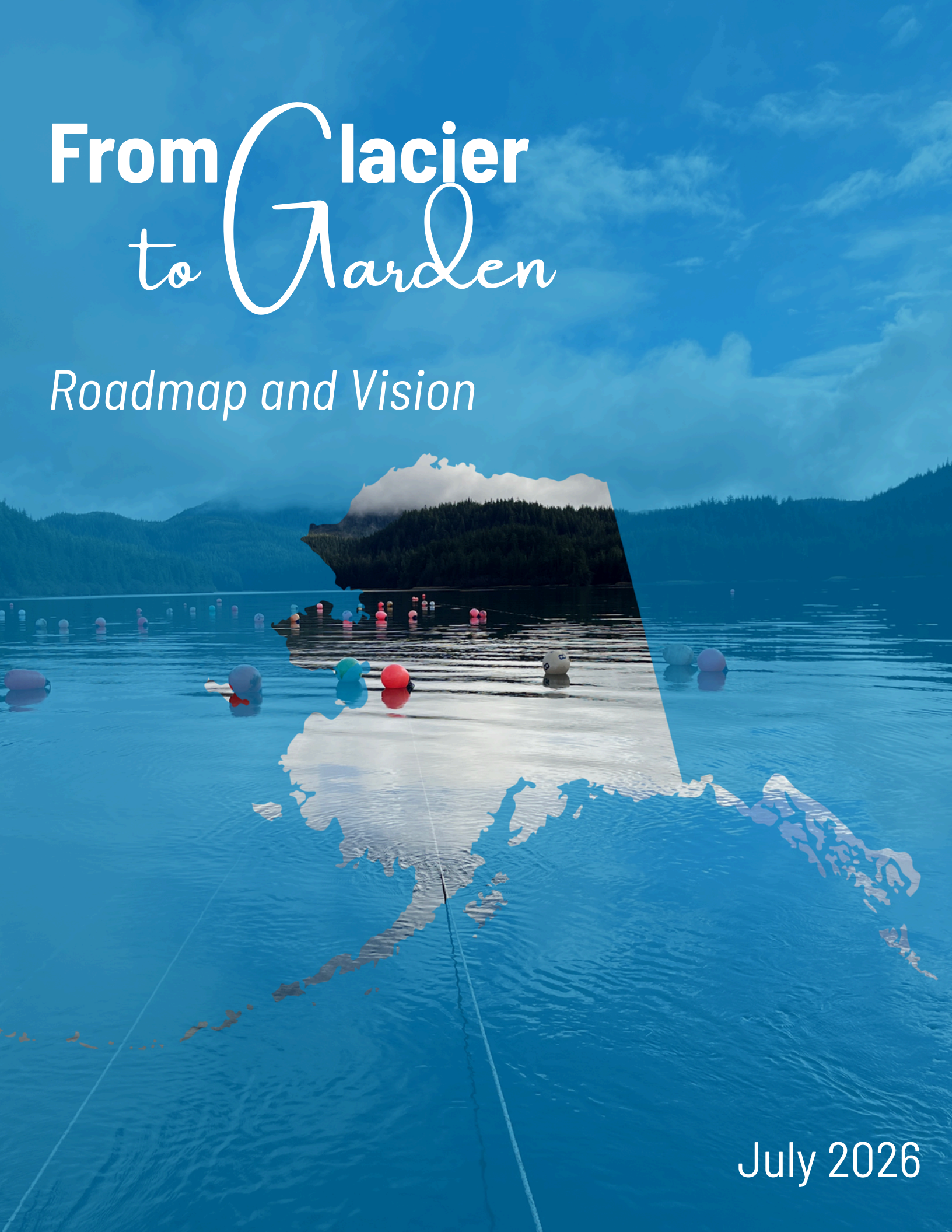
From Glacier to Garden

Roadmap and Vision



July 2026

Credits

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EXECUTIVE SUMMARY

Our Vision: An Alaska-developed high-value gardening product that supports a thriving kelp industry and local economies.

Alaska offers a uniquely compelling environment for kelp production and an abundance of finely ground glacial rock flour (GRF) that we argue could make a beneficial and accessible natural resource.[1] The need for natural soil amendments is increasing across the globe due to rising costs of synthetic fertilizers paired with decreasing soil fertility due to intensive monocropping and land degradation.[2] We present an opportunity for the development of Glacier to Garden: a soil amendment made with GRF from the banks of the Copper River and kelp farmed in Prince William Sound.

