APRIL 2020 **#3**

Stabilization of sand dunes with lyme grass and protection with vegetation has allowed the town of Thorlákshöfn to prosper where previously were regular sand and dust storms.
(Photo: Hanspeter Liniger)

SLM POLICY BRIEF

Devastating sand and dust storms: the role of Sustainable Land Management (SLM) for an Icelandic fishing town

Thorlákshöfn – a port and fishing town on the southern shore of Iceland - owes its existence to soil conservation and wind erosion measures on the severely degraded adjacent land. Because of efforts to improve vegetation, the frequency of damaging sand and dust storms has decreased, thus protecting the town. Following SLM interventions, Thorlákshöfn has developed its infrastructure, social facilities and industries, sustaining its 1,700 inhabitants. Although this case study presents compelling evidence to support the spread of SLM practices against wind erosion in other areas, there remain questions about complex impacts and interactions offsite/ downwind. Further investigations are required to establish the costs and benefits of SLM and to identify promising practices that are in harmony with the sensitive Icelandic ecosystems.

ICELAND

Key message

- The vulnerability of unique landscapes to severe land degradation, related to sand and dust storms and water erosion, requires awareness-raising about the impacts both onsite (where the land is managed) and offsite (downstream / downwind).
- Despite successful restoration efforts, further investment in sustainable land management (SLM) is needed to enhance onsite productivity and to protect land and people offsite.
- It is crucial to promote SLM practices that increase vegetation cover on the volcanic soils.
- The ecological systems within Iceland are particularly sensitive, therefore interventions must be fine-tuned.
- Further and continued assessment is necessary to understand both the on- and offsite impacts of land management practices in upland areas, and their effects on the growing downstream populations.

BOX 1: Definitions

Onsite: Locations where land management practices are applied – e.g. where SLM is implemented.

Offsite: Areas where land management practices applied somewhere else have an impact on the land and people. This includes areas downstream (related to water) or downwind (related to wind transporting sand, dust and moisture).

Uplands: Upper lowlands (hilly areas under 500 m) and highlands (over 500 m).

Upwind: In the opposite direction to that in which the wind is blowing; against the wind.[1]

Downwind: In the direction in which the wind is blowing.[1]

Dust storm or sand storm: An ensemble of particles of dust or sand energetically lifted to great heights and over large areas by a strong and turbulent wind.[2]

Tephra: Fragmental material produced by volcanic eruptions and spread over the land surface.[1]

Desertification: The reduction in the capacity of the land to provide ecosystem goods and services, over a period of time, for its beneficiaries because the land is turning into a desert.[3]

Iceland's problem with erosion

Although the isolated, impressive landscapes of Iceland are often perceived to be original, they actually result from a process of land degradation by wind and water erosion and extreme sand and dust storms. In 1997, about three quarters of the country were affected: representing 70,000 km^2 of degraded land out of which 6,300 km^2 were assessed to be severely affected by desertification[4]. On average, Iceland is subject to 135 dust storm events per year with regular wind speeds over 100 km/h in the lowlands, while the highlands and mountain areas face speeds of up to 180 km/h. Some transport sand and dust over 1,000 km[5]. From ancient times to today, volcanic eruptions have expelled massive amount of tephra (Box 1), which covers the surface with layers of loose substrate. Tephra is colonised by pioneer plants and, over time soils form and grassland and birch forest develop. This vegetation traps finer material in the wind and soils with high organic matter levels build up. Repeated volcanic eruptions cover the vegetation and new soils are formed with another vegetation cover. If anything affects this protective vegetation, the fine particles are prone once again to wind erosion.

