The picture shows the flower of the lupine, which is used for land reclamation in Iceland (see background). (Jan Reichert)

Seeding lupine for land reclamation and to protect the soil against wind erosion (Iceland)

Nootka lupine or Alaska lupine

DESCRIPTION

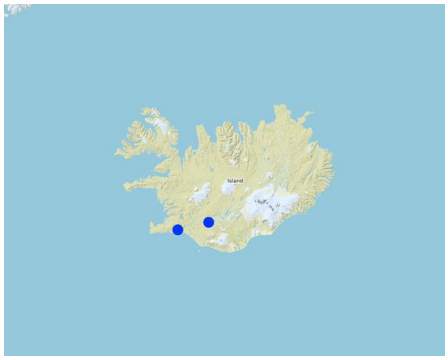
The nootka lupine is sown in sandy and gravelly areas to increase the vegetation cover and fertilize the soil.

The nootka lupine (Lupinus nootkatensis) is a legume that can survive in the harsh climate of Iceland. It was introduced from Alaska to increase soil cover and fertilize the sandy and gravelly soil. For that purpose, it has been widely used from 1990 onwards in degraded areas all over Iceland. Because of its large amount of seed production, the plant is able to reproduce rapidly and spread. The ability of the lupine to fix nitrogen through its root system reduces the need for fertilizer - especially when planting trees. Increased vegetation cover due to the lupine plants minimizes vulnerability to wind erosion. The ground is protected and sandstorms can be reduced. This also protects neighbouring fields, and public and private infrastructure from sand and dust storms.

The lupine is seeded with machinery in spring or very late autumn. It is planted in strips – rather than all over the ground - because the plant readily spreads and colonise. Before planting, lupine seed have to be inoculated with rhizobium bacteria. These bacteria help the plant to fix nitrogen: without this inoculation the plant wouldn't survive in the bare soil. These bacteria are produced during winter time in a laboratory. The lupine needs no fertilizer after planting. Planting of lupine is an extremely cost-efficient and effective way of increasing soil cover and soil fertility. It is a one-off operation: no further action needs to be carried out afterwards.

However, the nootka lupin is very controversial in Iceland despite its apparent advantages both on and offsite. The use of lupines should be carefully considered, especially in sensitive and protected areas. The reason is that this non-native plant is very invasive and leads to the displacement of the native vegetation. Grazing does not stop lupines spreading: only young plants are eaten by sheep, but once mature, its bitterness renders it unpalatable. On a small-scale, it is possible - with great effort - to slow down the spread by cutting the flowers. On a large-scale, the spread can only be stopped with herbicides which is highly controversial. From the land user's view, the planting of lupine reduces the aesthetic value of the landscape because of monoculture: diversity is lost. That is why people try to plant trees in such fields. Because of the controversy surrounding the plant, the technology has been little adopted by farmers and due to its invasiveness, the Soil Conservation Service stopped using the lupine in 2018.

LOCATION



Location: Thorlákshöfn, Hekla area, South of Iceland, Iceland

No. of Technology sites analysed: 2-10 sites

Geo-reference of selected sites

- -21.33257, 63.89227
- -19.80396, 64.05382

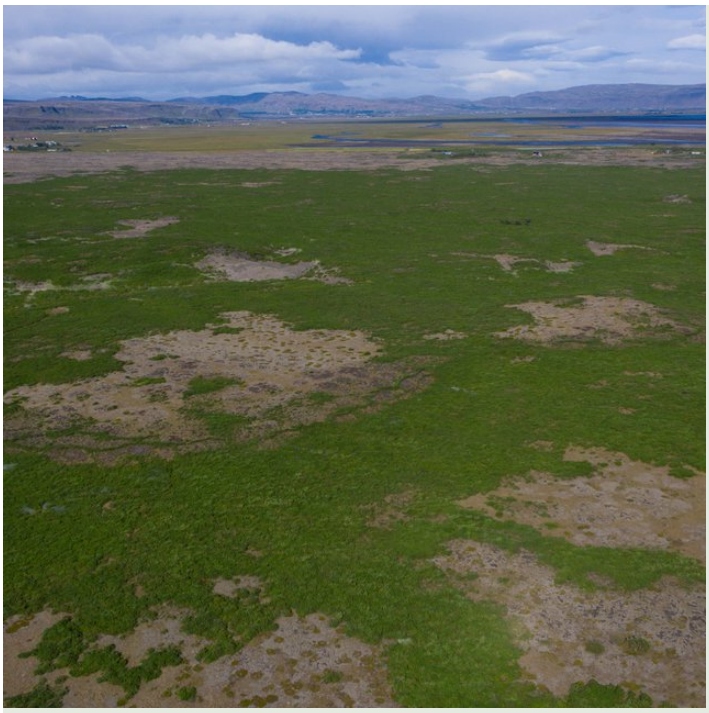
Spread of the Technology: evenly spread over an area (approx. 10-100 km2)

