

WPI

Assessing Lupine as an Environmental Conservation Tool in Iceland



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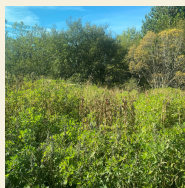
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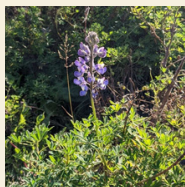
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SUMMARY

Iceland's environment is highly prone to erosion and has conditions that make plant growth challenging. Conservationists in mid-twentieth century Iceland brought lupine along with different species of trees that live in the arctic to stop the huge soil erosion issues and reforest the country. Lupine became a divisive solution to soil erosion and reforestation that has been found successful in some regions of Iceland but not all. We researched the issue through extensive document research, expert interviews from different perspectives, and surveys of native Icelanders, to get as complete and unbiased a picture of the issue as possible. We used this to create a restoration decision guide.

Surveys were conducted in-person as well as online. We found that while the majority of Icelanders believe lupine has a positive impact on the environment overall, many still believe it to be invasive. While lupine is not native to Iceland, most Icelanders were actually ok with the fact that it isn't native. These findings suggest that Icelanders would be happy with using non-native trees, grasses, and legumes like lupine, as long as they are controlled and not invasive. This provided key information about what our decision guide should suggest and what environmental tools Icelanders want to see used.

We interviewed multiple organizations such as the Icelandic Forestry Service, Icelandic Farmers Association, and Soil Conservation Service of Iceland. The interview with Aðalsteinn Sigurgeirsson from the Icelandic Forestry Service provided information on the plant lupine and its effect on the reforestation. He showed us sites where lupine had a huge positive impact on reforestation efforts. The interview with Hlynur Gauti Sigurðsson and Valur Klemensson from the Icelandic Farmers Associations provided the perspective of what Icelandic farmers think of lupine and how erosion and reforestation issues affect farmers and sheep grazing. In our final interview with Kristín Svavarsdóttir from the Soil Conservation Service of Iceland we discussed the challenges that arise when working with a whole ecosystem and not just one portion of it. We learned about how there are many types of grasses that can be used to initiate the natural ecosystem growth, and how lupine can threaten natural flora.

To consolidate the findings from our surveys and research from the experts we interviewed into one easy to access tool, we created a decision guide. The decision guide creates a comprehensive account any person in Iceland can use in order to choose what they would like to do to address soil conservation and reforestation issues on their land. Key issues the decision guide covers are soil conservation, reforestation, and removal of lupine. We recognize Iceland has a diverse landscape, and the decision guide gives many options for how to restore different environments in Iceland. Along with the decision guide, we include a decisional balance sheet to show the pros and cons of lupine usage in Iceland and a plant infographic to teach about the plants in the decision guide. We hope to share these tools with farmers in Iceland through our contacts at the Icelandic Farmers Association.



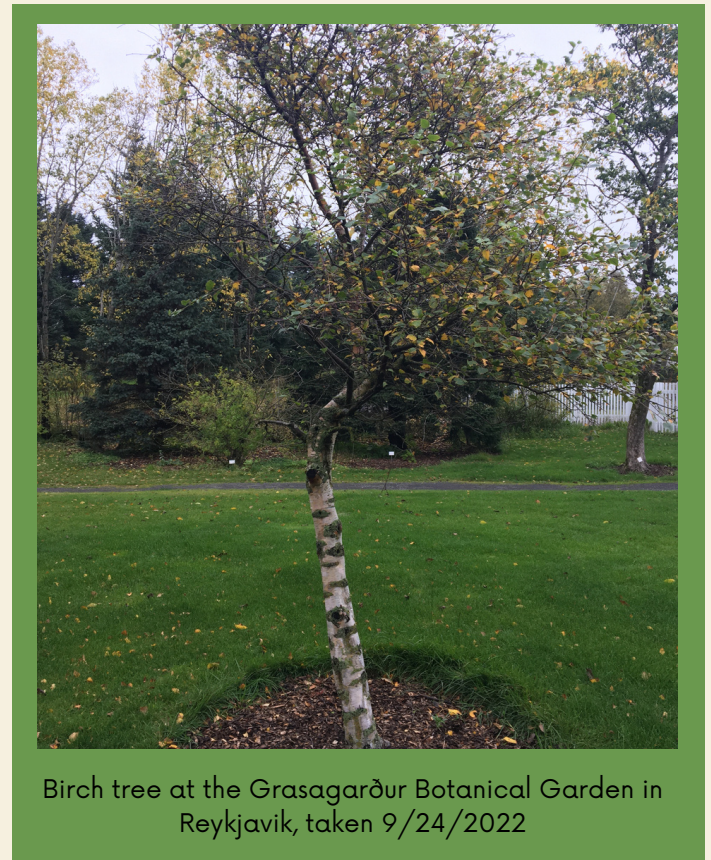
Lupine plant found on Ulfarsfell mountain, taken 9/5/2022

BACKGROUND

Much of Iceland is a barren landscape caused by large-scale Viking deforestation in the 9th century. The nitrogen-poor soil combined with massive erosion caused by deforestation makes reforestation very challenging. The most prominent tool to address soil erosion and poor soil quality issues has been the lupine plant. Lupine can easily grow in sandy and rocky environments while aiding in soil formation and adding nitrogen to the soil. Unfortunately, lupine is a non-native plant and can overtake native species if not properly kept in check. This has led to widespread controversy regarding its usage.

Soil Nutrients to Grow Trees

There are various reasons for seed mortality including frost heaving, drought or competing vegetation. However, a central reason for the lack of tree growth in Iceland is the deficiency of nitrogen and phosphorus in the volcanic andisol soil. Scientists have been experimenting with various fertilizer applications and different tree species to see what grows best. In 1995, researchers conducted a six year study to find the best method for tree growth. They utilized two sites to collect data, Haukadalur and Mosfell, both future sites for reforestation located in the southern region of Iceland. One year old sitka spruce, downy birch, and siberian larch seedlings were planted with nine different fertilizer treatments. Each fertilizer contained different combinations of nitrogen, phosphorus and potassium. In 1995, the overall survival rate was approximately 95%, but in 2000, it decreased to 66%. Spruce had the highest survival rate (82%) while larch had the lowest (54%) (Óskarsson et al., 2006). In both sites, the survival rate of each tree ranged because of the soil treatments. This shows that if the right methods are used, tree growth in a reasonable amount of time is possible.



Birch tree at the Grasagarður Botanical Garden in Reykjavik, taken 9/24/2022

Controlling Soil Erosion in a Contained Area

Devegetation and naturally sandy soil cause mass soil erosion in Iceland. Each day more of Iceland is blown out to sea. The most commonly tried solution is spreading plants with deep roots across the landscape, but this is difficult as about a third of Iceland's land is barren deserts of sandy andisol soil (Arnalds, 2000). Many soil stabilization techniques have been tried to address this.

Soil stabilization techniques that do not involve planting can be temporarily used until soil conditions improve enough for low-lying vegetation. These techniques include wood chips, straw bedding, geo-jute fabric, and curlex blankets. A 2009 study in Louisiana proved that all of these methods are effective in slowing soil erosion over an eight month period. It was shown that of these methods, the geo-jute fabric and curlex blankets were far more effective than anything else, with virtually no soil erosion over the period. The same study also calculated the cost effectiveness of these methods represented as tons of protected soil per acre, per year, per dollar. Straw bedding did best (0.5), followed by wood chips (0.2), with both geo-jute fabric and curlex blankets close behind (0.1). Additional factors such as labor must also be considered. For example, erosion control blankets require significantly more labor to deploy than a simpler solution like wood chips (Jin & Englande, 2009). Similar techniques might be employed in Iceland.

Opposing Views about Lupine

When first introduced in the 1940s, lupine seemed like the most viable solution to Iceland's soil erosion problem. Hakon Bjarnason, the director of Iceland Forestry Service, demonstrated that lupine has an excellent nitrogen-fixing capacity and published multiple articles promoting its use in reforestation. Over the next few decades, lupine made occasional appearances in newspapers and other media and was generally supported. By the late 1900's, the public opinion on lupine changed as ecologists realized the plant has invasive characteristics and could be harmful to the environment. Since then, lupine has been a heavily debated issue.

The pro-lupine argument is based on how lupine is a "fertilizer factory" (Benediktsson, 2015). Unlike aerial fertilizers and planting grass seeds, the lupine is a cost effective solution that does a better job of revitalizing the soil. Eventually, the fight for keeping lupine was linked to nationalism. Extreme pro-lupine Icelanders believe planting this shows they care for the country's environment. Some went so far as to link the eradication of the lupine to xenophobia and racism, even comparing anti-lupine sentiment to Nazism. Nature and nationalism were directly correlated with one other (Benediktsson, 2015).

Anti-lupine feelings began in the 1970's when gardening magazines warned readers that the lupine can decrease natural vegetation. Since the 1980's, nature conservationists began stating that irreversible damage can take place if the cultivation of lupine continues, classifying lupine as an invasive species (Benediktsson, 2015). In addition to experts fearing the decline of native biodiversity, many members of the public dislike the aesthetics of the landscape. Some Icelanders believe the vast lava fields across Iceland give the country a unique touch and promote tourism. Others believe the barren landscape is a sign of strength and determination to survive in tough conditions (Kuprian, 2018).



Lupine fields at Ulfarsfell mountain, taken 9/5/2022

Controlling Invasive Species Growth

There are many factors that increase or decrease the spread of an invasive species. Factors such as increased climate change can increase the natural spread of the lupine (Vetter et al., 2018). For lupine in particular, the plant often spreads through human activities and intentional planting (Magnusson, 2010). A better public campaign to raise awareness about the dangers of lupine could help prevent humans spreading lupine to fragile ecosystems.

Research has been done into different methods of organizing the removal of an invasive species for different situations. For example, a top-down approach utilizes government incentives and policies while a bottom-up approach focuses on the individuals in the community doing their part. Understanding organization of removal efforts could provide significant insight into how to control lupine spread (Epanchin-Niell et al., 2010).

Environmental Policy in Iceland

The Ministry of Environment, Energy and Climate in Iceland has three main projects that they are working on: restoration of the wetlands, land reclamation, and afforestation of Mt. Hekla. All of these projects aim to help Iceland become carbon neutral by 2040 (Ministry of the Environment, Energy and Climate, n.d.). Soil is the biggest storage area of carbon on land and soil erosion releases this carbon into the atmosphere. Reforesting Iceland and preventing soil erosion are therefore priorities for the Icelandic government. Lupine has aided both these causes substantially, despite damaging native plants.

