Advancing a Dual-Function Soil Amendment for Carbon Sequestration and Soil Health using Alaska-Grown Kelp and Glacial Rock Flour

Quarter 3 Progress Report

Project: Advancing a dual-function soil amendment for carbon sequestration and soil health using Alaska-grown kelp and glacial rock flour

Funder: Southeast Conference – Alaska Mariculture Cluster Grant

Implementing Organization: Alaska Center for Energy and Power

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Project Overview

The goal of this project is to develop, test, and evaluate a novel soil amendment that combines Alaska-grown kelp and glacial rock flour (GRF). The concept builds on Alaska's natural abundance of marine macroalgae and GRF to produce a blended product that enhances soil fertility while capturing and storing atmospheric carbon dioxide (CO_2) through both organic and mineral pathways.

The dual-function amendment is envisioned to: 1) Provide a sustainable, value-added product that enhances soil health; 2) Support regenerative agriculture practices; 3) Contribute to measurable carbon sequestration (through kelp-derived organic matter and enhanced weathering of GRF); and 4) Create potential revenue streams for Alaska mariculture producers via a unique premium product.

Summary of Progress

Progress on Task 1: Soil Fertility and Plant Response Trials

Goal: Initiate controlled trials to evaluate the effects of different amendment formulations on soil fertility and crop performance.

Five rounds of greenhouse trials have been completed, and the final soil health analysis is described below. The scope of Task 1 has been expanded to include trials through an ongoing partnership with Calypso Farm and Ecology Center in Ester, Alaska. These trials include silt and kelp field trials, silt-only greenhouse trials, and a series of trials in plexiglass root boxes. Progress on these is described below. The GRF used in all trials was from the same location as in the Quarter 1 report, though the GRF used at Calypso was collected several months later.

Soil Health Analysis

Soil samples from Trials 3 and 4 were sent to Ward Laboratories for Phospholipid Fatty Acid (PLFA) analysis. In each trial, butterhead lettuce was grown in peat moss for 7-10 days before

transplantation into treatment soils. Artificial day lengths were 16 hours, temperature was kept at approximately 70ºF, and humidity was kept at 70%. The kelp used was food-grade milled sugar kelp from Kachemak Kelp Hub. Trial 3 includes kelp only, kelp and silt, and two variations of silt only. In Trial 3, the kelp treatment was reduced to a concentration of 2.5 kg/m^2 from one of 5 kg/m^2, to determine if Trial 2 suffered due to an over-concentration of kelp in the soil. Additionally, there were two silt-only treatments in Trial 3 to measure carbon sequestration via enhanced weathering, as outlined in Task 2.

