Quarterly Progress Report

Project Title: Kelp-based Amendments to Increase Agricultural Carbon Storage (KAIACS)

Reporting Period: January – April 2026

Submitted to: Alaska Mariculture Cluster / Southeast Conference

Submitted by: Native Village of Eyak

In Partnership with Washington State University and the Matanuska Experimental Farm and UAF Extension Office

Project Overview

The Native Village of Eyak (NVE; Fig. 1) in partnership with Washington State University is leading the Kelp-based Amendments to Increase Agricultural Carbon Storage project (KAIACS) to evaluate whether sugar kelp, grown through the Tribe's mariculture program, can be used as an amendment to improve soil health in a manner that may enhance carbon sequestration in agricultural fields. The project includes both laboratory and field components to understand these dynamics. Laboratory incubations were carried out to determine how kelp and carbon amendments affect microbial activity, nutrient cycling, and carbon dynamics in soil under controlled conditions. Field trials will then apply those findings to agricultural plots to evaluate how these amendments influence crop growth and soil health in real growing conditions.

During this reporting period, work focused on completing laboratory incubation experiments and preparing for field trials during the 2026 growing season. This phase of the project has generated a detailed dataset that will guide amendment selection, application rates, and field trial design.

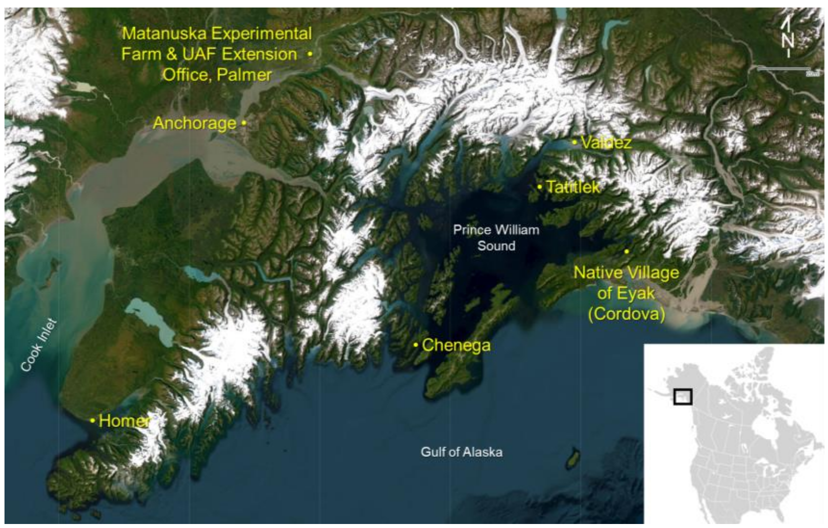

Figure 1: Map of Southcentral Alaska where the present study took place at the Matanuska Experimental Farm and where sugar kelp was grown in the Prince William Sound.

Task 1: Laboratory Trials

Background

While investigating sugar kelp's effectiveness as a soil amendment during the 2025 growing season, we found that kelp increased microbial activity (microbial respiration and biomass production) and provided important nutrients for crops including nitrogen and potassium.

The efficiency with which microbes use carbon sources and nutrients depends on the ratio of carbon to nitrogen (C:N). Materials with a high C:N have a lot of carbon but relatively less nitrogen. When the C:N of a pool of nutrients is too high, microbes begin to immobilize nitrogen rather than recycling it and making it plant available. Materials with low C:N have a greater amount of nitrogen but relatively less carbon. In this case if nitrogen is too high it may leach out of the soil rather than get taken up by plants. Finding the right C:N is important for both carbon and nitrogen to be used most efficiently.

Typically a C:N around 25:1 is considered ideal for microbial use. Kelp has a relatively low C:N (~10:1) making it a good source of nitrogen but a poor source of carbon. We wanted to find out if we could add a carbon source along with the kelp to boost the C:N and increase the efficiency with which the soil microbes are using C and N. In this study we added shredded cardboard (which has a C:N of ~500:1) along with the dried, shredded sugar kelp to soils stored in mason jars over a 56 day period. Throughout the incubation period we measured microbial activity along with nitrogen availability and other soil health metrics to determine if the combination of shredded cardboard and kelp was an effective soil amendment. We combined kelp and cardboard in three different ratios to get a final C:N of 20:1, 30:1, and 50:1 (Fig. 2).

Methods

Kelp + Cardboard (C:N = 20:1) | Kelp + Cardboard (C:N = 30:1) | Kelp + Cardboard (C:N = 50:1)

Figure 2: Dried and ground kelp and combined with shredded cardboard mixed into soil samples collected from the Matanuska Experiment Farm.

Soils collected from the University of Alaska Fairbanks Matanuska Experiment Farm (Palmer, AK) were incubated for 56 days and amended with one of six treatments including a control (no amendments added), cardboard only, kelp only (equivalent of 5000 lbs/acre), and three combinations of cardboard and kelp to achieve a C:N ratio of 20:1, 30:1, and 50:1 (Tbl. 1). Each treatment was replicated four times. The day 0 samples are based on eight replicate unamended soil samples to provide a baseline to compare each treatment with.

Soils were incubated in mason jars at room temperature and periodically sampled for respiration rates, microbial biomass, available N, potassium permanganate oxidizable carbon (POXC) to measure active carbon, pH, and salinity.

Table 1: Treatment descriptions

Treatment	C:N ratio of amendment	Kelp (g)	Cardboard (g)
Control	-	-	-
Cardboard	500:1	-	1.5
Kelp	6:1	2.5	-
Kelp + Cardboard (20:1)	20:1	2.5	0.65
Kelp + Cardboard (30:1)	30:1	2.5	1.31
Kelp + Cardboard (50:1)	50:1	2.5	2.72

Respiration was measured using the PP Systems EGM-5 CO_2 analyzer. Mason jar lids were fitted with a rubber septa for gas sampling. CO_2 content was measured at the beginning and end of a 24-hour period and respiration rates calculated based on the amount of CO_2 that accumulated during that time.