Climate Change Effect on Invasive Species

A study in China found that as carbon emissions and temperature increase, some invasive species will become more tolerant and expand the area that they can spread to (Zhang et al., 2021). A project in Spain found that in areas where aridification occurs, invasive species are more likely to thrive and expand their habitat (Fernández de Castro et al., 2018). Aridification has been occurring in Iceland for decades in the wetlands. Recently, new policies were created to restore Iceland's wetlands in the next few decades. Hopefully, the restoration of the wetlands will promote the growth of native plant species and prevent unwanted lupine spread.

Using Native Plants to Facilitate Tree Growth and Erosion Prevention

Many studies have been done on the growth of various native Icelandic plants. A study done on the island of Stursey off the Icelandic mainland allowed scientists to observe the initial pioneer species colonize the island. Researchers found several species that thrived in harsh conditions with little to no soil or nutrients. Species like *Honckenya peploides*, *Elymus arenarius*, and *Mertensia maritima* spread throughout the barren island. All 3 of these plants could be candidates for revegetation in areas that have poor soil conditions to decrease erosion and add nutrients back into the soil (Fridriksson, 1987).

While these plants can help revegetate areas suffering from soil erosion, areas that have stable soil may benefit more from other plant growth. Nitrogen is crucial to soil growth, and studies have researched the nitrogen fixing capabilities of various varieties of legumes. One study identified *Trifolium repens*, a white clover native to Iceland, as a species of legume that has good nitrogen providing qualities even at cold temperatures (Prévost et al., 1999).

Research has been done on how to bring the birch (*Betula pubescens*) forests back to Iceland. Grasses used for land revegetation already in Iceland include *Deschampsia beringensis* from Alaska, *Festuca rubra* from Norway, and native species *Deschampsia caespitosa* and *Festuca richardsonii*. Low growing mosses like *Bryum* and *Ceratodon* form a thin crust on the surface of the ground and can help facilitate growth of native birch and willow. In addition, birch tree growth was significantly more successful around existing willow plants. All these native Icelandic plants could prove useful in reforestation and soil conservation efforts (Urbanska et al., 1997).

Grasses Used for Erosion Control

Various kinds of grasses have been used to combat soil erosion for many years. Experiments were done to see which of these grasses were most effective at preventing soil erosion in different situations. 50 different native and non-native grass species were tested. *Poa pratensis* and *Festuca rubra* were 2 kinds of grasses that showed promise in being able to survive in sandy soil and prevent erosion. However, the success of different species varied greatly based on many conditions including weather, soil type, and grazing. All species thrived significantly better with the presence of fertilizer than without. The experiment concluded that because there are so many factors to control for, for the best results multiple species of grass should be planted in the same area and the best one will naturally survive. Learning about these grass species and conditions they survive in helps further our research into alternatives to lupine (Helgadóttir, 1988).



Trees planted in the same year outside Bugar forest, with and without nitrogen fixing plants, taken 9/7/2022

METHODOLOGY

Lupine is a widespread divisive soil conservation and reforestation tool that some argue has caused more harm to native Icelandic flora than good. The divisiveness of this issue is not only due to the pros and cons it has environmentally, but nationalist feelings of a duty to restore Iceland to its former forested glory. Iceland was deforested when it was first colonized, but due to the poor soil quality and lack of nutrients, tree growth has been stunted. Large scale solutions to improve soil quality, like lupine, have been aggressively executed, leading to unnecessary division within the public.

The most important topics for us to address and evaluate within this issue are:

- 1.Environmental policy enacted by the government
- 2.Effective restoration techniques
- 3.Strategies for increased use of restoration techniques

Subsequent sections of this methodology explain how our team gathered data to evaluate these issues. We used this data to develop an accessible decision guide that can help Icelanders understand solutions to various restoration issues including reforestation, soil conservation, and removal of invasive species.

Research Question 1

What governmental, political, or social influences have promoted lupine as a soil erosion mitigation strategy?

Lupine is a flowering legume that was brought to Iceland by the Icelandic Forestry Service in 1945 with widespread use in the 1960s. It was a part of a government program to improve soil quality and prevent erosion with the end goal of revegetation and reforestation. Since then, lupine has spread to overtake many native species and has been classified as an invasive species, leading to conflicting ideas regarding its usage. There are two main ideologies to restore Iceland: using lupine for reforestation and using grasses to stabilize soil so natural seed banks can grow. Different groups have different reasons for why they support each of these ideas, and understanding the reasons for their opinions is crucial.



Barren landscape around Pingvellir National Park, taken 9/2/2022

Objective 1.1

Assess governmental policy and public opinion on using lupine as a tool for reforestation in Iceland.

To understand the complex governmental policy, we collected information through document research and interviewed experts from government organizations. Document research provided valuable information that enabled us to ask educated questions during our expert interviews. Our team held a virtual interview with the deputy director of the Icelandic Forestry Service (Skógræktin), Aðalsteinn Sigurgeirsson. Aðalsteinn is very pro-lupine, and he taught us about the use of lupine as a phenomenal reforestation tool in Iceland. In a later in-person interview, he showed us how the Icelandic Forestry Service uses lupine in its work and how they do not believe it to be invasive at all. We learned a more moderate view on lupine from an interview with two representatives from the Icelandic Farmer's Association, Valur Klemensson and Hlynur Sigurðsson. This helped provide an additional view of government policy, as the Farmer's Association lobbies the Icelandic government for policy that helps farmers. Another interview was conducted with Kristín Svavarsdóttir, an ecologist at the Soil Conservation Service of Iceland (SCSI). She provided the perspective of a scientist working for the government and taught us the dangers of using invasive lupine for restoration.

To understand the public's opinion on environmental stewardship, we conducted the Online Survey and In-Person Survey. The Online Survey was posted to the subreddit on Reddit, r/Iceland, and linked to a survey questioning Icelanders about their opinions on lupine. The In-Person Survey was conducted in person outside different Bónus grocery stores in Iceland at different times of day. By surveying in-person as well as online, we help reduce sampling bias.

An additional survey, the Farmer Survey, was sent out in the Iceland farmer's newspaper, Bændablaðið. A link to the survey was published along with a brief description of our team's project. Icelandic landowners were asked about how they feel about reforestation efforts on their land and how lupine should or shouldn't play a role.

Unfortunately, our contact at the newspaper was unavailable for some time during our project and wasn't able to publish the survey until it was too late for us to thoroughly analyze the data. Instead, our perspective on how farmers see lupine and restoration is gathered from expert interviews with the Icelandic Farmer's Association. We hope the Icelandic Farmer's Association and future IQPs in Iceland can use this data.

Research Question 2

What are the methods that promote restoration for varying conditions?

There are numerous strategies used in restoration efforts in Iceland. The main restoration efforts are soil erosion prevention and reforestation. Methods to achieve these restoration goals must be understood in order to make a positive change in Iceland's environment.



Tree growing in loose, sandy soil outside Bugar forest, taken 9/7/2022



Vast lupine spread at Ulfarsfell mountain, taken 9/5/2022

Objective 2.1

Evaluate methods to prevent soil erosion and add soil nutrients necessary for restoration and reforestation under different conditions in Iceland.

We used two methods to understand the ways Icelanders prevent soil erosion and add nutrients to the soil for reforestation: document research and interviews. We found resources that taught about several erosion control techniques including soil erosion blankets, wood chips, and pioneer plants (Jin & Englande, 2009). We also found research on methods for adding nutrients to the soil. These are primarily the seeding of pioneer plants, such as legumes, that naturally add nutrients to the soil, or fertilizers (Óskarsson et al., 2006). We chose this method because the studies were accessible online and gave background information about possible solutions.

While document research was helpful, the bulk of Objective 2.1 was achieved thanks to our expert interviews. We interviewed Kristín Svavarsdóttir, an ecologist and botanist at the Soil Conservation Service of Iceland who has been working with methods to prevent soil erosion for over 20 years. She gave us great advice on various native and non-native pioneer species used for soil conservation efforts. In addition, she cautioned against the use of lupine in restoration efforts due to ecological concerns. An interview and tour of reforestation sites with Aðalsteinn Sigurgeirsson, the deputy director of the Icelandic Forestry Service, provided a different viewpoint on lupine and its use in reforestation. At each site he showed us, we observed how lupine had a substantial positive impact on the rate of reforestation and soil quality. Subsequently, we learned about the different tree varieties used for reforestation throughout Iceland and what reforestation methods are most successful. The information provided from both of these experts offered ideas of restoration methods.

Objective 2.2

Find methods to control the spread of lupine.

This was done via document research and interviews with experts on lupine. Documents were found on removal of lupine specifically and on applicable removal of other invasive species. Much of this research was completed before expert interviews, which enabled us to ask informed questions. Experts were selected for interviews who had first-hand knowledge on lupine, and significant insight was gained from their perspectives. Experts from the Icelandic Forestry Service, Soil Conservation Service of Iceland, and the Icelandic Farmer's Association all provided insight and their evaluation of various methods. Methods include pulling up individual plants by the root, removing seed pods to prevent further growth, and using sheep to trample existing lupine over time. We included information on the most viable lupine removal techniques in our decision guide deliverable.

Research Question 3

What can be done to increase adoption of these varying restoration techniques?

We want to increase appropriate usage of the restoration methods we researched in Research Question 2, as well as increase understanding of proper lupine control and removal. This will be done in the form of a guide as well as several supplemental materials. It is important to make information not only accurate and comprehensive, but coherent and easily accessible. Restoration efforts will vary greatly depending on a number of factors, including region, soil type, presence of lupine, cost, and labor available.

Objective 3.1

Create a selection tool for applying viable restoration techniques.

We constructed a decision guide that allows individuals to view ways on how best to reforest their land based on their specific circumstances. It was made utilizing the data we gathered from completing our other objectives including document research, interviews, and surveys. The guide has several possible options for different circumstances with different land restoration goals in mind. Allowing stakeholders the decision on how to best maintain their land should produce the greatest environmental improvement. This avoids the negative social impact of foreigners telling native Icelanders how they should interact with their environment.



View of large farmlands with few trees from top of a hill at Geysir, taken 9/7/2022

Interview Methodology

For the first and second research questions, experts were interviewed about controlling soil erosion and government environmental policy. Each expert interviewed was asked the same primary questions, as well as possible secondary questions specific to their knowledge and/or position in the government.

Interviews were conducted with experts we researched prior to meeting. The experts we interviewed were all given the questions prior to meeting to prepare, as well as information about the WPI IQP and our project's goals. Results from the interviews were gathered via audio recordings and notes. Audio recordings were later transcribed for easier review. Kristín Svavarsdóttir, our contact at the Soil Conservation Service of Iceland, requested that the audio recording as well as the transcript be deleted after we used them to gather data, and the team has done so. The tour of the reforestation sites with Aðalsteinn Sigurgeirsson was not recorded as the tour lasted several hours and recording and transcription would not have been practical.

Interviews were divided into 4 categories each expert discussed most and are represented in mind maps in our results section. Mind maps were sent to the experts for approval prior to booklet submission. See appendices A, B, and C for interview questions.