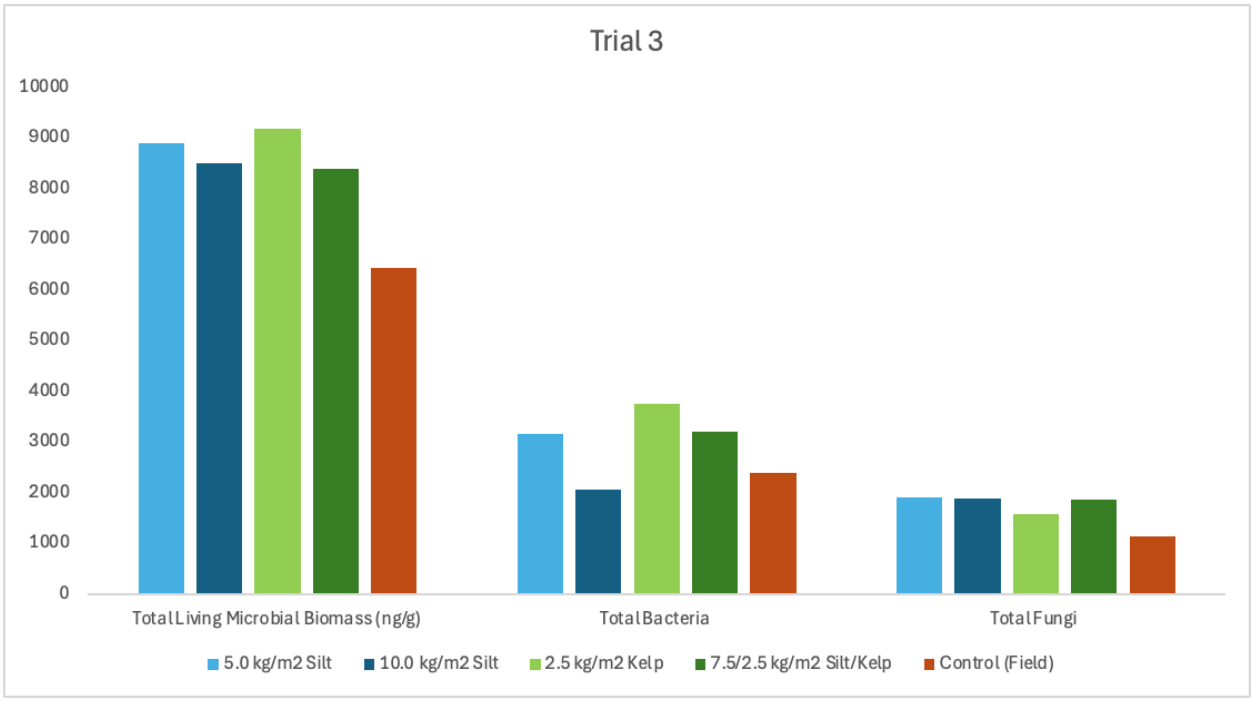

Figure 1. Results from the Phospholipid Fatty Acid Analysis performed by Ward Laboratories for Trial 3.

While it is difficult to make broad statements about the significance of this specific trial, it is promising that both kelp and silt treatments maintained higher Total Living Microbial Biomass (TLMB, ng/g) than the controls (Fig. 1). It should be noted that the high silt treatment experienced lower Total Bacteria than the control, which again, does not necessarily pose any significance to the overall study, but is important to recognize that such a high treatment has the potential to decrease bacterial activity in the soil.

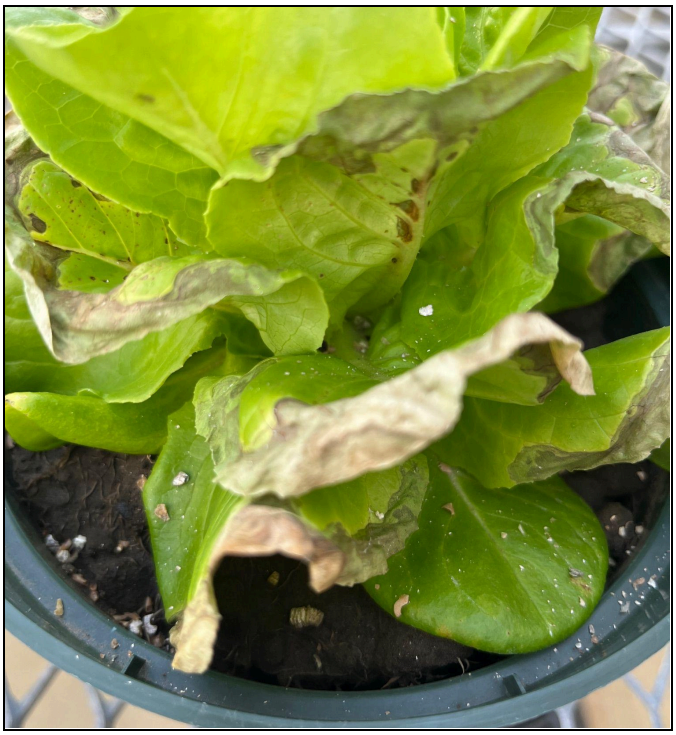

Figure 2. A struggling lettuce plant from Trial 4 that we anticipate has a fungus.