In a permanently protected area?: No

Date of implementation: 10-50 years ago

Type of introduction

- ☐ through land users' innovation
- ☐ as part of a traditional system (> 50 years)
- ☑ during experiments/ research
- ☑ through projects/ external interventions



Lupine increases the vegetation cover and spreads rapidly and widely after introduction. (Hanspeter Liniger)

CLASSIFICATION OF THE TECHNOLOGY

Main purpose

- [ ] improve production
- [x] reduce, prevent, restore land degradation
- [ ] conserve ecosystem
- [ ] protect a watershed/ downstream areas – in combination with other Technologies
- [ ] preserve/ improve biodiversity
- [x] reduce risk of disasters
- [ ] adapt to climate change/ extremes and its impacts
- [ ] mitigate climate change and its impacts
- [ ] create beneficial economic impact
- [ ] create beneficial social impact

Land use

Land use mixed within the same land unit: No

Grazing land

- Ranching
- Cut-and-carry/ zero grazing

Animal type: horses, sheep
Products and services: meat, whool

Unproductive land - Specify: eroded land, degraded land

Water supply

- [x] rainfed
- [ ] mixed rainfed-irrigated
- [ ] full irrigation

Purpose related to land degradation

- [ ] prevent land degradation
- [x] reduce land degradation
- [x] restore/ rehabilitate severely degraded land
- [ ] adapt to land degradation
- [ ] not applicable

Degradation addressed

soil erosion by wind - Et: loss of topsoil, Ed: deflation and deposition, Eo: offsite degradation effects

SLM group

- improved ground/ vegetation cover
- ecosystem-based disaster risk reduction

SLM measures

vegetative measures - V2: Grasses and perennial herbaceous plants

TECHNICAL DRAWING

Technical specifications

Lupine seeds are being inoculated with rhizobium bacteria prior to seeding. These bacteria help the plant to fix nitrogen. Without this inoculation the Lupine wouldn't survive in the soil.
The seeds are seeded in by machinery in stripes because the plant spreads fast itself. No fertilizer is needed. Normally 5 kg of lupine seeds per ha is used.

Author: Sveinn Runólfsson

ESTABLISHMENT AND MAINTENANCE: ACTIVITIES, INPUTS AND COSTS

Calculation of inputs and costs

- Costs are calculated: per Technology area (size and area unit: **Project costs in Thorlákshöfn**)
- Currency used for cost calculation: **ISK**
- Exchange rate (to USD): 1 USD = 138.0 ISK
- Average wage cost of hired labour per day: n.a

Most important factors affecting the costs

workers, seeds, machinery

Establishment activities

1. production of bakteria in labratory at Gunnarsholt (Timing/ frequency: winter)
2. inoculat the seeds before seeding (Timing/ frequency: spring time and very late autumn)
3. seeding lupine (Timing/ frequency: spring time and very late autumn)

Establishment inputs and costs (per Project costs in Thorlákshöfn)

Specify input	Unit	Quantity	Costs per Unit (ISK)	Total costs per input (ISK)	% of costs borne by land users
Other					
Seeding lupine (total costs)	ha	1.0	30000.0	30000.0	
Total costs for establishment of the Technology				**30'000.0**	
Total costs for establishment of the Technology in USD				*217.39*	

Maintenance activities

n.a.

NATURAL ENVIRONMENT

Average annual rainfall

- ☐ < 250 mm
- ☐ 251-500 mm
- ☑ 501-750 mm
- ☑ 751-1,000 mm
- ☐ 1,001-1,500 mm
- ☐ 1,501-2,000 mm
- ☐ 2,001-3,000 mm
- ☐ 3,001-4,000 mm
- ☐ > 4,000 mm

Agro-climatic zone

- ☐ humid
- ☑ sub-humid
- ☑ semi-arid
- ☐ arid

Specifications on climate

n.a.