The Glacier to Garden roadmap establishes a vision for a soil amendment product that supports a thriving mariculture economy and utilizes accessible natural resources to benefit the local economy. This report provides scaffolding for the necessary steps to achieve the vision we have created.

The roadmap describes a research effort supported by the Southeast Conference and theAlaska Mariculture Cluster. Knowledge shared by generous kelp growers, farmers, and stakeholders helped shape the Glacier to Garden product and vision.

The recommendations presented below are based on 11 months of collaborative research informed by kelp growers, soil scientists, and industry experts. Among the research conducted are:

- National Science Foundation Innovation Corps (NSF I-Corps™) program for customer discovery and stakeholder engagement.
- Five rounds of greenhouse trials testing various treatment cases of kelp and GRF.
- Cation loss testing as a proxy for carbon sequestration.
- Ongoing field trials through a partnership with Calypso Farm and Ecology Center.

In the NSF I-Corps™ program we explored current challenges and gaps in the kelp industry. We honed our customer base, shaping the product to provide for a home gardening audience, including locals and visitors. Success at this scale will advise future efforts to scale to commercial markets.

The greenhouse trials identified the best ratio of kelp and GRF to support plant growth. These formed a basis for future research including ongoing work at Calypso Farm and Ecology Center.

The cation loss testing was used as preliminary evidence of carbon sequestration via enhanced weathering of GRF. The testing yielded qualitative evidence of carbon sequestration, highlighting potential use as a carbon removal technology if scaled. Significant further research is required to accurately quantify carbon sequestration.

Ongoing field trials at Calypso Farm and Ecology Center are being performed to determine how Glacier to Garden performs in the field. While greenhouse trials yielded positive results, success in the greenhouse looks different than in the field, and testing the product in a more variable environment is necessary to quantify benefits and determine the efficacy of the product.

The vision and plan for Glacier to Garden is based on an understanding of the current kelp industry, where biostimulant production is increasing, yet Alaska kelp growers are having difficulty competing in the market. We outline key challenges in GRF extraction and kelp processing, and establish market opportunities for Glacier to Garden.

The next phase of Glacier to Garden efforts will focus on developing a marketing strategy that will center the Alaska brand and capitalize on the opportunities for growth that an Alaska-specific product provides. We are committed to outlining the future efforts required to support the development and commercialization of the Glacier to Garden product.

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[1] Glacial Rock Flour is a finely ground rock powder deposited along the banks of glacial rivers. GRF from the Copper River Delta is largely composed of silt (*p50<38μm*), and has high levels of Calcium and Magnesium, minerals essential for plant growth.

[2] United Nations Environment Programme, "Five Reasons Why Soil Health Is Declining Worldwide"; Thompson et al., "Iran War Forces Farmers to Seek Fertilizer Alternatives from Cow Dung to Compost."

RECOMMENDATIONS

In order to move Glacier to Garden towards commercialization and consumer markets, we have outlined the following necessary steps.

GOAL 1

Expand research surrounding GRF products for improvement of crop yields, soil health, and crop nutrition. Explore potential use of kelp and GRF as a carbon sink.

Expand research on crop yield and soil health to multi-year studies on multiple crops in various soil types. Determine rates of carbon sequestration via enhanced weathering of GRF and research the feasibility of creating carbon credits in the voluntary carbon market. Evaluate the improved nutritional value of crops to promote human and livestock health.

GOAL 2

Improve the viability of mariculture in Alaska through the development of a product that is unique to its coast.

While maintaining the sustainability of the agriculture industry, we hope Glacier to Garden will aid the expansion of kelp markets to support Alaskan kelp farmers and the local economies in coastal Alaska.

GOAL 3

Determine the economic viability of a GRF product, starting the business at a smaller boutique level while leaving room for scaling the customer base to commercial farmers.

Conduct further market research before beginning sales and develop a financial plan with specific projections and benchmarks for scalability of the Glacier to Garden product.

GOAL 4

Determine regulatory requirements to begin removal of GRF from the Copper River Delta in Cordova, AK.

Working with the community of Cordova and state regulators, it is important to determine what extraction of GRF from the Copper River would look like, including permitting requirements and regulatory frameworks.

THEMES *Principles guiding our product development.*

THEME 1

The mariculture industry in Alaska is young, growing quickly, and looking for profit stability.