Trial 4 included only liquid kelp treatments. Treatment 1 received 40 mL per week of *Sea2Sprout* from Kachemak Kelp Hub, a product in the early stages of commercialization. This treatment was diluted as per instructions on the bottle: 1:100 with water. Treatment 2 received 40 mL /week of kelp extract, which was made by stirring 10% w/v dried sugar kelp from Kachemak Kelp Hub in purified water for 7 days, straining through cheesecloth, and diluting the final liquid 1:3 with purified water. All plants— in all treatments and controls, and in peat moss and field soil— developed dried, brown leaf tips, with rings potentially indicating a fungus. In conversation with Evie Witten of Kachemak Kelp Hub, we also learned that we may have been significantly overapplying the kelp treatments to the plants. We do not believe this caused the brown rings on the plants, however, as the controls had the same issue.

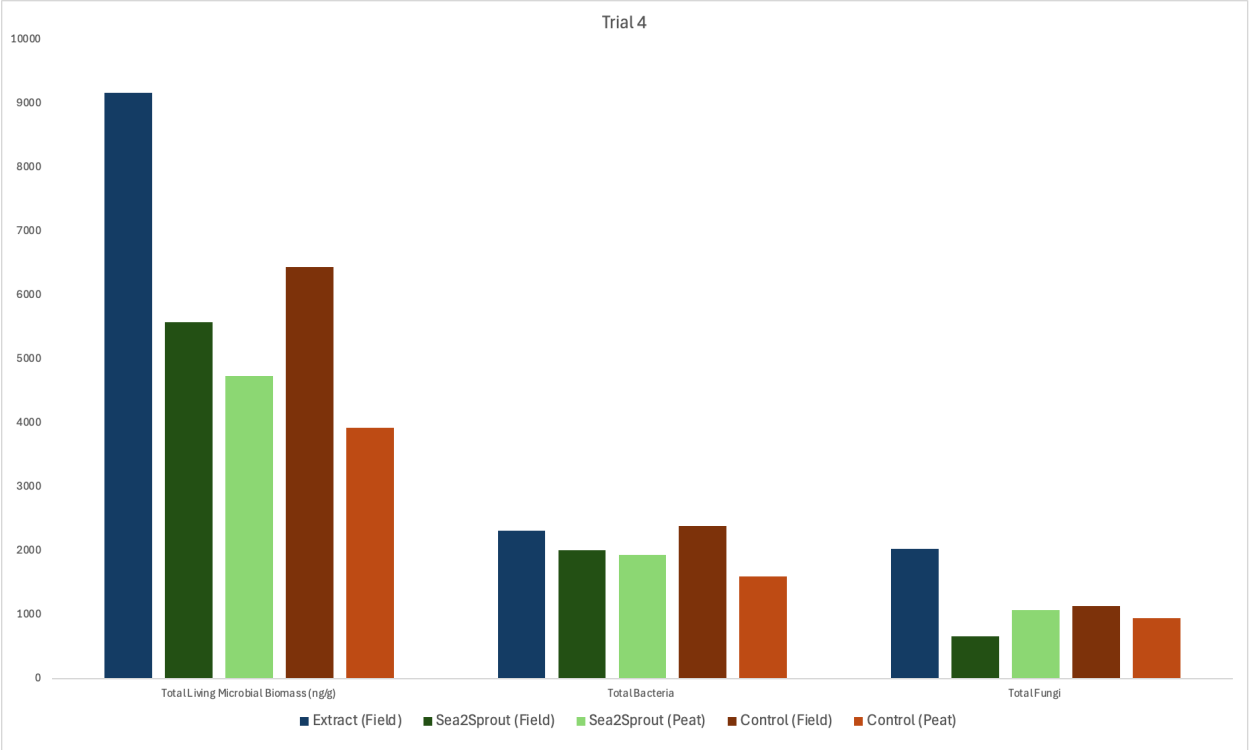

Figure 3. Results from the Phospholipid Fatty Acid Analysis performed by Ward Laboratories for Trial 4. Note that the omission of extract treatment in peat moss was due to sample loss at Ward Laboratories.