Survey Methodology

Getting a complete picture of differing opinions about lupine was challenging. We got a data set of over 100 Icelanders from both in-person and online surveys. This survey was written in such a way to not ask leading questions to get accurate data. Many of the questions were written on a strongly disagree to strongly agree scale. This provided qualitative feedback and results that can be compared. In addition, there was a free response question at the end of the survey to allow Icelanders to share any other concerns. These surveys, combined with our other research, offered a comprehensive idea of restoration methods and the opinions of Icelanders on those methods. Specific survey details can be found in the methodology section and supplemental materials.

We conducted another survey in the Icelandic farmer's newspaper. This survey had questions that are geared more towards soil conservation and land usage from farmers. Unfortunately, the newspaper was not published until shortly before this booklet's completion so no time was available to fully analyze the data. We hope the data will be of use to the Icelandic Farmer's Association as well as future IOPs on land restoration in Iceland.

Ethical Concerns

There are no significant ethical concerns in our methodology. Our survey questions only ask about environmental issues and nothing invasive. The demographic information we collect is limited to if they live in Iceland and their age demographic. Both of these pieces of information are not sensitive and necessary for our results.

While surveying Icelanders in person we made sure to not be pushy while requesting that passersby answer our survey. We made sure to tell the respondents about the topic of the survey prior to taking it in case they do not want to share their opinions on lupine. In addition, we checked with the managers of the stores we surveyed outside of to make sure we were allowed to conduct our survey on the premises.

Different populations we are aware of that may be particularly vulnerable are: farmers due to their economic standings, migrants due to being a minority group in the country, laborers working on farms that may be migrants, along with stateless people who may be a part of the refugees that Iceland intakes every year (The Human Rights Protection of Vulnerable Groups, n.d.). We made sure our surveying does not negatively impact these vulnerable groups.

Summary of Deliverables

Our group designed a decision guide based on our background research and data from our various interviews and surveys. The purpose of the guide is to help Icelanders decide the best method of improving their land. There are three categories: reforestation of land, soil restoration and removal of lupine. Those using the decision guide follow several questions until they reach a final result based on their specific circumstances. The final result depends on the pathways they choose, and they can see all possible results if another result might fit them better.

Several supplementals were developed to support the decision guide. We created a pros and cons of lupine infographic to help the reader make an informed decision if they want to know more about lupine. Once people have made a decision on what plants they want on their land, they can use The Flora Information Table.

This table gives key facts about each plant and the environment they would best survive in. We also made a "Choose Your Own Adventure" style online form. This is an online form Icelanders can fill out that has the same pathways as the choose your own adventure guide, but with more detailed final results. While the decision guide is easier to publish as an infographic in a newspaper, this link would be best used on a website. We hope to publish our deliverables in the Icelandic Farmer's Newspaper so they can reach the farmers they are intended for.



Spruce tree at the Grasagarður Botanical Garden in Reykjavik, taken 9/24/2022

RESULTS AND FINDINGS

In-Person Survey Results

In total we received 48 survey results from surveying on 4 different days. See public survey results in Appendix D. From these results, 44 out of 48 respondents are from Iceland. Data from people outside of Iceland is not crucial to our research as these issues do not affect them and they are less familiar with these issues, so results of non-Icelanders are filtered out of our findings. Note that for all images not labeled as otherwise, data is from the 44 Icelandic responses across all age ranges. For the most part the age of respondents varied greatly, giving a good picture of a broad range of Icelanders opinions across generational gaps. Unfortunately there were significantly fewer respondents older than 45, a limitation discussed further in our limitations section. Of the 44 Icelanders surveyed, 34 said they were familiar with the plant lupine.

When asked to describe the Icelandic landscape in a few words, many gave a simple response like "beautiful" or "amazing" (Figure 4.1). This is likely due to the language barrier and respondents being in a hurry to finish the survey. However, these responses almost all show a deep pride and love for their country. While some want to bring in lupine to make Iceland beautiful and purple, Icelanders already believe that their country is beautiful. While later survey results show that Icelanders support more forests, this shows Icelanders do not need to change their country to be proud of it.

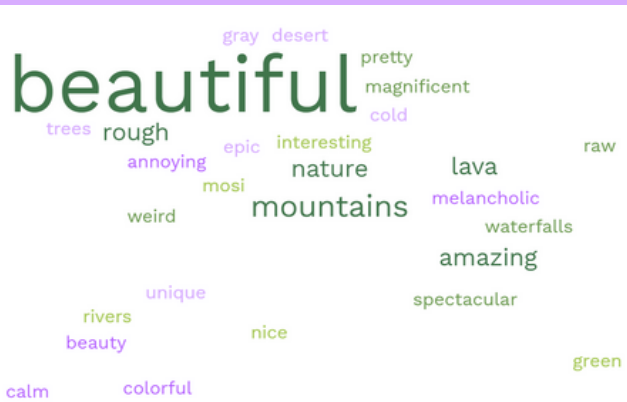


Figure 4.1: Results of survey question: "Describe the Icelandic landscape in a few words". Size of words corresponds to number of responses.

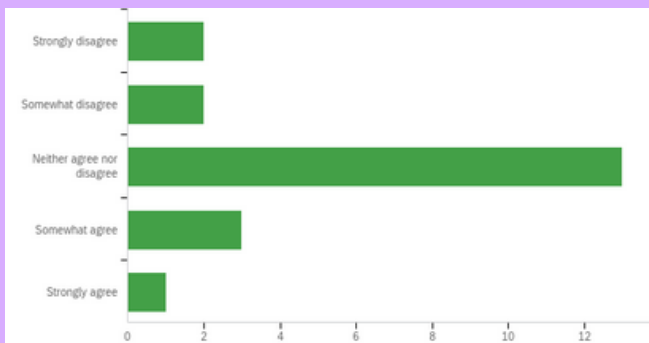


Figure 4.2: Results of survey question: "I have strong opinions about lupine " for ages under 26

Our first multiple choice survey question was "I have strong opinions about lupine". Many respondents who had no opinion on lupine whatsoever selected neither agree or disagree. Therefore, results of either agree or disagree should be viewed the same as disagree or strongly disagree. Only 19% of Icelanders under 26 had strong opinions on lupine (Figure 4.2). However, 46% of Icelanders older than 25 had strong opinions (Figure 4.3). These results show that lupine is a fairly divisive among middle aged and older generations.

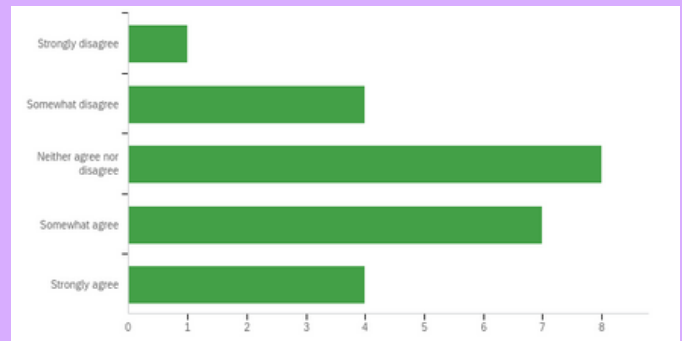


Figure 4.3: Results of survey question: "I have strong opinions about lupine " for ages older than 25

One of our most important survey questions was if Icelanders believe lupine is beneficial to the environment. Results show that Icelanders are fairly evenly split on the topic (Figure 4.4). This shows that lupine is in fact a divisive issue, with a very broad range of opinions and no general public consensus.

The results in Figure 4.4 vary widely based on demographics. 50% of respondents under 25 were neutral on lupine's environmental impact, while only 25% of respondents over 25 had a neutral opinion. This shows that older groups have significantly stronger opinions, confirming the analysis from Figure 4.2 and Figure 4.3.

While Icelanders were evenly split on lupine's environmental impact, most respondents like how it looks and think it makes Iceland more beautiful. Only 18% disagreed with lupine visually improving the Icelandic landscape (Figure 4.5). Those who replied that they disliked lupine were significantly more likely to think lupine has a negative impact on the environment. Understanding if the appearance of lupine is correlated to this is more complicated and requires further research for a complete answer. However, Figure 4.1 shows that Icelanders think Iceland is beautiful, which is evidence in favor of Icelanders not wanting lupine solely to make Iceland look better.

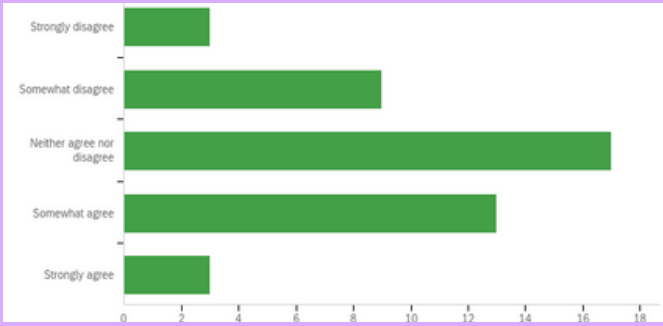


Figure 4.4: Results of survey question: "Lupine has a positive impact on the Icelandic environment"

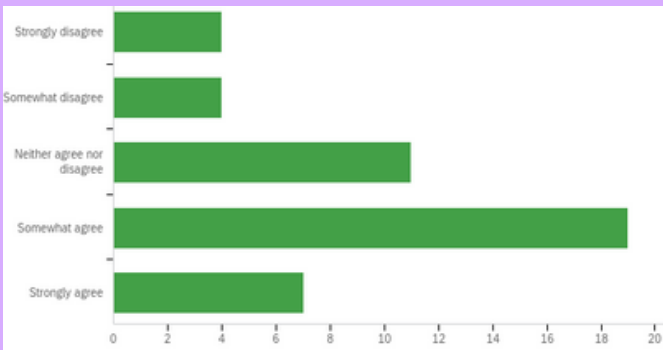


Figure 4.5: Results of survey question: "Lupine visually improves the Icelandic landscape"

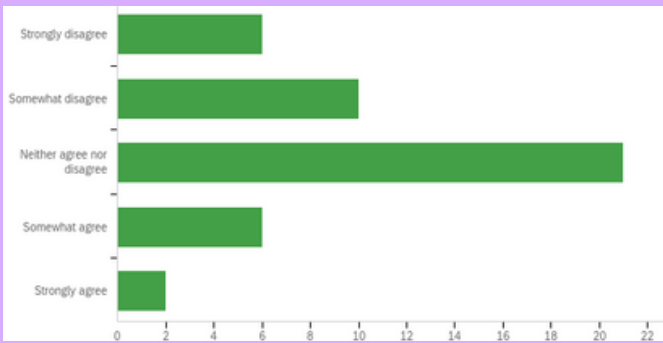


Figure 4.6: Results of survey question: "Alien species like lupine do not belong in Iceland"

Our next question asks how many respondents agree with "Alien species like lupine do not belong in Iceland". This question is important not only because lupine is alien, but because almost all trees used for reforestation in Iceland are alien to Iceland. Only 18% of respondents said that alien species do not belong in Iceland (Figure 4.6). Many lupine supporters claim that people are opposed to lupine because it is alien, but these results help show that few are opposed to lupine simply because it is alien. This helps us come to the initial conclusion that alien species including trees and grasses are viable candidates for restoration in the eyes of the Icelandic public as long as they do not become invasive.