Alaskan kelp farmers often struggle to compete with prices in the Lower 48, and we hope our product can become a niche in the market that provides a unique opportunity where Alaskan kelp growers are at the forefront of this industry development. Due in part to the infancy of the Alaska mariculture industry and in part to the mindset of Alaskan kelp farmers, the mariculture industry is very collaborative and innovative. We aim to maintain this effort and create a positive addition to the wide breadth of work and research happening at this time.

THEME 2

Farmed kelp is a sustainable and regenerative resource.

The inputs for farming kelp and seaweed are minimal; kelp grows extremely quickly, and it is not energy-intensive to produce. Diversity of seed collection stipulated by the 50-50 rule allows for continued support of native kelp populations.[3] This provides an opportunity for product marketing as well as the potential to push the fertilizer industry towards a greener future where the life cycle of the inputs is considered in the development and application of fertilizer methods.

THEME 3

Alaska Brand sells; this is a big opportunity, as GRF is unique to Alaska.

The Alaska brand is one that Alaskans look for in stores, and one that tourists are excited to bring home to their families.[4] Glacier to Garden will be a product that local home gardeners use to proudly support their local economy, while a non-local may take some home to share with their gardening club, widening the customer base and maintaining a higher value than an at-scale commercial product.

THEME 4

The Copper River Delta provides a uniquely mineral-rich GRF that has the potential to provide important nutrients to agricultural soils.

The GRF that we are using is alkaline and extremely calcium-rich. This gives it the ability to both decrease the acidity of overly acidic soils and provide essential nutrients, including calcium, magnesium, potassium, and other critical trace minerals, to support plant growth, soil health, and increased nutritional value of crops.

THEME 5

Community informed decision is necessary before extraction of natural resources from the Copper River Delta begins.

We maintain that the community of Cordova as well as members of the Native Village of Eyak on which Cordova exists, deserve to have input in the use of their natural resources and be fully aware of the environmental and community impacts of significant GRF removal from the Copper River Delta.

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[3] The 50-50 Rule stipulates that kelp seedstock is to be sourced from at least 50 unrelated wild individuals and out-planted within 50 kilometers of the original collection site (Courtesy of Alaska Department of Fish and Game).

[4] Megan Koch, "NSF I-Corps Interview," January 14, 2026, Call.

CURRENT INDUSTRY

OVERVIEW

The Fall 2025 Report on the status of the mariculture industry in Alaska from the Alaska Mariculture Cluster reported significant harvest increases, but low price points make it a challenge for Alaska kelp farmers to make ends meet.[5] According to the report, 240,000 pounds of wet kelp were harvested in 2025, a nearly 55% increase in production from 2024, when 155,000 pounds were harvested. Stability of seed quality was also a significant improvement from 2024, with two more seed hatcheries coming online and a record-breaking 350,000 feet of seed line sold.[6] Biostimulants were a newly significant product in the industry in Alaska this year, though wild kelp is "a well-established component" of biostimulants in the US, specifically in Maine, where wild rockweed harvest is the largest volume application of seaweed in the US.[7] Unfortunately, buyers for biostimulant products are demanding significantly lower prices than the current cost of production of $0.85 to $1.00 per wet pound of kelp.[8]



CHALLENGES

KELP PROCESSING INFRASTRUCTURE

Based on interviews with multiple stakeholders and kelp industry experts, the biggest bottleneck in the kelp industry currently is processing.[9] There are many processing methods that kelp growers are working to streamline across the state, and each comes with its own challenges and benefits. Drying kelp in the extremely humid and rainy conditions of Southcentral and Southeast Alaska requires significant energy and indoor space.[10] Acid stabilization is promising but results in a wet, and therefore heavy, product with a low pH.[11] Additionally, consistency is difficult with acid stabilization, and the citric acid needed is expensive to ship to Alaska.[12] Fermentation is another promising option that stabilizes kelp and can make nutrients bioavailable without adding citric acid, but it is more time-intensive.[13]

Shipping liquid weight is often considered to be an inefficient process, as water is heavy and can be added back to dried products easily. However, with kelp from coastal Alaska, this may not be the case. Due to the significant energy input required to dry kelp in temperate rainforests, and the fact that liquid biostimulants are often hyper-concentrated with dilution recommendations up to 1:100, it may not be true that drying a product is overall a more efficient process than creating a concentrated liquid.