PLFA results from Ward Laboratories for Trial 4 indicated that the kelp extract experienced elevated levels of Total Living Microbial Biomass (TLMB, ng/g) as compared to the Sea2Sprout treatments as well as the controls. The Sea2Sprout, conversely, experienced decreased TLMB levels as compared to the controls, but we anticipate that this may be due to our overapplication of the treatment.

Calypso Field Trials

In order to further determine the effectiveness of GRF and kelp as a soil amendment, we partnered with Calypso Farms in Fairbanks, Alaska, to complete in-field trials. We used three beds, each 3' by 150', that had previously been planted with potatoes for four years, likely leading to imbalanced soils. Though crops will be planted along the entire bed, treatments will not be placed at the start or end of each bed to prevent data skewing from edge effects. Each treatment plot is

approximately 15 ft long, with a 6 ft buffer in between each. Treatments will be distributed to have one replicate in each row, as shown in the schematic below.

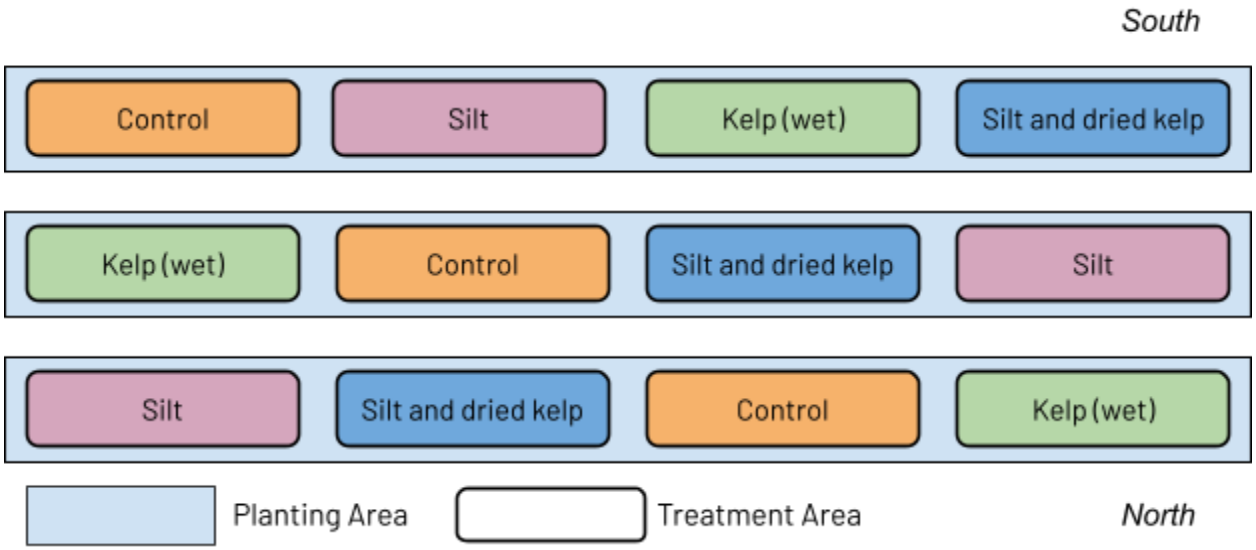

Figure 4. Diagram of Calypso Farms Field Trial treatments

We applied the equivalent of 45,000 lbs/acre of silt to the soil, or 1 lb / ft^2. This added up to 60 lbs of silt per treatment plot, which was applied to all silt and silt/kelp combination plots and raked in approximately 2" into the soil. Combination plots additionally received 3.3 lbs of Kachemak Bay Kelp, which is food-grade sugar kelp that has been dried and finely milled to <1 mm, raked 2" deep as well. Both silt and dried kelp were added before planting. Kelp-only plots will be mulched with fresh frozen kelp once plants reach substantive size. The kelp that will be used was transported to Fairbanks, AK, from Cordova, AK via car and was thawed during travel. It was stored in coolers for up to two weeks at Calypso Farms, where it was left unfrozen. The kelp will likely begin to decompose before on-field application.