The last question was "lupine is an invasive species". There is a fairly clear agreement that lupine is somewhat invasive (Figure 4.7). So while there is significant disagreement on whether or not lupine improves the environment, there is a general consensus among the public that lupine is invasive. This shows that the public disagrees with the assessment of many pro-lupine advocates that lupine is not invasive. If experts hope to change public opinion on the use of lupine, they need to first demonstrate to the public that it is not as invasive as many believe, or at least that this invasiveness can be controlled. If lupine is to be used as a restoration tool, its aggressive nature must be controlled.

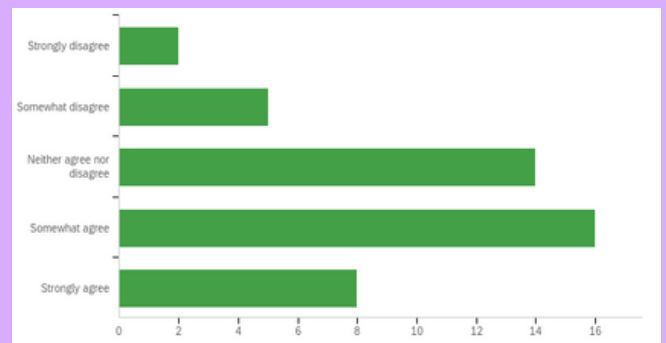


Figure 4.7: Results of survey question: "Lupine is an invasive species"

Online Survey Results

In addition to the survey conducted in person, an identical survey was posted online on the subreddit, r/iceland. Results for the online survey can be found in Appendix E. 46 people responded to this online survey, with results dramatically different than that of the in person survey. Key differences include demographic differences, differences in strength of opinion, and the amount that respondents were willing to write in the two short response questions.

Of the 46 respondents, 43 lived in Iceland. A surprising 70% of the respondents were ages 25-45, with only 9% above the age of 45 (Figure 4.8). This difference alone would be enough to separate the survey results between the online and the in person survey, but an additional key difference also suggested evaluating data separately.

Every single respondent online said they were familiar with lupine as opposed to 75% of in person respondents. This suggests either severe sampling bias towards those who know about lupine, or people only taking the survey after researching lupine to become familiar with it. Therefore, these results must be evaluated completely differently from the in-person survey results.

In addition to the demographic and familiarity with lupine differences between the online and in-person differences, online respondents wrote significantly more for short response questions. This is shown clearly when respondents were asked to describe the Icelandic landscape in a few words (Figure 4.9). While in-person respondents usually just answered with one word, online respondents responded typically with two to five words. While many descriptions were positive, many also recognized how barren Iceland is.

Online respondents had significantly stronger opinions on lupine than in-person respondents (Figure 4.10). 63% of Icelanders online had strong or somewhat-strong opinions on lupine, as opposed to only 33% of in-person respondents. This puts the rest of our online survey results in a context of Icelanders with very strong opinions.

Results for the question "lupine has a positive impact on the Icelandic environment" were very divisive (Figure 4.11). As opposed to 37% in the in-person survey, only 9% of respondents were neutral. This shows that at least for Icelanders younger than 45 online, lupine is an incredibly divisive issue. Interestingly, this group also was significantly more in support of lupine than in-person respondents. This is weak evidence that Icelanders who have stronger opinions on lupine tend to be more in support of lupine.

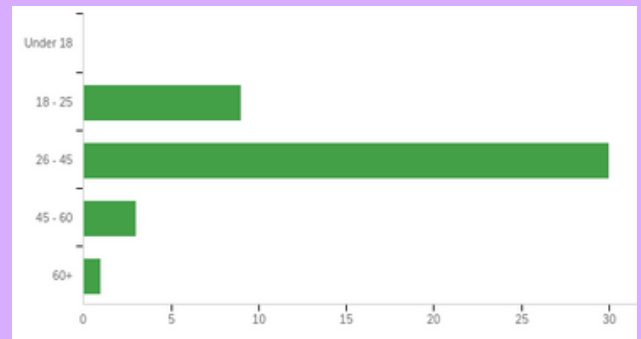


Figure 4.8: Age demographics of online survey



Figure 4.9: Results of online survey question: "Describe the Icelandic landscape in a few words". Size of words corresponds to number of responses.

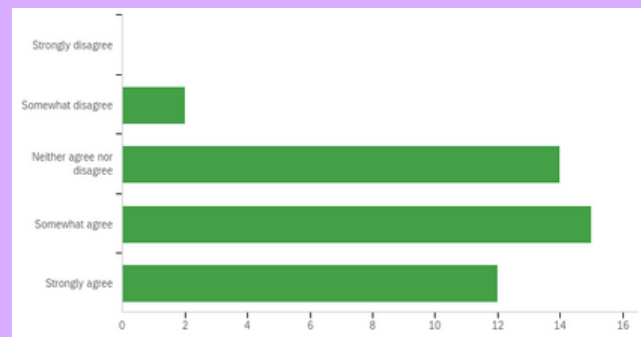


Figure 4.10: Results of online survey question: "I have strong opinions about lupine"

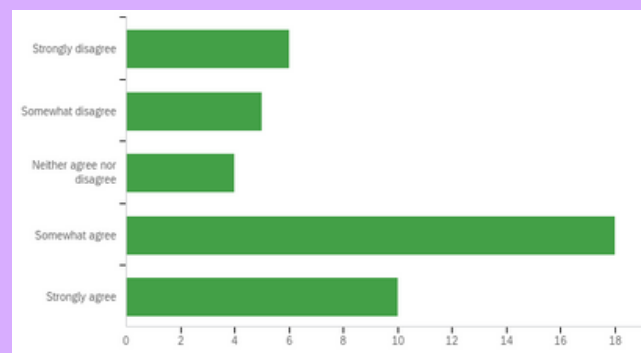


Figure 4.11: Results of survey online question: "Lupine has a positive impact on the Icelandic environment"

The final two multiple choice questions match what was seen in the in-person survey fairly closely. Significantly more people are ok with alien species than not ok with them (Figure 4.13), but many people believe lupine is not just alien but also invasive. This confirms survey findings from the in-person survey that alien species can be used in Iceland for environmental conservation without significant backlash. Invasive species like lupine, however, must be controlled effectively and used minimally to be considered an effective restoration tool.

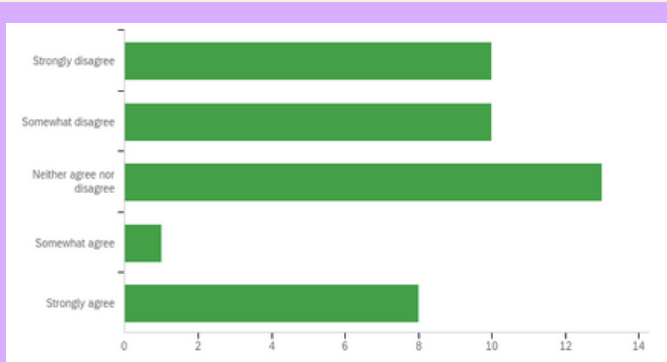


Figure 4.13: Results of online survey question: "Alien species like lupine do not belong in Iceland"

Famer's Newspaper Survey Results

We sent out our survey in the Icelandic Farmer's Newspaper, Bændablaðið, through our contacts at the Icelandic Farmer's Association. The newspaper was sent out on October 6th, leaving us very little time to analyze the data and draw conclusions from it. Overall, we got 51 results from farmers around Iceland. Results can be seen in Appendix F.

These survey respondents were strongly in favor of lupine. When asked if they have more lupine on their land than they would like, 69% said they strongly disagree that they have too much lupine. These results mostly make sense, given that we saw many of those who filled out our survey use their land for reforestation or recreation. For these purposes, lupine works great.

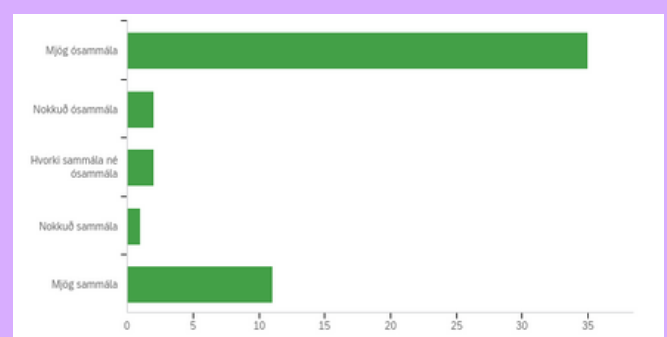


Figure 4.14: Results of farmers newspaper survey question: "I have more lupine on my land than I would like"

Key Survey Findings Conclusion

Several key findings can be found from these surveys by examining the data without bias.

- The vast majority of Icelanders know of lupine, and a significant portion of those who know of it have strong opinions on it
- Icelanders with strong opinions on lupine fall into 2 distinct categories, either pro-lupine or anti-lupine (Figures 4.4 and 4.11)
- Older generations of Icelanders generally have stronger opinions on lupine (Figures 4.2 and 4.3)
- While proud of their beautiful country, most Icelanders also see how barren it is (Figures 4.1 and 4.9)
- Most Icelanders are ok with alien species (Figures 4.6 and 4.13)
- While Icelanders are ok with alien species, they see lupine as invasive (Figures 4.7 and 4.14)
- Despite agreeing that lupine is invasive, Icelanders still see the positive impact it can have on the environment (Figures 4.4 and 4.11)
- Farmers and landowners are for the most part in support of lupine usage despite it's recorded invasivity (Figure 4.14)
- Farmers do not think that lupine is bad for native Icelandic flora and fauna (See supplemental materials)

These takeaways have several implications for our deliverables. We are comfortable suggesting many alien species for reforestation and revegetation, as Icelanders are generally ok with non-invasive non-native species. However, our suggestions must take into strong consideration the dislike of invasive lupine. As many Icelanders agree on, lupine can have a positive impact on the environment, however it must be used responsibly without damaging native ecosystems. Therefore, we suggest lupine only for reforestation.

We would like to stress the importance of our results from our Farmer's Newspaper Survey. While we did not have time to analyze many of the results, especially because all of the results need to be translated, the data is extremely important. We hope that it can be of use for both the Icelandic Farmer's Association and future IQPs in Iceland on lupine. To see the full results of our survey please see our supplemental booklet.