Slope

- ☑ flat (0-2%)
- ☑ gentle (3-5%)
- ☐ moderate (6-10%)
- ☐ rolling (11-15%)
- ☐ hilly (16-30%)
- ☐ steep (31-60%)
- ☐ very steep (>60%)

Landforms

- ☑ plateau/plains
- ☑ ridges
- ☐ mountain slopes
- ☐ hill slopes
- ☐ footslopes
- ☐ valley floors

Altitude

- ☑ 0-100 m a.s.l.
- ☑ 101-500 m a.s.l.
- ☐ 501-1,000 m a.s.l.
- ☐ 1,001-1,500 m a.s.l.
- ☐ 1,501-2,000 m a.s.l.
- ☐ 2,001-2,500 m a.s.l.
- ☐ 2,501-3,000 m a.s.l.
- ☐ 3,001-4,000 m a.s.l.
- ☐ > 4,000 m a.s.l.

Technology is applied in

- ☐ convex situations
- ☐ concave situations
- ☑ not relevant

Soil depth

- ☑ very shallow (0-20 cm)
- ☐ shallow (21-50 cm)

Soil texture (topsoil)

- ☑ coarse/ light (sandy)
- ☐ medium (loamy, silty)

Soil texture (> 20 cm below surface)

- ☑ coarse/ light (sandy)

Topsoil organic matter content

- ☐ high (>3%)
- ☐ medium (1-3%)

- [ ] moderately deep (51-80 cm)
- [ ] deep (81-120 cm)
- [ ] very deep (> 120 cm)

- [ ] fine/ heavy (clay)

- [ ] medium (loamy, silty)
- [ ] fine/ heavy (clay)

- [x] low (<1%)

Groundwater table
- [ ] on surface
- [x] < 5 m
- [ ] 5-50 m
- [ ] > 50 m

Availability of surface water
- [ ] excess
- [ ] good
- [ ] medium
- [x] poor/ none

Water quality (untreated)
- [x] good drinking water
- [ ] poor drinking water (treatment required)
- [ ] for agricultural use only (irrigation)
- [ ] unusable

Water quality refers to: ground water

Is salinity a problem?
- [ ] Yes
- [x] No

Occurrence of flooding
- [ ] Yes
- [x] No

Species diversity
- [ ] high
- [ ] medium
- [x] low

Habitat diversity
- [ ] high
- [ ] medium
- [x] low

CHARACTERISTICS OF LAND USERS APPLYING THE TECHNOLOGY

Market orientation
- [ ] subsistence (self-supply)
- [ ] mixed (subsistence/ commercial)
- [x] commercial/ market

Off-farm income
- [ ] less than 10% of all income
- [x] 10-50% of all income
- [ ] > 50% of all income

Relative level of wealth
- [ ] very poor
- [ ] poor
- [ ] average
- [x] rich
- [ ] very rich

Level of mechanization
- [ ] manual work
- [ ] animal traction
- [x] mechanized/ motorized

Sedentary or nomadic
- [x] Sedentary
- [ ] Semi-nomadic
- [ ] Nomadic

Individuals or groups
- [ ] individual/ household
- [x] groups/ community
- [ ] cooperative
- [x] employee (company, government)

Gender
- [x] women
- [x] men

Age
- [ ] children
- [ ] youth
- [x] middle-aged
- [ ] elderly

Area used per household
- [ ] < 0.5 ha
- [ ] 0.5-1 ha
- [ ] 1-2 ha
- [ ] 2-5 ha
- [ ] 5-15 ha
- [ ] 15-50 ha
- [ ] 50-100 ha
- [ ] 100-500 ha
- [x] 500-1,000 ha
- [ ] 1,000-10,000 ha
- [ ] > 10,000 ha

Scale
- [ ] small-scale
- [x] medium-scale
- [ ] large-scale

Land ownership
- [x] state
- [ ] company
- [x] communal/ village
- [ ] group
- [ ] individual, not titled
- [ ] individual, titled

Land use rights
- [ ] open access (unorganized)
- [ ] communal (organized)
- [ ] leased
- [x] individual

Water use rights
- [ ] open access (unorganized)
- [ ] communal (organized)
- [ ] leased
- [x] individual

Access to services and infrastructure

health	poor	✓ good
education	poor	✓ good
technical assistance	poor	✓ good
employment (e.g. off-farm)	poor	✓ good
markets	poor	✓ good
energy	poor	✓ good
roads and transport	poor ✓	good
drinking water and sanitation	poor	✓ good
financial services	poor	✓ good

IMPACTS

Socio-economic impacts

drinking water availability	decreased	✓ increased
drinking water quality	decreased	✓ increased

Socio-cultural impacts

health situation	worsened	✓ improved
cultural opportunities (eg spiritual, aesthetic, others)	reduced	✓ improved
recreational opportunities	reduced	✓ improved
community institutions	weakened	✓ strengthened
national institutions	weakened	✓ strengthened
SLM/ land degradation knowledge	reduced	✓ improved

Less dust in the air during windstorms due to increased ground cover and therefore fewer health consequences.