The beds were tilled and broadforked before planting. Cover crops of annual rye and field peas were planted via a 6-row seeder along the entire field, into 12 rows per plot. These crops were selected due to their nitrogen-fixing qualities to prepare the fields for crops to be planted next year, and due to ease of planting and consistency of germination. This will allow us to measure total biomass as a proxy for soil amendment success. This should help with the scientific integrity of the experiment as the quantity of individual cover crop plants will be significantly increased compared to individual plants, decreasing the influence of random error or plant failure.

Soil samples were taken before application of GRF and kelp, and immediately after. Samples will continue to be taken regularly over the course of the growing season.

Calypso Supplementary Experiments

In addition to the field trials, two root boxes were built, each with six sections to plant and a plexiglass front. This front will allow us to see root formation through different soil levels. This is a useful proxy for soil health and is a helpful visual aid for showing interested community members. Field peas were planted, two in each box. Six soil amendments were added to potting soil, as shown below, and were replicated in the second box.

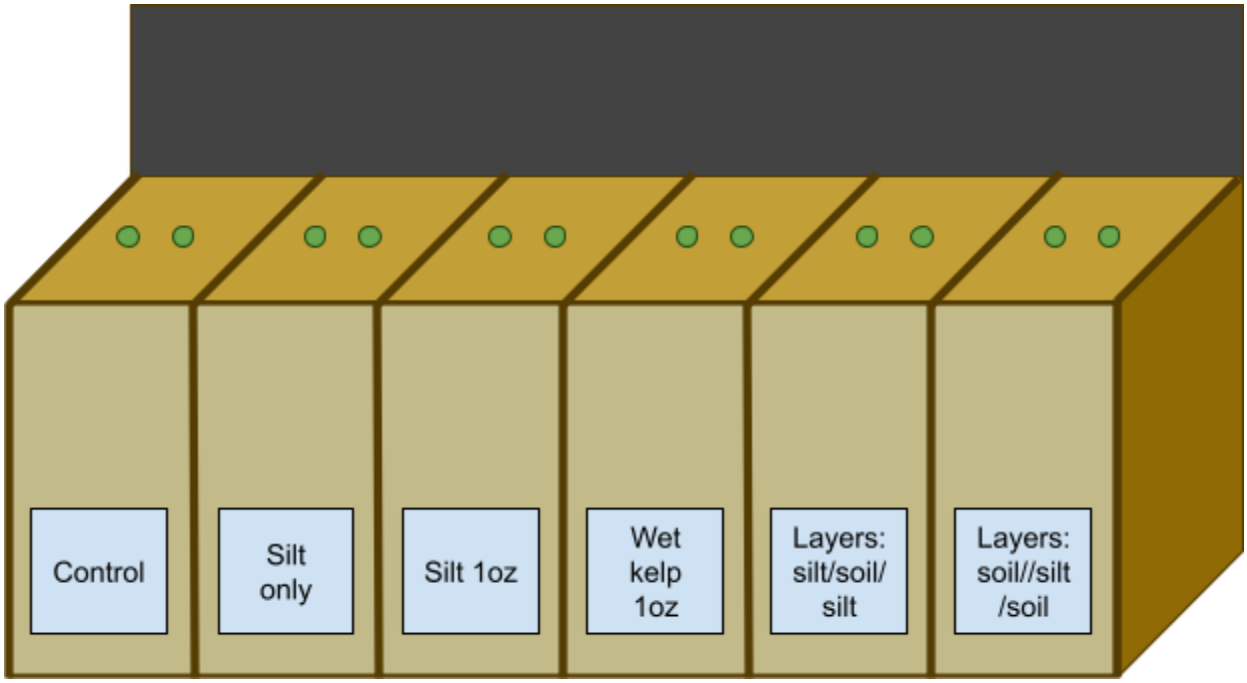

Figure 5. Diagram of Calypso Farms Root Box treatments

The photograph below was taken approximately three weeks after planting. Photographs will be taken continuously throughout the growing season.