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[5] McKinley Research Group and Pacific Shellfish Institute, Alaska Mariculture Industry Update.
[6] McKinley Research Group and Pacific Shellfish Institute, Alaska Mariculture Industry Update.
[7] McKinley Research Group and Pacific Shellfish Institute, Alaska Mariculture Industry Update.
[8] McKinley Research Group and Pacific Shellfish Institute, Alaska Mariculture Industry Update.
[9] Sean Den Adel, "NSF I-Corps Interview," January 15, 2026, Call.
[10] Tommy Sheridan, "NSF I-Corps Interview," January 14, 2026, Video Call.
[11] Den Adel, "NSF I-Corps Interview."
[12] Den Adel, "NSF I-Corps Interview."
[13] Evie Witten, "NSF I-Corps Interview," January 22, 2026, Call.

However, the Glacier to Garden product requires a dried kelp product to mix with the GRF while maintaining ease of field application. While drying kelp is still a bottleneck in the kelp industry, improvements are being made: Cordova set up an industrial dryer in 2026 that will allow for faster drying for kelp farms in Prince William Sound.[14] We hope that with continued work towards efficient processing across the state, dried kelp will be more accessible and cost competitive.

GLACIAL ROCK FLOUR EXTRACTION

Regulatory Environment

Regulations for the Copper River Delta are difficult to determine, as there are no current extraction efforts. Determining the regulatory environment in which extraction will begin will require conversations and individualized permitting with the Alaska Department of Natural Resources, as well as significant conversations with the local community of Cordova and the Native Village of Eyak to gain community input and support for the project.

Environmental Impact

Environmental impact is another concern of GRF extraction. In order to quantify and minimize potential impact, it is necessary to obtain an estimate of the scale at which GRF will be extracted. Based on the determined scale, from manual collection (as was done for testing) to a full-scale commercial extraction, the environmental impact will differ significantly. A robust environmental impact assessment should be performed to determine potential issues caused, as ultimately the mission of Glacier to Garden is to support sustainable home-scale agriculture, and sustainability is only possible if the product itself is created in a sustainable manner.

Social Concern

Social concern may also be a factor in beginning scaled extraction of GRF from the Copper River. Potential environmental impacts may cause social pushback, so Glacier to Garden should work directly with the local community, maintaining a transparent approach to decision making- holding open conversations with the community before extraction occurs.

Subsistence fishing and hunting are federally protected rights of Tribal members and rural citizens in Alaska.[15] Nearly all citizens in Cordova participate in some form of subsistence activity- subsistence is a way of life for Tribal members and rural citizens alike. Potential interference with the local fluvial environment may affect fish and other wildlife habitat and populations, directly impacting subsistence activities: this should be studied extensively before extraction begins. The community should be informed of all findings during the assessment period.

GLACIAL ROCK FLOUR PROCESSING

Similar to kelp, it is necessary to dry GRF both for shipping costs and field application. It may be possible to air-dry GRF. However, if a significant scale is reached, it will be necessary to dry GRF using heat and potential mechanical movement. Currently, we know of no large-scale GRF drying operations in Alaska, so we anticipate that drying processes used by Anchorage Sand and Gravel would be the best proxy for energy, cost, and time estimates for GRF drying operations at scale.

While there is minimal concern, before reaching market, the GRF should be tested for any potential contamination upon field application, including any bacteria, viruses, or fungi. It is unlikely that organisms that live in the GRF on the river banks at pH 8.4 would survive in agricultural soils at pH 5-7.5, but this should be tested to avoid problems after production has begun.

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[14] At the time of this report, cost analysis of the new drying system was not yet complete, though initial reports indicate drying cost is significant and prohibitively expensive without external funding.

[15] "Subsistence Program," Bureau of Land Management, accessed August 8, 2026, https://www.blm.gov/programs/natural-resources/subsistence.
Subsistence is defined by federal law as "the customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools or transportation; for the making and selling of handicraft articles out of nonedible by-products of fish and wildlife resources taken for personal or family consumption; and for the customary trade, barter or sharing for personal or family consumption."

SHIPPING

GRF is an extremely dense and therefore heavy material, requiring significant energy and costs to ship from Cordova, which is not on the road system. This is one of the benefits of starting production of Glacier to Garden at a small scale and selling only from Alaska, or potentially including online ordering capacity. This allows shipping fees to be adopted by a willing consumer, and the distance between the manufacturer and consumer is minimized. If the product is to be scaled, there is concern that the cost of shipping may be so high that it prices out commercial farms and profit margins would shrink significantly, making the business less viable. This should be considered as the company considers scaling towards commercial farms once it has significant capital from starting at retail scale.