We have also seen that Icelanders have a deep pride for their country. Icelanders believe that their land is beautiful and rugged and unique, but they also see how barren and deserted it is. This makes our work all the more meaningful because we know we can contribute to making this already beautiful country even more special.

State Forestry Survey Results

Our other source of data was from a survey conducted in 2004 by the Mógilsá State Forestry. The organization sent a survey to the Icelandic public regarding reforestation and soil erosion. In total 814 Icelanders responded, providing very significant data. Note that the survey was initially in Icelandic, and formatting errors in the graphs are due to errors in pdf translation software.

We analysed their data describing the public's opinion on soil erosion and forests. According to the survey, 95.9% of people answered "important" to the question "How important or unimportant do you think it is to stop and prevent soil erosion?" (Figure 4.15).

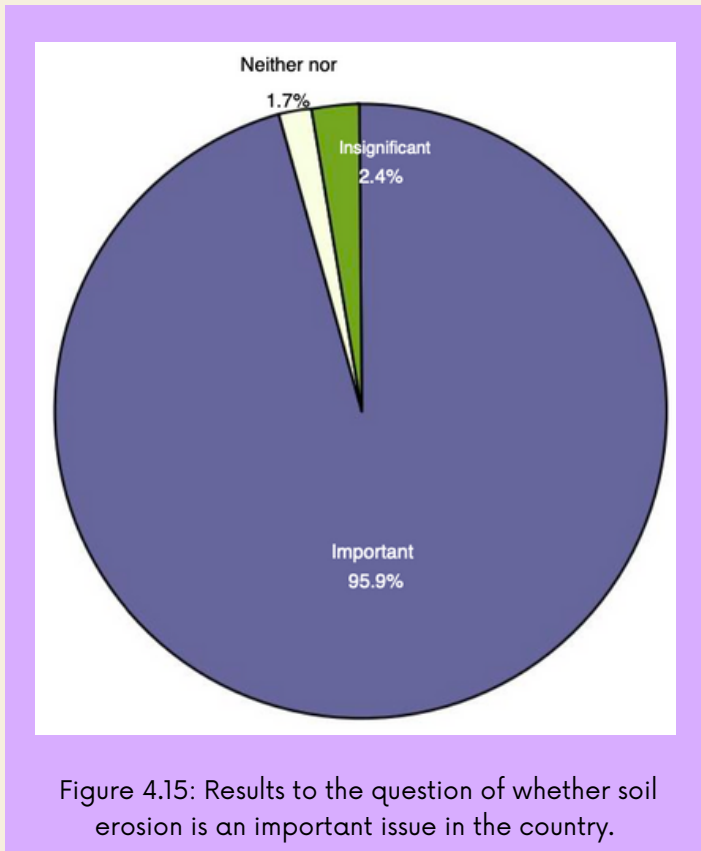


Figure 4.15: Results to the question of whether soil erosion is an important issue in the country.

The data showed that ages 35-44 had the highest percentage of answering important while ages 18-24 had the lowest percentage. This confirms our survey results, that the older generation believes soil erosion is a major issue. This data is important because it shows that nearly two decades ago, people acknowledged soil erosion was a problem. As a result, the public is open to hearing different suggestions on how to improve the issue. This also clearly indicates to us that we need a special section of our decision guide on soil erosion.

Another major question was "Would you like to increase or decrease the forests in this country or do you think the forests are suitable?" The pie chart (Figure 4.16) illustrates that 84.6% of the public desires to increase forests while 0.9% think forests should be reduced. This shows an obvious desire from the Icelandic public to reforest.

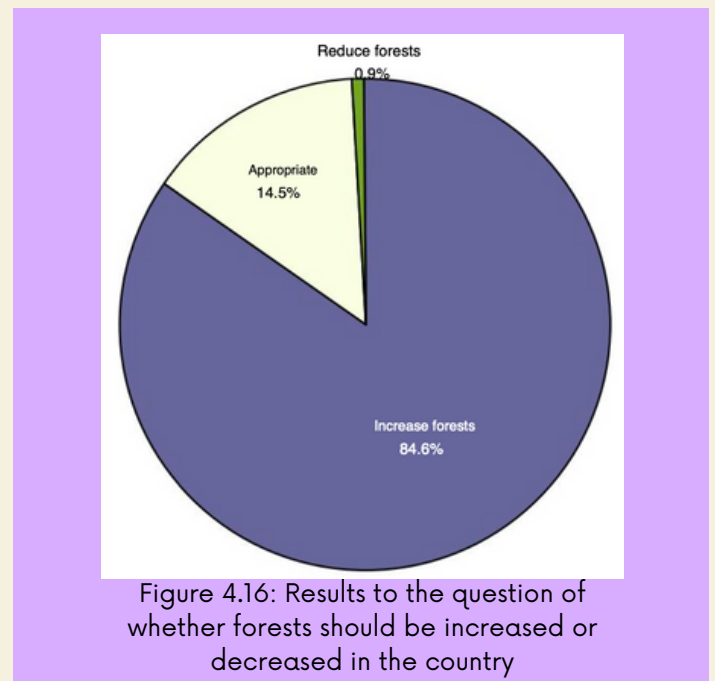


Figure 4.16: Results to the question of whether forests should be increased or decreased in the country

Interestingly, ages 18-24 had the lowest percentage of people wanting more forests, while ages 45-54 had the highest percentage. This data is useful because it shows most of the country wants Iceland's landscape to change. This demonstrates the public is willing to take an initiative and gives us a better basis for our recommendations and decision guide.

Another question that indicates the public's opinion on environmental issues is "How important or unimportant do you think increasing biodiversity is?" (Figure 4.17). 74.3% answered that increasing biodiversity is important, while only 14.1% answered that it was not important. This shows that while the public wants to reduce soil erosion and increase forests, the majority of the public does not want to sacrifice biodiversity to meet these goals. This suggests that while a little bit of controlled lupine might be used, out of control invasive lupine would be against the will of the Icelandic public.

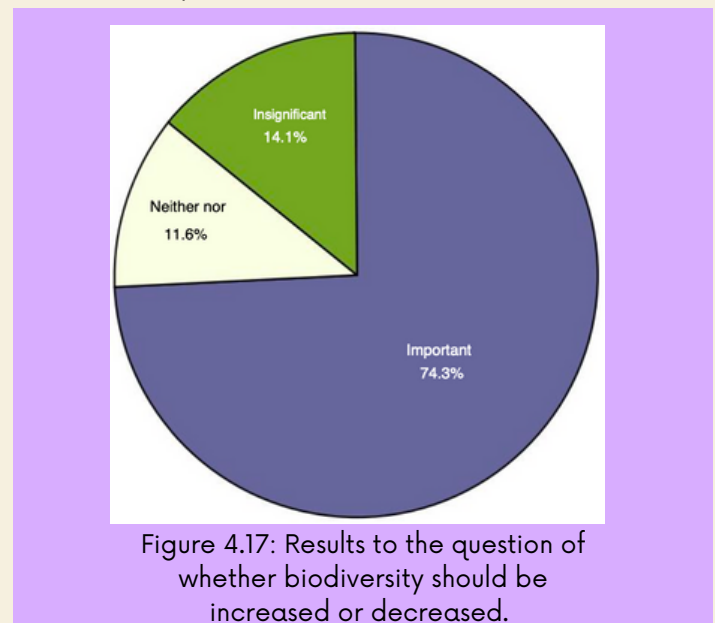


Figure 4.17: Results to the question of whether biodiversity should be increased or decreased.

We can see from this result that Icelanders want the landscape to contain a diverse set of flora. Ergo, our suggestions should include several different trees that are suitable to live with and without the lupine.

The question "What is your favorite type of tree" gave very important results crucial to our decision guide (Figure 4.18). The most popular tree was birch followed by spruce. Birch we expected, as it is the most prevalent native tree, but we found the Icelandic love of non-native spruce to be very surprising.

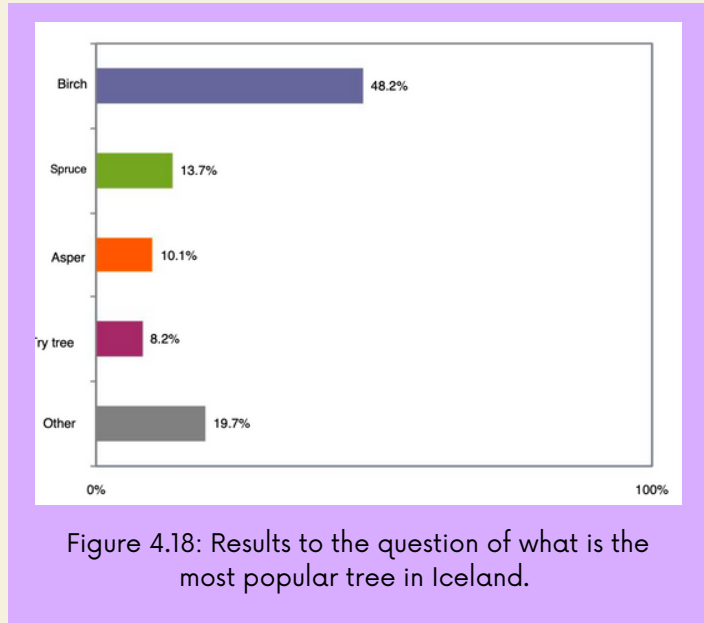


Figure 4.18: Results to the question of what is the most popular tree in Iceland.

Note that the "Asper" result in the above graph should be Aspen, and the "Try tree" result was translated from the Icelandic word Reynitré, which should be Rowan. We made sure to include Birch, Spruce, Aspen, and Rowan as main results from our decision guide.

The last question important to our research was "Which of the following factors do you think forests in Iceland have the most positive effect on?" (Figure 4.19). Approximately 50.6% of the population believed forests had a positive impact on land reclamation and soil protection. This information demonstrated that people mainly want forests to restore Iceland's ecosystems and stabilize the soil, which is key information to our research.

Several key results can be drawn from the state survey that are important to our project. These include:

- Soil erosion and reforestation are more important to older Icelanders (Figure 4.15 and 4.16)
- Icelanders prefer Birch and Spruce trees (Figure 4.18)
- Icelanders want more trees (Figure 4.16)
- Icelanders don't want a single tree species or plant species solving their ecological problems (Figure 4.17)
- Icelanders realize how trees help prevent soil erosion and land degradation (Figure 4.19)

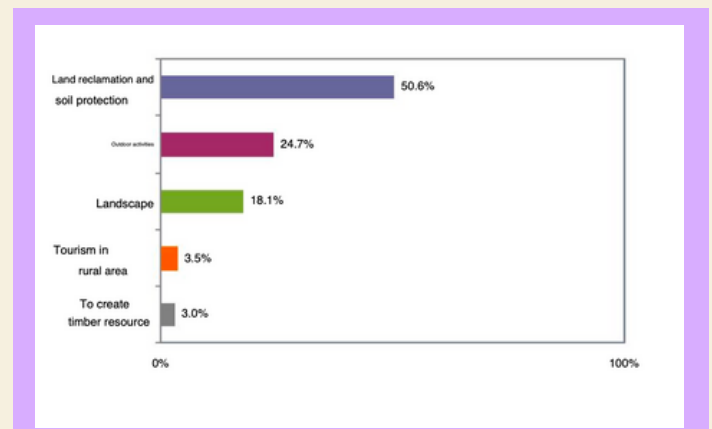


Figure 4.19: Results to the question of what factors forests have the most positive impact on in Iceland.