Figure 5. Calypso Farms Root Box treatments growth

Finally, in May, tomato plants were transplanted into larger pots in the greenhouse at Calypso Farms. Half of the plants were given 2 cups of silt per 5-gallon pot, while controls were potted in soil only. All are watered via drip irrigation. Since the up-potting, all tomatoes have been trellised and undergone regular pruning. Growth will be compared anecdotally throughout the growing season, and photos will be taken at the peak of the season.

Progress on Task 2: Controlled CO_2 Sequestration Experiments

Goal: Replicate and adapt laboratory-based enhanced weathering experiments originally conducted by Dr. Rosing and colleagues to quantify the CO_2 sequestration potential of Alaska GRF under local soil conditions.

Carbon Sequestration Analysis

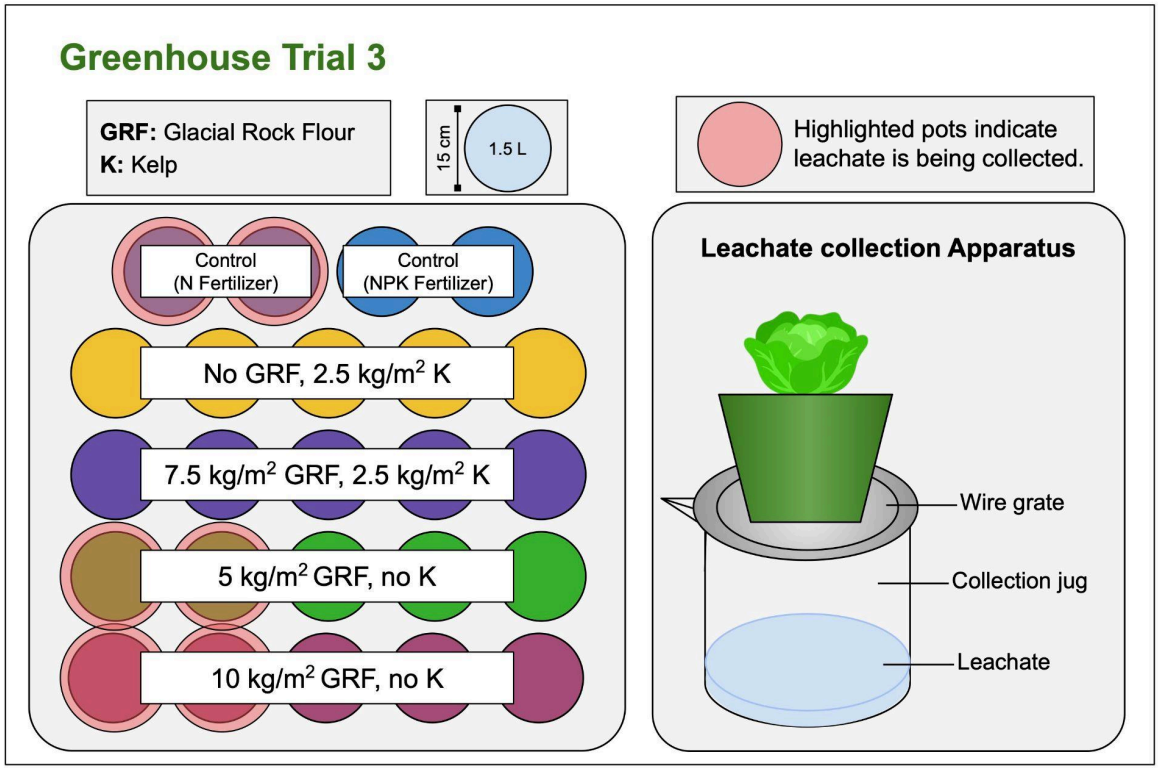

Figure 2. Trial 3 used a leachate collection apparatus under some plants to measure carbon capture using mineral concentration in the leachate as a proxy.