OPPORTUNITIES

MARKET NICHE

Glacier to Garden is a product that checks many boxes and can create many opportunities for Alaska kelp farmers and stimulate the economy in Cordova, Alaska. Kelp farmers from Alaska are often unable to compete with prices of kelp in the lower 48 due to the remote setting of many coastal communities in Alaska. As the GRF that Glacier to Garden uses is specific to the Copper River Delta, it makes this product impossible to replicate without sourcing resources from Alaska, thereby shaping a niche in the market where Alaska kelp growers can compete with similar kelp-based products.

The Alaska brand is one that consumers, both tourists and locals, will look for in the store. The Alaska brand sells an idea of ruggedness, grit, and unmatched beauty that consumers are drawn to. We believe this can extend to home gardening products, both for local consumers who love to buy local and support small businesses, and for tourists who are looking for a packable product that they can take home with them as gifts for friends and family, or as a souvenir from their trip up to Alaska. We will use this to our advantage and center the story of Alaska and our product in our marketing efforts.

SCALABILITY VIA THE VOLUNTARY CARBON MARKET

Scaling the Glacier to Garden product may not be feasible as simply a soil amendment. However, we anticipate that potentially quantifiable carbon may be sequestered upon application to agricultural soils through the process of enhanced weathering. This will require significant long-term field trials to quantify carbon sequestration, but the literature suggests that GRF with significant exchangeable cation levels, such as the GRF from the Copper River Delta, has the potential to be a significant carbon dioxide sink for future efforts to reduce the extent of anthropogenic climate change. A high-capital long-term study to quantify any carbon dioxide removal from enhanced weathering is necessary before this pathway can be realized. There would be an opportunity then for commercial farmers who use Glacier to Garden to participate in the voluntary carbon market, giving them a secondary income stream, stabilizing what is a generally marginal industry, and incentivizing the purchase of Glacier to Garden at scale.

THE VISION

An Alaska-developed, high-value gardening product that supports a thriving kelp industry and local economies.

THIS VISION WILL BE ACHIEVED THROUGH

- Shaping a market niche that is unique to Alaska, and thereby supporting local kelp growers and continuing to grow the fledgling kelp industry/Alaska economy.
- Developing a marketing strategy centered around the Alaska brand.
- Building a customer base that includes Alaskans as well as visitors, allowing the market to be expanded beyond Alaska through tourism.
- Maintaining a community-focused approach to business growth, keeping production local to support Cordova's economy, and working to minimize the environmental impact of GRF extraction.

THE PLAN

The name recognition of the Alaska Brand, as well as a current push for the kelp industry, offers an incredible niche for this product. To achieve our vision, it is necessary to expand upon active research for CDR and the voluntary carbon market, as well as improve the solidity of data on the effects of our product. To balance the needs of growing a business and maintaining our values of sustainability and community support, we developed the following strategies to implement Glacier to Garden's Vision.

GOAL 1: EXPAND RESEARCH SURROUNDING GRF PRODUCTS FOR THE IMPROVEMENT OF CROP YIELDS AND SOIL HEALTH, THE POTENTIAL TO USE KELP AND GRF AS A CARBON SINK, AND ENHANCED NUTRITIONAL VALUE OF CROPS PRODUCED WITH GRF PRODUCTS.

Strategy 1A

Conduct a longer-term and broader study that will accurately show the benefits and/or risks of applying Glacier to Garden repeatedly to home gardening soils in various conditions and on various crops. Additionally, conduct a shorter-term lab-controlled experiment performing rapid acid dissolution on the GRF to determine maximum CDR potential.

Strategy 1B

Develop plans for a long-term study on agricultural fields to determine the efficacy of enhanced weathering for carbon sequestration based on literature on geochemical processes for carbon dioxide removal, enhanced weathering of mechanically ground basalts, and enhanced weathering of glacial flour from Greenland.

Strategy 1C

Determine if the voluntary carbon market is a potential avenue for a secondary income stream for farmers to support the scaling of Glacier to Garden to a commercial scale.

Strategy 1D

Determine the nutritional value of crops that use Glacier to Garden. Research market potential for positioning the product as a nutrition enhancing amendment, dependent on test results.

GOAL 2: IMPROVE THE VIABILITY OF MARICULTURE IN ALASKA THROUGH THE DEVELOPMENT OF A PRODUCT THAT IS UNIQUE TO COASTAL ALASKA.

Strategy 2A

Ascertain the volume of kelp that local farmers can grow, while maintaining sustainable farming practices, as well as an accurate estimate of how much kelp our production requires.

Strategy 2B

Develop a financial model that fully supports Alaskan kelp farmers and ensures they are paid fair wages when pricing products.