In-Person and Online Survey Limitations

The language barrier is probably the biggest limitation of our survey. While all Icelanders who said they were unfamiliar with lupine put that they did not have strong opinions on lupine, half of them said that lupine has a positive or negative impact on the environment. This suggests that many of the Icelanders who responded that they were unfamiliar with lupine simply did so due to the language barrier. An additional language barrier may be in the terms "alien" and "invasive" species. The definitions of these are very close and while surveying we were often asked to clarify the terms. An Icelandic who is not extremely fluent in English might easily confuse these terms.

An additional limitation of our survey is our survey demographics. While we had many results 45 and under, we only got 12 results over 45. While surveying, we found that younger people were significantly more likely to take the survey than older people who were more likely to refuse to take the survey. Specifically surveying in an area older people visit more often might be a way to fix this, but could add additional biases into our data.

State Survey Limitations

In general the state survey results are much more robust and reliable than our survey results, as they have a significantly larger data set. However, one of the limitations was that the state forestry survey was taken about two decades ago. This means certain opinions on reforestation or soil conservation could have changed. For example, the non-native tree that Icelanders favor the most may no longer be spruce but rather rowan or aspen. Getting a more recent set of survey results would help us ensure we are making decisions based on modern Iceland, rather than Iceland 20 years ago.

Interview Results

Our team conducted three interviews with experts in the fields relevant to the project. Our goal was to get perspectives on lupine and soil conservation from individuals and organizations who have implemented these methods and managed the land themselves. This is in contrast to the public, whose opinions largely come from the news and media, rather than personal experiences. The important groups we chose are the Icelandic Forestry Service (Skógræktin), the Soil Conservation Service of Iceland (SCSI), and the Icelandic Farmers Association. The forestry service is the leading entity in reforesting Iceland. They are funded by the government to grow new forests in Iceland, whether for public recreation or plant research. From them we hoped to learn how lupine has affected reforestation efforts, as well as its use in sustaining existing forests. The main focus of the SCSI is conserving the ecosystem and preventing soil erosion through revegetation. They are also government funded. They were able to provide information on the effect of lupine on the land, and how it changes the ability of native plants to grow. We were also curious about the SCSI's goals in educating Icelanders on good land use practices to conserve soil. Lastly, the farmers association represents the farmers of Iceland. They are the voice of the farmers in the political scene, while providing new insight back to the farmers. The goal of the association is to ensure good land use practices from the farmers, while also focusing on their needs. Many farmers in Iceland operate on very large plots of land, so we were hoping to gain an understanding about how they maintain their land, and if they employ any methods for environmental conservation. We were also hoping to learn about lupine's effect on farming from the farmers association. After reaching out to these groups, we were able to organize three useful interviews to gather relevant information.

Aðalsteinn Sigurgeirsson Interview

Our first interview was conducted with Aðalsteinn Sigurgeirsson, the deputy director from the Icelandic Forestry Service. He spoke of his organization's ongoing efforts to restore Iceland to how it was before it was settled. He provided useful information about reforestation, and lupine's effect on the process. His opinion of lupine was overwhelmingly positive, stating that trees simply have an easier time growing when lupine is present to provide nitrogen to the soil. If lupine was not available, their reforestation efforts would be much slower and more involved. Having lupine present in the area allows for saplings to survive on their own, without external assistance. When asked about the invasivity of lupine, Aðalsteinn responded that it is easy to control once sheep are released into the area to graze. The sheep will quickly eat and trample almost any low-lying vegetation in the area, halting the spread of lupine. However, sheep grazing also hinders reforestation efforts, as they will eat newly planted saplings. He also asserted that once trees planted in lupine fields reach a certain height, the canopy blocks the sun from reaching the lupine and the lupine naturally dies. Interview results are shown in Figure 4.20.



Figure 4.20: Mind map illustrating information gained from the interview with Aðalsteinn Sigurgeirsson

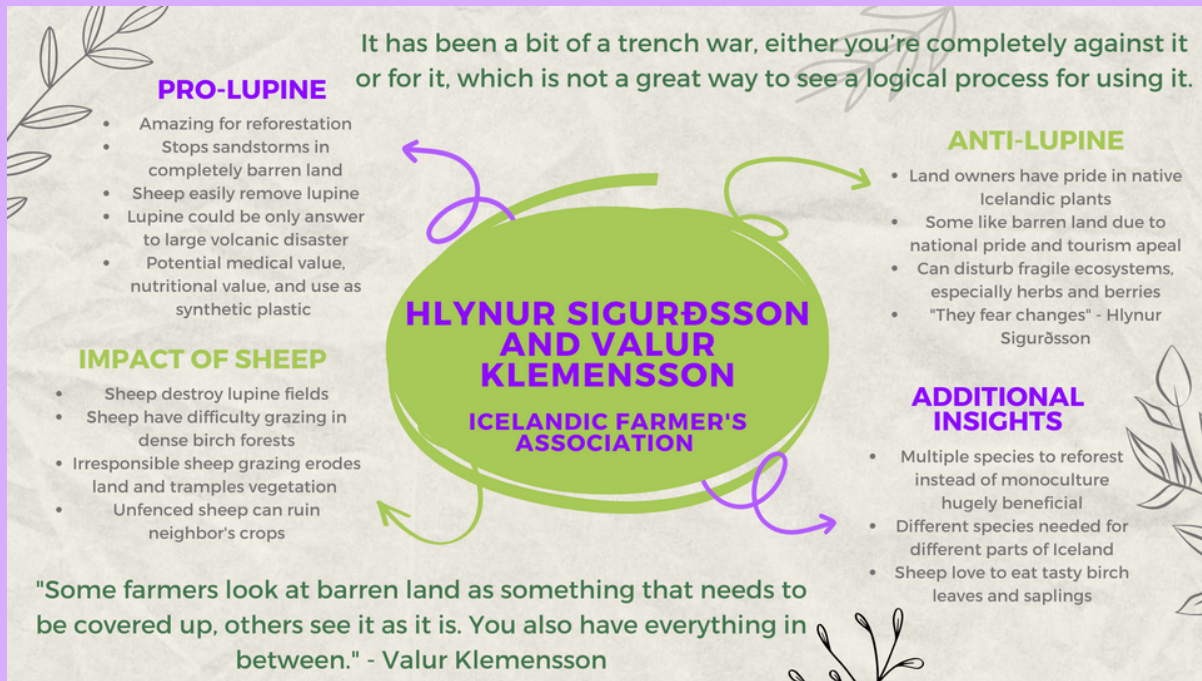


Figure 4.21: Mind map illustrating information gained from the interview with the Icelandic Farmers Association

Hlynur Gauti Sigurðsson and Valur Klemensson Interview

The second interview we conducted was with representatives from the Icelandic Farmers Association. We met with Hlynur Gauti Sigurðsson, the association's forestry specialist, and Valur Klemensson, the environmental specialist. From them we gathered useful information on how lupine impacts the land and landowners. We also heard how lupine affects animals like insects and birds. Both Hlynur and Valur shared the same positive outlook on lupine. However, they recognize that there are some areas with vulnerable native species, like berry bushes, where introducing lupine will cause more harm than good. They also told us just how significant the impact of sheep grazing is on starting the reforestation or revegetation process. Sheep in Iceland are generally allowed to roam wherever they please, and will eat or trample most low lying plants and young trees. This makes some uncontrolled areas difficult to plant in, but the question of who's responsibility it is to fence in the sheep is a widely contested issue. This seems to be an ongoing issue, as Iceland has always relied heavily on sheep, and they play a large part in the culture. In regards to soil erosion, it seems as if farm owners are taking some action. Hlynur and Valur told us how some farmers dump extra hay down the sides of mountains, creating a barrier between the soil and the elements, preventing erosion. Interview results are shown in Figure 4.21.



Photo of the team with Hlynur Gauti Sigurðsson and Valur Klemensson of the farmers association. From left to right: William Michels, Tiffany Foote, Nishan Grandhi, Gabriel Brown, Valur Klemensson, Hlynur Sigurðsson, taken 9/14/2022

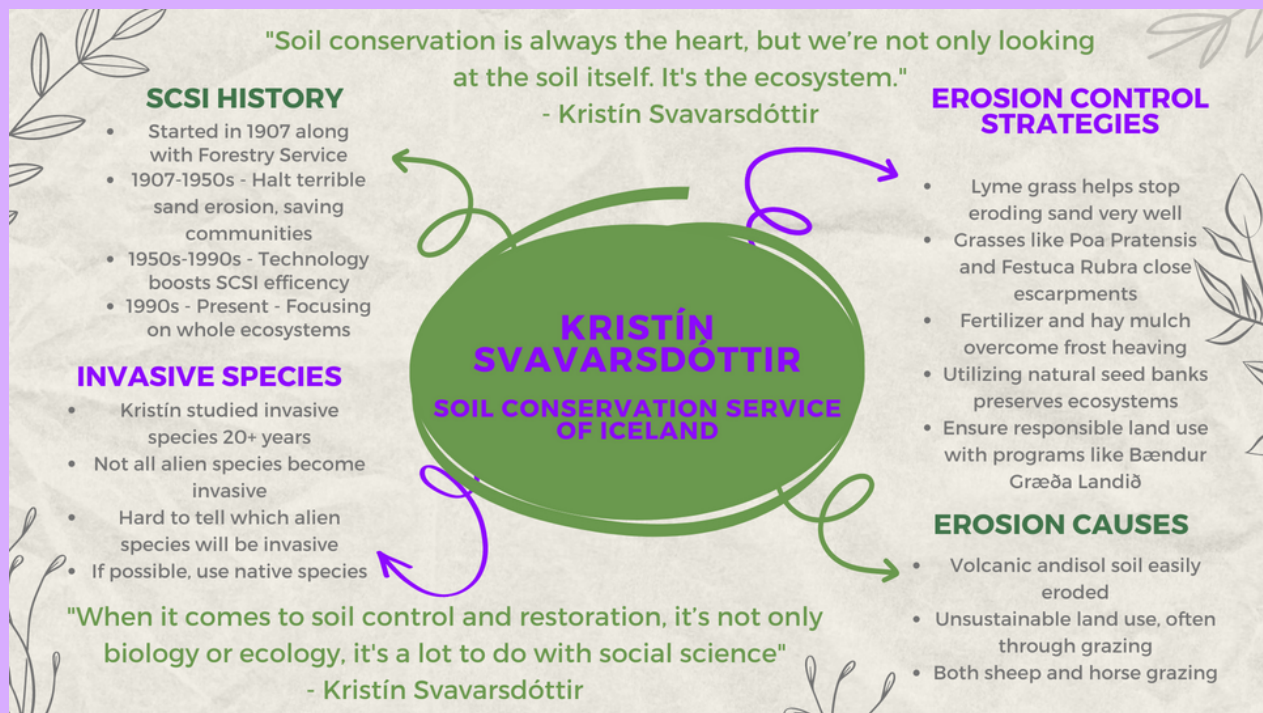


Figure 4.23: Mind map illustrating information gained from the interview with Kristín Svavarsdóttir