Trial 3 treatments were set up with a leachate collection apparatus to analyze exchangeable cation concentrations to determine the carbon sequestration levels of enhanced weathering with the GRF. The setup mimics the mesocosms developed by Reershimius et al.[1]

Leachate and soils were collected on March 23, 2026, for testing via ICP-MS. Results from the ICP-MS, run by Piper Kramer and Shane Billings at the UAF Critical Minerals Laboratory, show

preliminary anecdotal evidence of carbon sequestration. This data will be included in a separate report submitted to Southeast Conference. A longer-term and larger-scale study will be necessary to determine a more exact sequestration rate, as most enhanced weathering experiments in the literature take place over multiple years.

Finally, we will meet with Peter Webley from the UAF Center for Innovation to discuss contacts he may have who would have the capabilities to perform a lab-controlled leaching experiment. We will discuss the possibility of performing these experiments in Quarter 4, given constraints of time, budget, and expertise.

Progress on Task 3: Market Readiness, Lifecycle Assessment, and mCDR Hub Strategy

Goal: Prepare the kelp-glacial flour product for future development, adoption, and broader climate relevance concurrently with Tasks 1 and 2. This includes a lifecycle assessment (LCA) to evaluate the net climate benefit of the amendment, and the application of a customer discovery framework modeled after the NSF I-Corps program to explore product-market fit, user needs, and commercialization strategies. Begin to develop a strategic roadmap for producing a dual-function soil amendment.

The project has brought on Magnus De Witt, a research assistant professor with a background in decarbonization, and Neil McMahon, a research assistant professor of economics, to provide expertise and complete a rigorous life cycle assessment (LCA). They have experience in performing LCAs and will be able to support this project by providing this deliverable. DeWitt is currently writing up the results of the LCA and will have a brief report to submit to SEC in Quarter 4. The CO_2 sequestration study performed by Welsh partnering with Critical Minerals Laboratory at INE/UAF was able to show preliminary and anecdotal results that, while not yet scientifically rigorous, are promising for the possibility of GRF being used as a carbon sink. A more rigorous and long-term study will be necessary to quantify CO_2 sequestration via enhanced weathering, and this will be outlined in the strategic roadmap.

We have developed a strategic roadmap, focused on creating revenue streams for Alaska mariculture producers. We have pivoted our customer base towards a small-scale boutique product aimed at home gardeners, due to the financial difficulties of serving large-scale farmers, who are extremely budgetarily constrained due to the slim margins of their industry. There is potential to scale up to serving farms and other large applications if production costs, especially shipping, are reduced and if the financial benefits of the voluntary carbon market allow farmers to pursue our product.

Overall Progress

This project is on track, with milestones completed or in progress as expected. In Quarter 1, we completed two greenhouse trials, NSF I-Corps training, and began planning for summer field trials. In Quarter 2, we completed two more greenhouse trials and partially completed a fifth. We established a framework for a life cycle assessment of the GRF and finalized plans for summer field trials. In Quarter 3, we have moved forward with the summer field trials, planting annual rye and field peas, as well as completing an additional round of greenhouse trials and starting an exploratory round of root box experimentation. The strategic roadmap is in the final stages of editing, detailing the potential of bringing a soil amendment product to market.

Next Steps

1) Complete LCA and pursue further enhanced weathering research to quantify CO_2 sequestration potential.
2) Finalize strategic roadmap and preliminary carbon sequestration reports.
3) Complete summer field trials with Calypso Farms and analyze soil tests.

Conclusion

At the third quarter milestone, we have completed the original goals for Task 1 and have made significant progress on the expanded goals of field trials at Calypso Farms. We have made progress on Task 2 and have completed preliminary carbon sequestration work to the best of our ability, given expertise and time constraints.
Furthermore, we are finalizing the strategic roadmap and LCA as described in Task 3, and, crucially, have pivoted in the short term towards home gardeners and away from the voluntary carbon market as a source of supplemental funding for commercial farmers.

We believe this project will provide a resource and direction for future work with kelp and GRF soil amendments across Alaska, and are on track to provide impactful deliverables at the end of the funding period.