer	21,000	50	1,050,000
2019	Re-seeding		10%	456,000
2019	Re-fertilization	21,000	50	1,050,000
2019	Re-planting and fertilization	76,000	6ha (10%)	456,000
2019	Re fertilization of trees	21,000	15	315,000
2023	Re-fertilization of grass	21,000	100	2,100,000
2022	Re-fertilization on trees	21,000	10	210,000
	Sub total			8,713,500
2017	Planning	15% of the project cost		1,307,025
2019 - 2027	Monitoring	15% of the project cost		1,307,025
	Total			11,327,550

4. CONCLUSIONS AND RECOMMENDATIONS

Restoration planning is the basis of an inquisitive form of finding useful information required to undertake effective reclamation methods for sustainable ecosystem recovery. A good restoration plan at the beginning of the project becomes a useful tool, which applies very well to the goals and vision of the project, and therefore achievement of the outcome will be ensured.

In this case, history of land use in Dagverðarnes revealed that unsustainable use of rangelands resulted in overgrazing. Detailed analysis and site assessment confirmed that loss of vegetation cover led to exposed soil that was easily eroded by wind and water causing the soil erosion that is experienced on the site today. In this study, the recommended modifications were drawn from the experiences of the SCSI on previous projects. On the intact areas, self-recovery is recommended, while in the areas that have crossed the biotic threshold only fertilization will be required, but for the most degraded areas that have crossed the abiotic threshold, grass seeding with fertilizer application is recommended. The implementation plan of Dagverðarnes was developed for all the categories, but the most degraded area will be given priority, and costing was done for ten years. Information about how monitoring data will be collected is elaborately discussed to closely monitor progress.

The study showed that by following the restoration plan, it is easier to make a thorough land assessment which then leads to treating the causes of land degradation rather than the symptoms. Restoration interventions can be determined based on the constraints of the site in relation to the project goals and adaptable methods to suit the conditions. Restoration planning provides a detailed implementation plan, with detailed schedule and cost estimate over a specific time.

Compilation of a restoration plan and identifying appropriate restoration measures for the degraded landscape in Dagverðarnes in Iceland has provided me with experience to develop a plan for different landscapes and to utilize different restoration measures for varying degraded areas. The knowledge of the techniques will be shared with policymakers, land managers and land users to improve degraded ecosystems to help improve livelihoods in Lesotho. Furthermore, knowledge about incorporating monitoring will give information about when adaptive management is required to maintain the goals and the vision of the restoration purposes. This approach will provide long-term stability and protection of the ecosystem and, because it is site specific, it is adaptable to different landscapes.

It is recommended that documentation and demonstration of restoration projects undertaken should be accessed by the public and policymakers to improve dissemination of research results and recommendations to the relevant stakeholders. All projects should be well written up, elaborating the experiences and successes, as this would help to secure funding from NGOs and other corporations, for restoration projects, which is sometimes not enough because outcomes are realised after a long time and may cost more in the end. To improve replicable success, genuine engagement of community stakeholders' information sharing will provide the community with understanding of landscape conditions, challenges and opportunities. There should be collaborative planning on action plans, monitoring and accountability. Shared understanding should be maintained from the local level, starting with informal knowledge.

Encouragement of use of local seeds and plants for easy survival and successful reseeding provides sustainability. There should be introduction of seed collection from the local site to ensure availability when the project starts, as well as development of seed banks for storage of native species to safeguard the cost of restoration. Adaptive management should be taken seriously to give adjustment to management plans which accommodate new, different and versatile skills in relation to the changes that can affect the ecosystem and result in the goals of restoration.

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