Figure 1. Overgrazing destroys the protective vegetation cover that secures the very erodible soil on the slopes of Mount Hekla, one of the most active volcanoes. Strong wind storms can even hollow out the soil on bare patches (Box2). (Photo: Hanspeter Liniger)

Natural vegetation has also been severely disturbed by human intervention. Until last century, natural birch forests were widely exploited for timber and fuel. Unrestricted grazing of sheep hindered natural rejuvenation – as sheep preferentially consume birch seedlings. Common user rights and unmanaged grazing – letting animals roam from spring to autumn in the highlands – has increased pressure on vegetation and soil health, intensifying wind erosion especially on the exposed upper slopes of mountains and hills (see Figure 1). Without any protective measures, degradation can be rapid and devastating (see Box 2).

BOX 2: The Black Sandstorm

During the spring of 1882, there were a succession of severe sandstorms in the south of Iceland. Over extended areas, three to five meter's depth of soil over extended areas was blown away. Sheep were unable to move because of the absorbed weight from sand, and the animals that survived the initial storm eventually starved. Farmers were forced to abandon their severely degraded land. These storms were particularly disastrous because they hit the productive land in early spring when vegetation was sparse and overgrazed. They also affect the lowlands[6].

Figure 2. Land degradation (left and foreground) fertile soil has been blown away during heavy wind storms. Soil protected with productive grassland management (right) has not been affected by wind storms. Remnants of birch forests, which would be the undisturbed native vegetation also protect the soil (insert right), the lowlands and Thorlákshöfn. (Photos: Hanspeter Linger)

SLM Efforts

In 1907, the Icelandic Soil Conservation Service (SCSI), the oldest soil conservation agency in the world, was formed to reduce soil erosion, mitigate land degradation from dust and storms, and protect farmland. Through implementing technologies that focused on excluding grazing of the most eroded areas and minimizing erosion through revegetation, 5.5% of the island (5,710 km^2) that was considered desertified was restored in the last century[6]. Ongoing SLM efforts have demonstrated continued progress in reducing land degradation and decreasing disaster risk and damage from sand and dust storms[7].

Thorlákshöfn: from dust desert to coastal refuge

Thorlákshöfn, a small town on the coast of south west Iceland is adjacent to one of the most water rich rivers, the Ölfusá, which flows into the sea close by. The river's catchment area (6,190 km^2) extends into the central highlands[8].

In early times, Icelanders came seasonally to the peninsula, profiting from plentiful fish. However land around Thorlákshöfn comprised a barren, sandy desert and the few inhabitants experienced regular sand and dust storms. The sand originates from eroded sediment in the rivers Ölfusá and Thjórsá and other rivers further east. The ocean currents sweep the sediment from the river outlets into the bay of Thorlákshöfn, from where it is then blown inland and west into the town (see Figure 3, 5).

Land management around Thorlákshöfn

The relatively warm southern coastal lowlands provided early springtime grazing. However, uncontrolled grazing all year round increased, decreasing vegetation cover and greater frequency and intensity of sand and dust storms. The SCSI built a fence of barbed wire fence in 1935 to exclude grazing and allow the vegetation to recover. In 1954, a series of barriers, or "palisades", were made from timber and driftwood to allow lyme grass (*Leymus arenarius*) to grow and, through its creeping horizontal roots (rhizomes), to spread, establish and stabilize the sand dunes - protecting infrastructure (see Figure 4).

In the 1960s, the SCSI spread fertilizer over some areas by airplanes to stimulate the existing sparse vegetation (see Figure 5). Seeds of "creeping red fescue" grass (*Festuca rubra*) were also

Figure 3. Thorlákshöfn is located on the south coast of Iceland. The catchment area of the Ölfusá river extends far inland. The river flows from the uplands (brown) including the highlands through the lowlands into the ocean. (Source: Google Earth)

planted with fertilizer to increase cover. In the 1990s *Lupinus nootkatensis* was extensively sown, spreading cheaply and successfully in sandy and gravelly areas. The extensive planting of lyme grass at that time established a huge seawall along the coast (see Figure 4). Additionally, in a recent project, native birch saplings have been planted to re-establish forests.