Kristín Svavarsdóttir Interview

For our third interview, we met with Kristín Svavarsdóttir, a plant ecologist from the Soil Conservation Service of Iceland. So far, we had only spoken to experts on trees and reforestation, so Kristín was able to give a new perspective from the lens of a scientist working with soil conservation. One main focus of the SCSi is to vegetate areas where there is only loose andisol soils. Kristín stated that lupine simply has no place in these efforts, as native plants such as lyme grass can temporarily stabilize the soil for future plants just fine. She explained how many barren areas have a threshold in new vegetation, where plants can live and thrive off of each other without the use of additional fertilizer. This threshold can be easily passed without the use of lupine. In many cases, the presence of lupine only hurts these soil conservation efforts, as it can take over large areas very easily, leaving no room for native flora. Plus, removing lupine can be quite troublesome due to its invasive nature. The SCSi also acknowledges how important it is to educate people on environmental conservation. They have multiple programs in place to teach and promote these techniques, like GróLind and "Bændur græða landinn". GróLind is a resource for information on the state of vegetation and soil in the country, where "Bændur græða landinn" is a program that subsidizes farmers for employing good environmental practices on their land. Results for this interview are in Figure 4.23.

Interview Results Conclusion

Speaking to experts in these fields proved very useful for our research. Lupine is an incredibly useful tool in forestry, allowing for trees to grow where they never could previously. Entire forests have been cultivated thanks to the nitrogen fixing ability of lupine. However, it seems that while lupine allows for reforestation to thrive, it only gets in the way of soil conservation efforts and hurts the ecosystem as a whole. When growing plants other than nutrient-needy trees, native flora can survive and revegetate an area just fine. The existence of lupine in some areas makes revegetating with native plants almost impossible until the lupine is removed, which can be very difficult as well. While there are many ongoing efforts to improve Iceland's ecosystem, the interaction between lupine and native species is difficult to predict and often harmful. Our findings show a divide specifically between the forestry service and the soil conservation service. Skógræktin has worked for years using lupine to plant small forests across the country with hopes that they will grow and return Iceland to how it was before settlement. However, the SCSi is very much against lupine usage as lupine's invasive nature means it easily spreads to undesired areas disturbing natural ecosystems. Lupine may be the answer to some of Iceland's environmental issues, but certainly not all. These findings were the most important data by far in creating our decision guide.

Observational Results

Our team also gathered useful data by going out into the field to see lupine and its effect on the environment. This gave us a better understanding of what we were told by experts as we got to see some of what they spoke about firsthand. We first went to Mount Ulfarsfell, just outside downtown Reykjavik. The rolling hills there are covered in lupine fields where no other plants are able to grow, only interrupted by gravel hiking trails. Ulfarsfell showcases lupine's very invasive ability to completely take over a previously barren landscape. However, it ends up leaving no room for other plant species. The only diversity is the occasional flower peeking through the surrounding lupine.

We also conducted a followup interview with Aðalsteinn Sigurgeirsson of the forestry service, who took us to see some areas where lupine was used for reforestation efforts. He first brought us to the community forests outside of Reykjavik, where lupine was first utilized for reforestation. The forests there are grand and sprawling, with almost no lupine in sight despite how much lupine used to be there. Aðalsteinn said that once a tree canopy forms, the lupine does not get enough sunlight and dies off. This suggests that lupine may be a good temporary tool, as it will cease to exist after it has done its job in creating a lush forest. However, in the long time it takes for trees to grow, the lupine may still spread to other unwanted areas. Afterwards, Aðalsteinn took us to visit his experimental tree growing area next to the forest he grew himself, named Bugar (Figure 4.25). There we saw firsthand how lupine affects newly planted trees. He has planted birch, larch, pine, spruce, oak, and more there. One area stood out in particular, where Aðalsteinn planted many birch saplings in the same year, half with lupine and half without. The trees with lupine now stand about two meters tall, whereas the trees without lupine are only about a foot or two. This is significant evidence that there are situations where lupine greatly increases tree growth. Moving across the street to Bugar forest showcased the power of lupine in reforestation. Where Aðalsteinn had planted saplings about 40 years ago now stood a tall and lush forest. After seeing Aðalsteinn's beautiful summer house, we walked through the woods and opened our eyes to the fact that Iceland is capable of sustaining large forests. This gave us fantastic first-hand experience seeing the impact lupine can have on the environment. Further images can be seen in Appendix H.

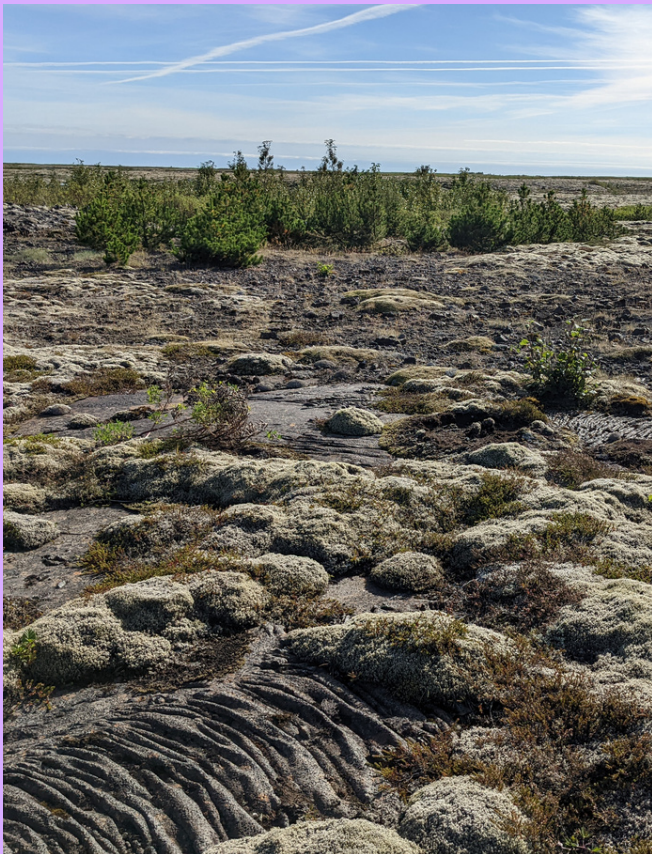


Figure 4.24: Image of the sandy ancient lava fields in the south of the Reykjanes Peninsula, with trees growing in the background. These are similar conditions to where Aðalsteinn planted saplings to grow Bugar forest, taken 9/7/2022



Figure 4.25: Image from the inside of Bugar forest where Aðalsteinn rerouted a stream to form a pond. Standing here gives the feel of being in the vast wilderness, even though the surrounding environment is lava fields, taken 9/7/2022

RECOMMENDATIONS

Decision Guide

Our recommendations are represented by a decision guide. We used the software Canva to create an infographic of our decision guide. Additionally, we utilized the program Typeform to produce a “Choose Your Own Adventure” supplemental decision guide that can be completed online with more comprehensive results. This format enables the reader to choose the outcome for their land, rather than being told directly what they should do. A QR code to this can be found in Appendix J.

The guide begins with the overarching question of “What is the goal for your land?” There are three options: reforestation of land, soil restoration and removal of lupine. Based on the needs of the reader, each pathway leads to various suggestions on how to best improve the land. We chose these pathways based both on our survey and interview results. Interviews with experts played a key role in helping us decide what each path should lead to, while survey results helped figure out what Icelanders want and what each path should be.

This guide works well with our additional resources. For more information about different plant species that the guide suggests, the reader can refer to our infographic on restoration plant species. If somebody doesn't know if they want lupine or not, they can refer to our decision balance sheet on lupine. A larger image of the decision guide is in Appendix H.