Ecological impacts

water quantity	decreased		increased
water quality	decreased		increased
harvesting/ collection of water (runoff, dew, snow, etc)	reduced		improved
surface runoff	increased		decreased
groundwater table/ aquifer	lowered		recharge
evaporation	increased		decreased
soil moisture	decreased		increased
soil cover	reduced		improved
soil loss	increased		decreased
nutrient cycling/ recharge	decreased		increased
vegetation cover	decreased		increased
biomass/ above ground C	decreased		increased
plant diversity	decreased		increased
habitat diversity	decreased		increased
emission of carbon and greenhouse gases	increased		decreased
wind velocity	increased		decreased

Due to its invasiveness and its enormously dense growth, other native plants are displaced by the lupine.

Due to its invasiveness and its enormously dense growth, other native plants are displaced by the lupine.

Off-site impacts

water availability (groundwater, springs)	decreased		increased
downstream flooding (undesired)	increased		reduced
downstream siltation	increased		decreased
groundwater/ river pollution	increased		reduced
buffering/ filtering capacity (by soil, vegetation, wetlands)	reduced		improved
wind transported sediments	increased		reduced
damage on neighbours' fields	increased		reduced
damage on public/ private infrastructure	increased		reduced
impact of greenhouse gases	increased		reduced

COST-BENEFIT ANALYSIS

Benefits compared with establishment costs

Short-term returns	very negative		very positive
Long-term returns	very negative		very positive

Benefits compared with maintenance costs

Short-term returns	very negative		very positive
Long-term returns	very negative		very positive

CLIMATE CHANGE

Climate-related extremes (disasters)

insect/ worm infestation	not well at all		very well

ADOPTION AND ADAPTATION

Percentage of land users in the area who have adopted the Technology

- [ ] single cases/ experimental
- [x] 1-10%
- [ ] 11-50%
- [ ] > 50%

Of all those who have adopted the Technology, how many have done so without receiving material incentives?

- [x] 0-10%
- [ ] 11-50%
- [ ] 51-90%
- [ ] 91-100%

Has the Technology been modified recently to adapt to changing conditions?

- [x] Yes
- [ ] No

Due to its invasiveness in Iceland, the Soil Conservation Service of Iceland stopped using the lupine in 2018.

To which changing conditions?

- [ ] climatic change/ extremes
- [ ] changing markets
- [ ] labour availability (e.g. due to migration)
- [x] stopp further seeding

CONCLUSIONS AND LESSONS LEARNT

Strengths: land user's view
- The use of lupines is a very cost-effective application, which protects the soil well against wind erosion.

Strengths: compiler's or other key resource person's view
- The use of lupines is a very cost-effective application, which protects the soil well against wind erosion.
- Less artificial fertiliser has to be used because the lupine fertilizes the soil.
- Sowing the lupine is a unique application. No further operations need to be carried out after that.

Weaknesses/ disadvantages/ risks: land user's view → how to overcome
- Lupine is very invasive and displaces native plants. → The use of lupines should be carefully considered. On a small scale, it is possible with great effort to slow down the spread by cutting the flowers. On a large scale, the only possibility to stop the spreading would be the use of herbicides.
- The aesthetic value of the landscape is reduced by the monoculture of lupines. → By planting trees in the lupines the aesthetic value can be increased.

Weaknesses/ disadvantages/ risks: compiler's or other key resource person's view → how to overcome
- The non-native plant is very invasive and produces large quantities of seeds why it is spreading rapidly. This leads to the displacement of the native vegetation. This can become a significant problem in protected areas (national parks). → The use of lupines should be carefully considered, especially in sensitive and protected areas. On a small scale, it is possible with great effort to slow down the spread by cutting the flowers. On a large scale, the only possibility to stop the spreading would be the use of herbicides.
- The lupine is very invasive and spreads very quickly. → The SCS has stopped planting lupine since 2018.

REFERENCES

Compiler
Jan Reichert

Reviewer
Hanspeter Liniger

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Resource persons
Sveinn Runólfsson - SLM specialist

Full description in the WOCAT database
https://qcat.wocat.net/en/wocat/technologies/view/technologies_5750/

Linked SLM data
n.a.

Documentation was faciliated by
Institution
- n.a.

Project
- n.a.

Links to relevant information which is available online
- Webpage Soil Conservation Service of Iceland: https://land.is/english/