Off-site impacts of implementing sustainable land management for the town of Thorlákshöfn

Since 1935, SLM interventions have achieved notable improvements in vegetation cover. However, the area is still predominantly sandy and vulnerable to erosion[9]. Despite its fragility to windstorms, the vegetation cover has continued to increase.

There are no agricultural benefits onsite from the now stabilized sand dunes but there is a landscape scale benefit, plus biodiversity, plus carbon sequestration. The lyme grass for example does sequest enourmous amount of carbon.

Furthermore, investments in land reclamation made it possible to establish a town that has infrastructure and facilities for its 1,700 inhabitants. Port facilities for fishing, fish processing, and trade have developed over the last decades. Nowadays, infrastructure and people are better protected from sand and dust storms (see Figure 6).

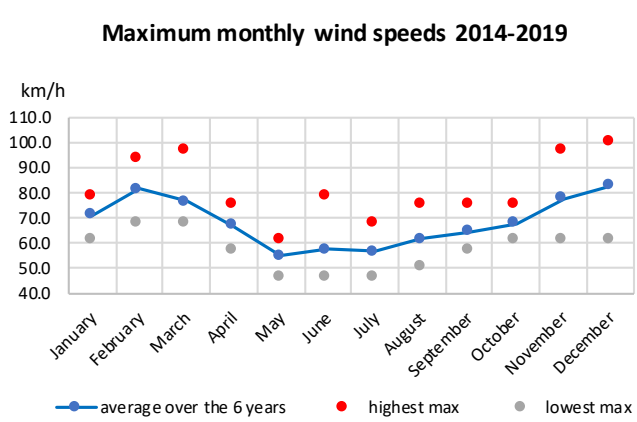

Figure 4. Maximum monthly wind speeds (right) in the years 2014 to 2019 in Thorlákshöfn. Stabilization by lyme grass created a sea wall 10-15 m high as sediments - brought by the rivers, then deposited by ocean currents along the coast – are carried by the wind inland and trapped (left). Remnants of protective wooden barriers (right). (Photos: Jan Reichert)

Figure 5. Overview of land reclamation around Thorlákshöfn. Red line: fence (approx. 20 km long) built by the SCSI in 1935. Orange lines: protective timber barriers (16.5 km). Light green areas: interventions by traktors machinery. Dark green lines and areas: interventions by airoplane. (Source: SCSI)

Insert: Eroded sediments from the highlands are transported by the rivers Ölfusá and Thjórsá and other rivers futher east into the sea. (1) Sediments are transported by currents and deposited ashore where they become exposed to strong winds when the tide retreats. (2). The exposed sediments are blown inland (3) North-easterly winds blow the debris to Thorlákshöfn mostly in the winter time (4). (Source: Google Earth)

Figure 6. The port of Thorlakshöfn harbouring a cargo ship and facilities for transport and fishing – key to local development and protected by land restoration in the neighbourhood (background) as well as restoration far away in the uplands. (Photos: Hanspeter Liniger)

Restoration work in the uplands

In the uplands, extended areas are seriously degraded and only a small part has been protected from wind erosion through biological interventions (planting lyme grass, lupine and birch for the lower altitudes) and other SLM practices (fertilizing and re-seeding, protective fences, grazing management). Restoration here is not feasible without fencing off from grazing for several years. However, about two thirds of all sheep farmers still bring their flocks to the highlands for grazing. Due to high cost for build up fences and the strong aversion of the farmers to agreements on excluding grazing in common grazing are-

BOX 3: Consequences of planting and spread of the nootka lupine in Iceland

The nootka, or "Alaska lupine" (Lupinus nootkatensis) is an exotic that was first introduced in 1945. After 1990, it was widely used for revegetation. Lupine spreads well in sandy and gravelly areas, on river banks and bare mountain slopes. It is very effective in establishing a dense vegetation cover and is an efficient nitrogen fixer. Despite these benefits, the lupine is very controversial because of invasiveness: it causes other unintended offsite impacts as it displaces native vegetation – a problem in national parks. There is a clear trade-off between soil conservation and biodiversity. Grazing does not stop lupines to spread only young plants are eaten by sheep, but once mature, its bitterness renders it unpalatable and cutting the plants during flowering to stop seed production is expensive. Due to its invasiveness, the SCSI stopped using the lupine in 2018.