GOAL 3: DETERMINE THE ECONOMIC VIABILITY OF A GRF PRODUCT, STARTING THE BUSINESS AT A SMALLER BOUTIQUE SCALE WHILE LEAVING ROOM FOR SCALING THE CUSTOMER BASE TO COMMERCIAL FARMERS.

Strategy 3A

Develop a business plan for Glacier to Garden, including the determination of the price point at which Glacier to Garden would be sold. Contact potential retailers, prioritizing those who earn a significant portion of their revenue from tourism.

Strategy 3B

Center marketing strategy around the Alaska experience: Alaskans are rugged and aren't afraid to get their hands dirty.

Strategy 3C

Conduct a feasibility study on the scale of Glacier to Garden, and determine the benefits and drawbacks of selling the product at commercial scales, including the possibility of introducing Glacier to Garden in the voluntary carbon market.

GOAL 4: DETERMINE REGULATORY REQUIREMENTS TO BEGIN EXTRACTION OF GRF FROM THE COPPER RIVER DELTA IN CORDOVA, AK.

Strategy 4A

Identify deposit locations and extraction challenges, including heavy metal and particle size testing.

Strategy 4B

Contact the Alaska Department of Natural Resources to begin the permitting process for extraction, as these processes take significant time. Maintain transparency with the local community to ensure community informed decision making remains a top priority.

Strategy 4C

Perform an Environmental Impact Assessment to determine the most sustainable way to extract GRF, and what methods can be used to reduce impact on the local environment and other resources, including fish and large animal habitats.





MARKET READINESS

To further understand the market that our product would enter, the team participated in the National Science Foundation Innovation Corps (I-Corps™) training through Oregon State University. During this training, we interviewed a total of 21 farmers, agriculture experts, and other stakeholders. From these interviews, we compiled five key findings on the agriculture industry and farmer needs that allowed us to determine the state of the market and industry.

While initially focused on scaling this product to support larger agricultural endeavors and potentially measure CO2 sequestration, we believe that starting the market on a high-value boutique scale will allow us to break into the market with lower upfront costs than an industrial scale, allowing us to build to a larger market. Profit margins are often higher in the boutique market, and the "Alaska Brand" will help to develop recognition of the product.

Selling a product to farmers is difficult; they want to spend minimally, as it is a highly marginal industry, and profits are tight.

Many of the farmers we spoke to prioritize using resources hyper-local to their farm to avoid purchasing additional products in the first place.[16] While many farmers were interested in our work, their main concern was the ratio of cost to function. In order for this product to be marketable to farmers, we need to ensure that it will both improve soil health on agricultural fields and reduce overall costs of inputs for farmers. Farmers reduce costs first by reducing purchases, and are unlikely to pay unless they are confident in results.[17]

We anticipate home-gardening or hobby-farm customers may be willing to pay a premium for the "Alaska brand." One avenue to access the commercial scale market is to explore the voluntary carbon market. Significant time and resources would be necessary to pursue this market, but a qualified product would allow farmers to profit from carbon sequestration, and therefore increase the value of the wholesale product and the incentive to purchase and use this product.

A boutique-scale product creates a specialty product that will allow home gardeners to experiment with their gardens while supporting local economies.

Ultimately, conversations with farmers lead us to believe that the commercial farming industry would not be open to purchasing Glacier to Garden at this time.[18] Due to this, our focus is a boutique product for home gardeners, including those living in and visiting Alaska. Home gardeners are more likely to try new products and experiment, as their livelihoods are not on the line if their crops do not perform well, and are more likely to have expendable income that could be swayed by the marketing of a product.

Scaling Glacier to Garden to a larger-scale product for commercial farms may be possible at a later time. Starting small-scale, high value will allow Glacier to Garden to build capital with lower overhead than mass production and shipments would require. A small-scale beginning will also increase capital that can be used for further research on the carbon market and how Glacier to Garden could fit into the voluntary carbon market as a second income stream for farmers, incentivising its purchase at scale in the future.

[16] Tom Zimmer, "NSF I-Corps Interview," January 21, 2026, cost-to-function Call; Isobelle Mahoney and Ryan Mahoney, "NSF I-Corps Interview," January 31, 2026, Call.

[17] Zimmer, "NSF I-Corps Interview."

[18] Laura Ballou and Dwayne Ballou, "NSF I-Corps Interview," January 29, 2026, Call; Mahoney and Mahoney, "NSF I-Corps Interview"; Zimmer, "NSF I-Corps Interview."

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