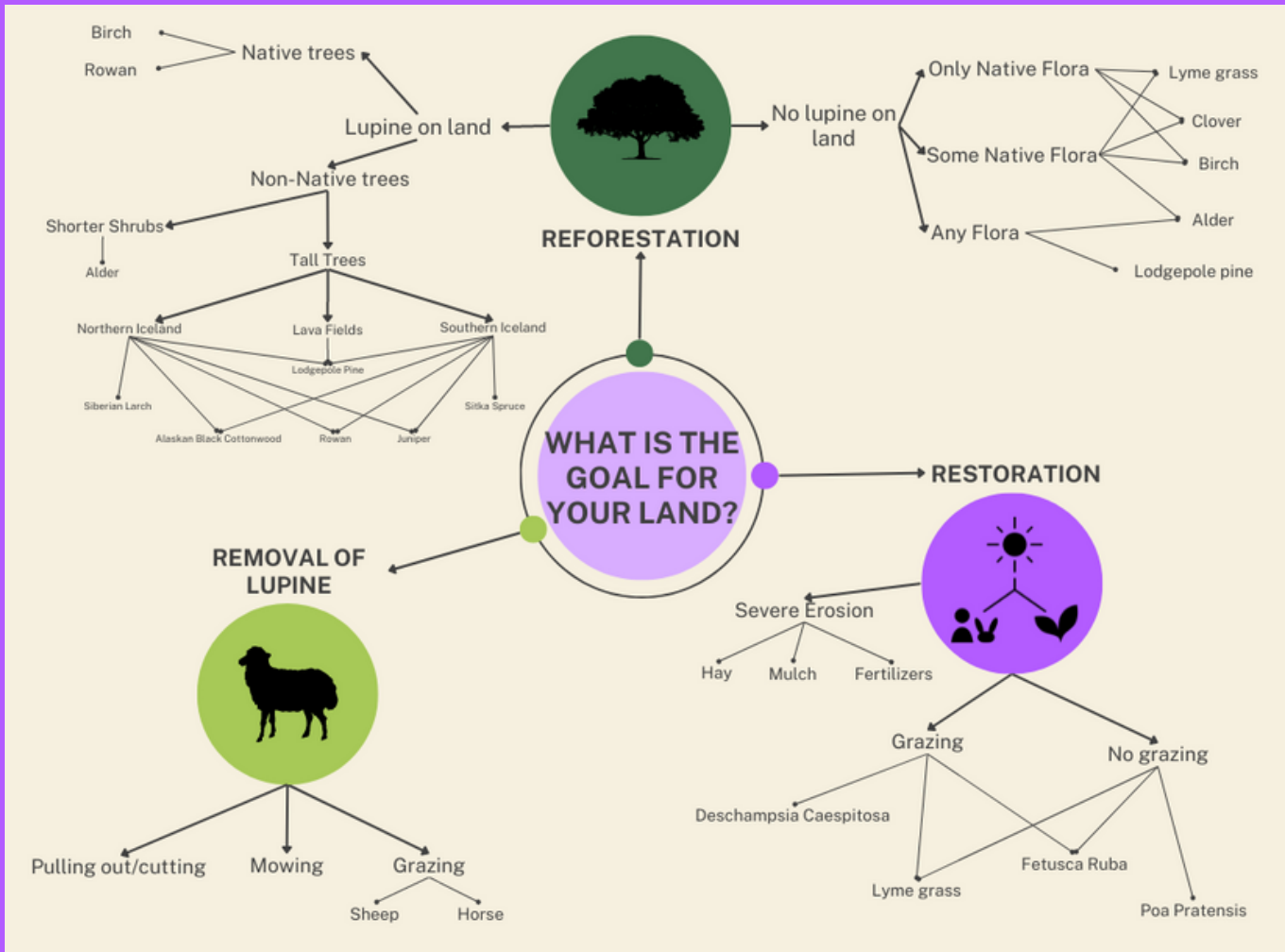


Figure 5.1: Decision guide recommending best land use practices to landowners

Decision Balance Sheet

Along with our decision guide, we chose to make a decision balance sheet for the pros and cons of lupine as an environmental restoration tool. The organization of the advantages and disadvantages of lupine being used should assist whoever uses our decision guide to see if lupine is the best plant to be used on their land. Our decision balance sheet should be used as a starting point for others to take time to evaluate the advantages and disadvantages for their land.

We used the information we learned from the interviews with the Icelandic Forestry Service, Icelandic Farmers' Association, and the Soil Conservation Service of Iceland to determine along with our own background research to determine the basic pros and cons to be used for our decision balance sheet. This is not a comprehensive list of all the pros and cons, some may not be important for specific people while some may be more important to others. Parts of the decision balance sheet may change depending on who is using the sheet with the guide because every person will have different land and different requirements for what their land needs at the time of them using our guide. However, it still gives a good idea of all the different environmental impacts lupine can have that some may not be aware of.

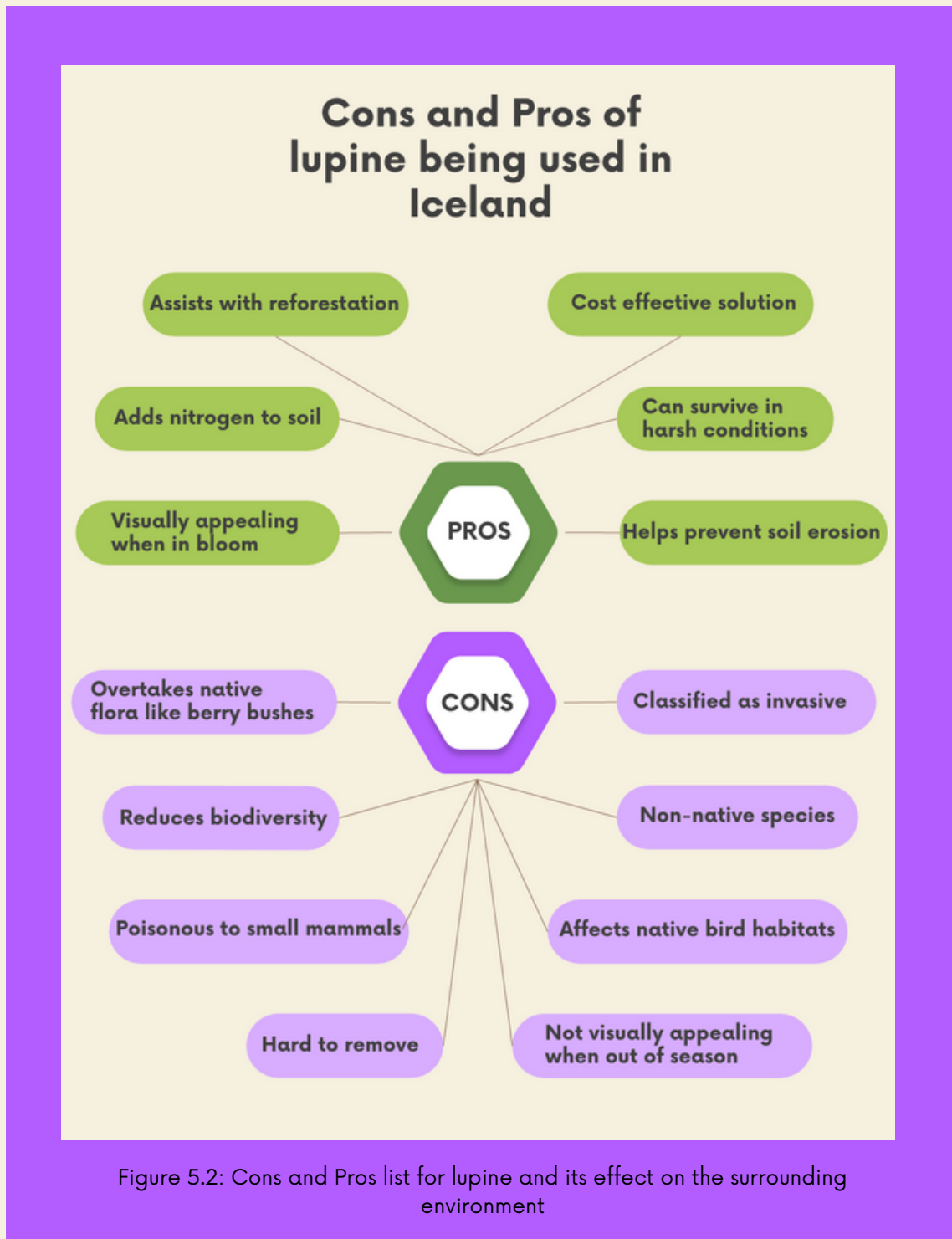


Figure 5.2: Cons and Pros list for lupine and its effect on the surrounding environment

Flora Information Sheet

Other supplemental information includes our flora information sheet. This gives information on the plants we reference in our decision guide. It includes non-native flora and native flora, giving a wide range of information. Each bubble contains a few of the plant's attributes such as the coldest temperature it can survive in or what area of Iceland it would thrive the most. The information on the sheet has been collected from the Icelandic Forestry Service, Icelandic Farmers' Association, and the Soil Conservation of Iceland. We hope the reader will use this tool to learn the basic characteristics of the flora from the decision guide. Further plants not included below can be found in Appendix I.

Betula (Birch)

- Lowest temperature it can survive is -45°C , thrives throughout Iceland
- Birds use it as a shelter
- Animals like sheep will not graze it because they can get stuck
 - Native to Iceland
- Needs nitrogen fixed soil



Leymus arenarius (Lyme Grass)

- Lowest temperature it can survive is -35°C , used in an area where you've got sand encroachment or sand movement
- Pioneer species, can grow in harsh conditions
 - Adds nitrogen to soil
 - Native to Iceland



Larix sibirica (Siberian Larch)

- Lowest temperature it can survive is -45°C , thrives in Northern Iceland or areas with salty ocean spray
- Non native plant, originates from Russia
- Needs nitrogen fixed soil



Alnus incana (Sitka Alder)

- Lowest temperature it can survive is -28°C , can be found in Northern Iceland and Southern Iceland
- Similar to the birch tree
 - Has nitrogen fixing capabilities if it has the right nutrients
- Native to Iceland



Picea sitchensis (Sitka Spruce)

- Lowest temperature it can survive is -30°C , thrives in Southern Iceland
- Imported to Iceland
- Needs nitrogen fixed soil



Trifolium repens (White Clover)

- Lowest temperature it can survive is -40°C , can be found in Northern Iceland
- Only 10% as productive of adding nitrogen to soil as lupine
- Native to Iceland



Pinus contorta (Lodgepole Pine)

- Lowest temperature it can survive is -35°C , can survive in any area
- Can regenerate in harsh locations such as lava fields
- Doesn't need nitrogen fixed soil to survive
- Vulnerable to grazing



Poa pratensis (Kentucky Bluegrass)

- Can survive in any temperature, thrives in Northern Iceland
- Non native to Iceland
- Doesn't need fertilizer to grow well
- Capable of adding nitrogen to soil



CONCLUSION AND ACKNOWLEDGEMENTS

There is no one perfect solution to address the vast soil erosion issues and need for trees in Iceland. While lupine may perform its job of adding nutrients to the soil and stabilizing the sandy Icelandic soil extraordinarily well, it comes at the cost of disrupting the natural ecosystem and endangering vulnerable Icelandic flora if not used responsibly. There are numerous native and non-invasive species that can stabilize the soil just as well as lupine, without the fear of severe damage to local biodiversity. While lupine still proves to be magnitudes better than other species for aiding in reforestation, it should be used extremely cautiously and only for reforestation, not soil erosion prevention, where other less risky species can do just as well.

We have drawn these conclusions through a number of sources including numerous surveys and interviews with experts on multiple sides of the issue including plant ecologists, reforestation experts, and advocates for farmers. Experts, just like the Icelandic population that we surveyed, were highly divided on the issue. While our answer of using lupine only in controlled environments for reforestation and not for soil erosion prevention does not fully appease either of the extreme anti or pro lupine groups, we believe it takes into account the concerns of both sides and would prove a good compromise that can have a beneficial impact on the Icelandic environment. To best communicate our findings, we created a decision guide with several supplemental materials that Icelanders can use to help decide how they can help restore their land based on their goals and their specific environment. We have loved our time in Iceland and the beautiful nature we have seen here, and we hope our project can help preserve Iceland's natural beauty.

For future projects, we think it may be best to split this project into multiple other projects like "Soil Conservation and Sheep Grazing", "Reforestation With and Without Lupine", and "Lupine Being Converted to a Crop". For the possible project about soil conservation and sheep grazing, we found that sheep have some of the largest impact on soil being severely eroded in Iceland. A good group to make a connection with would be the Soil Conservation Service of Iceland. For the project about reforestation with and without lupine, we noticed that lupine has a significant impact on the growth of trees in Iceland and a good contact to have is the Icelandic Forestry Service. For the possible project about lupine being converted to a crop has been developed from us learning about different groups that have begun to develop lupine into medicine and plastics.

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Photo of the team at Ulfarsfell. From left to right: Wil Michels, Gabe Brown, Nishan Grandhi, Tiffany Foote. Photo courtesy of Jacleen Becker.

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