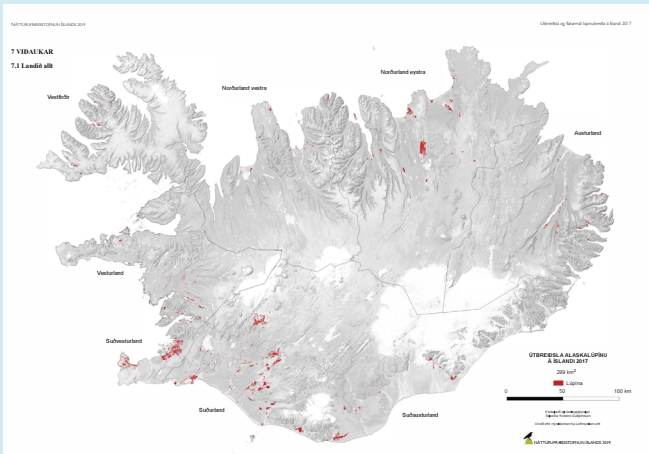

Figure 7. Left: The non-native lupine (Lupinus nootkatensis) grows vigourously and forms an almost inpenetrable mat, suppressing other plants. Right: Spread of lupine in Iceland lupine spreading outside a reclamation project, (right): "Distribution in Lupinus nootkatensis: Distribution 2017[10].

as in the highland protection is very limited. Nevertheless such measures have improved the vegetation cover and brought associated benefits (see Figure 8). Between 2007 and 2014, a reforestation and soil conservation project in the Hekla region in the upper lowlands planted more than 2.3 million birch seedlings in lyme grass and lupine, to restore woodlands in parts of the 90,000 hectares project area and reduce the negative impacts of tephra deposition from the active volcano.

On-site impacts of implementing sustainable land management in the uplands

Increasing the vegetation cover makes the soil less vulnerable to wind erosion. Surface runoff decreases, and the quality and quantity of the water improves. Biodiversity and the ability to sequest carbon increases. After reclamation of the lower parts of the highlands, controlled grazing in the summer months may be considered. However, the vegetation cover and the soils still remain fragile for a long period.

Off-site impacts of sustainable land management in the uplands

Sustainable land management on agricultural land has major off-site benefits including reduced surface runoff and improved river flow regimes. Less sediment transported means a reduced threat to hydropower turbines, less siltation of reservoirs and lower amounts transported to coastal outlets. Increased sediment in the ocean from rivers, which is then brought back by tides, can fill harbours with sand which has to be pumped out at high costs. Increased sediment accumulation along the shoreline feeds sand and dust storms and threatens the environment, infrastructure, and human health (as in Thorlákshöfn).

Figure 8. Grazing land in the uplands of Iceland Northwest of Mount Hekla volcano: Slopes (left) are completely degraded by wind erosion. The mountain slopes (background) are severely degraded due to both wind and water erosion. The right has been revegetated and thus protected from wind erosion. Restoration with native lyme grass and exotic lupines started around 2000 and birch trees were planted after 2014. These large restoration areas in the uplands also protect the downstream and downwind lowlands including the fishing town of Thorlákshöfn. (Photo Hanspeter Liniger)

Jan Reichert
Master student geography
University of Bern, Switzerland
jaenu.reichert@gmail.com

Dr Hanspeter Liniger
Senior Research Scientist, WOCAT Director
Centre for Development and Environment (CDE)
University of Bern, Switzerland
hanspeter.liniger@cde.unibe.ch

Dr Sveinn Runólfsson
Former/retired Director of the Soil Conservation Service of Iceland from 1972 to 2016
sveinnrun@gmail.com

Special Acknowledgements

Land users and inhabitants in Thorlákshöfn and the uplands, especially Adalbjörg Run Asgeirsdottir & Hrafnkell Karlsson for sharing their experiences.

Soil Conservation Service of Iceland for sharing their data and experiences.

Soil Conservation of Iceland staff especially Thórunn Péturs-dóttir & Gudmundur Halldórsson for project support.

Swiss Agency for Development and Coorperation for the financial support.

Further information

Link to all results from 'on- and offsite benefits of SLM':

- SLM Policy Briefs: www.wocat.net\ …
- Synthesis Report: www.wocat.net\ …
- Videos: www.wocat.net\ …
- Land management practices: WOCAT SLM Technology and Approaches database: www.wocat.net\ …

1 – 10 The list of references is available in the online version of this policy brief: www.wocat.net

Implications for practice, policy and research

Iceland's cold and windy climate combined with volcanic activities has formed unique landscapes attracting tourists from all over the world. However, inappropriate management in this ecologically sensitive environment has led to widespread and severe land degradation related to sand and dust storms, and water erosion. There is need to raise awareness especially amongst policy makers that this not only seriously affects people on their land (onsite) but also non-agricultural communities far away e.g. in coastal towns (offsite).

Due to recognition of land degradation by dedicated politicians and land management specialists, various land management interventions have been made and their impacts assessed. Despite a history of rehabilitation efforts in Iceland's fragile ecosystems, further investment in SLM is needed to protect agricultural land and enhance its productivity – including the remote highlands where sheep farmers need more evidence on grazing impacts. This is justified as it protects farmers (onsite) but also other communities (offsite) from the life-threatening consequences triggered by accelerated wind and water erosion that is affecting livelihoods downstream.

Key to further improvements are to promote SLM practices that increase cover on the volcanic soil by improving productive grazing systems, reseeding grasses, stabilizing sand dunes with lyme grass, and reforestation with indigenous birch trees.

These interventions must be fine-tuned to Iceland's sensitive environment. Introduction of non-native plants like the Alaskan lupine may protect the soil but, in this case, has serious unintended consequences of invasive behaviour - replacing native vegetation and fundamentally altering ecosystems.

Though substantial progress has been made over the last century, the further search for appropriate SLM practices (for example identifying indigenous spreading leguminous species), and continued investments into assessment of on-and offsite impacts of SLM in these diverse landscapes will be advantageous for the country's sustainable development, environmental integrity, health, and livelihood security. The impacts of land management on degradation and the benefits of SLM interventions in the rural areas including the highlands (upstream and upwind) and their effects onland and people downstream and downwind must be properly assessed and monitored.

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WOCAT SLM Policy Briefs summarise key findings about aspects of sustainable land management. Topics include on- and offsite benefits, disaster risk reduction, biodiversity, climate change adaptation/mitigation, ecosystem services - and many more. The briefs are based on up-to-date research and implementation experience by specialists and land users. The briefs and other WOCAT resources are available at: www.wocat.net

Centre for Development and Environment (CDE)
University of Bern
Mittelstrasse 43
3012 Bern
Switzerland
www.cde.unibe.ch

This issue
Series editor: Hanspeter Liniger
Editor: Hanspeter Liniger
Language editor: Will Critchley, Jaclyn Bandy
Design: Simone Kummer
Printed by Varicolor AG, Bern

MIX Papier FSC FSC® C020328

ISSN 2296-8687

Citation: Linger HP, Reichert J, Runólfsson S. 2020: *Combating devastating sand and dust storms: the role of Sustainable Land Management for Thorlákshöfn, an Icelandic fishing town.* WOCAT SLM Policy Brief, No. 3. Bern, Switzerland:CDE.

Keywords: Sustainable land management, land reclamation, sand and dust storms, lupine, lyme grass, Iceland

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