Microbial biomass was measured using the chloroform fumigation method (Jenkinson and Powlson 1976). Each sample was divided into two and one subsample was fumigated with chloroform for 3 days and the other subsample was not fumigated. The fumigation process splits open microbial cells and allows for quantification of carbon stored in microbial biomass. DOC was measured in both samples and the difference between the two is considered microbial biomass carbon. DOC was measured using the method described in Bartlett and Ross 1988.

Available nitrogen was measured using a potassium chloride extraction. Both ammonium and nitrate concentrations from these extractions were quantified and then the combination of the two is used to calculate total available N. Ammonium is measured by using a colorimetric assay with nitroprusside and phenol (Dorich and Nelson 1983). Nitrate is measured using vanadium chloride reduction (Doane and Horwath 2003).

POXC is a pool of carbon that responds to management practices on shorter time scales compared to other carbon pools that can take years to show significant changes. Increases in POXC on the short term may lead to increased soil organic carbon in the longer term. This measurement helps us understand how this carbon could be sequestered in our soils. POXC was measured via the reduction of permanganate (Weil et al. 2003; Culman et al. 2012).

Soil pH was measured with a water extraction (2:1 water-to-soil) using a pH meter. Salinity was measured using a 1:5 soil to water ratio and quantified using an EC meter.

Results and Discussion (see Appendix)

Respiration

All treatments (except control) followed the same pattern of an initial peak in respiration in the first couple of weeks and then a steady decline in the remaining weeks (Fig. 3). The cardboard only treatment had a small increase in respiration peaking at three weeks after addition of amendments at about 1.39 µg $C\text{-}CO_2$/g soil/hr. The kelp only treatment peaked much earlier at one week with a rate of 4.20 µg $C\text{-}CO_2$/g soil/hr. The kelp and cardboard combination treatments peaked between 1-2 weeks but declined less than the other treatments in the following weeks indicating that the amendment was continuing to provide resources throughout the experiment. The low C:N ratio of the kelp only treatment explains why we see this rapid increase and then decrease for that treatment, there is little carbon for the microbes to use and once it is used up activity declines. The very high C:N ratio of the cardboard only provides a lot of carbon for the microbes to use but without other nutrients the carbon is not very accessible which is why we see a slower and lower overall peak. The combination of the kelp and cardboard helps to balance out the carbon and nitrogen needs of the microbes providing them with a steady supply of nutrients.

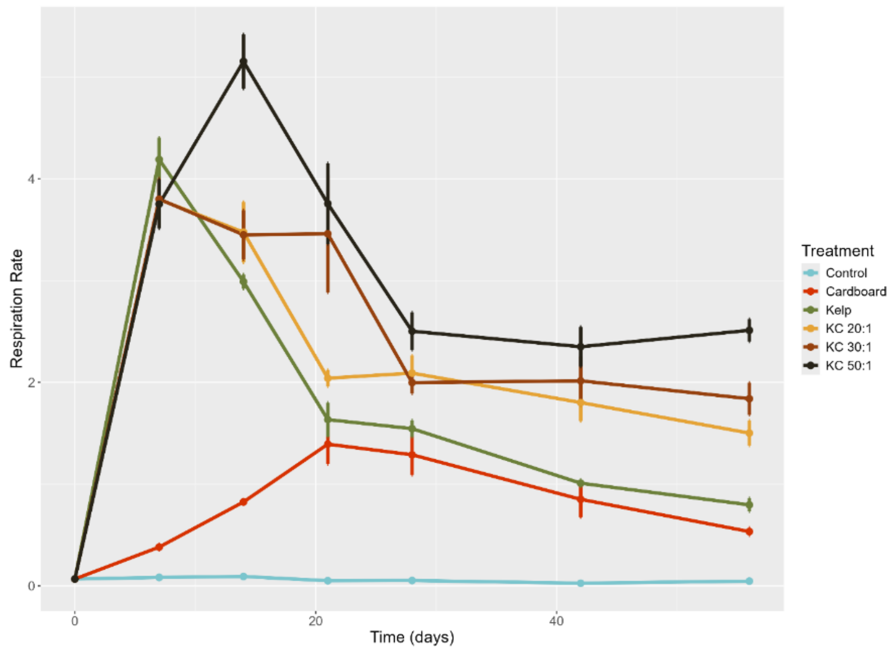

Figure 3: Respiration rates (µg C-CO_2/g soil/hr) for each treatment throughout the 56 day incubation. Control in blue, cardboard only in red, kelp only in green, kelp + cardboard 20:1 in orange, kelp + cardboard 30:1 in brown, kelp + cardboard 50:1 in black.

<u>Microbial Biomass</u>

Microbial biomass of both kelp only and the kelp combined with cardboard treatments increased compared to the control and the cardboard only treatments (Fig. 4). We see this pattern most strongly on Day 14 when the control and cardboard only treatments have an average biomass of 25.67 and 25.40 µg C/g soil, respectively. The kelp only treatment had the next highest biomass of 146.35 and the kelp + cardboard treatments had the highest biomass of 473.32, 505.56, and 404.22 for the 20:1, 30:1, and 50:1 treatments, respectively. Though the biomass decreased on days 28 and 42, the kelp combined with cardboard continued to result in a greater biomass compared to the control and cardboard only treatments. This decrease could be due to lower activity due to resource depletion. It is also natural for microbial populations to turnover in the soil, so these measurements tend to fluctuate on short-time scales. We have yet to evaluate microbial biomass for Day 56.

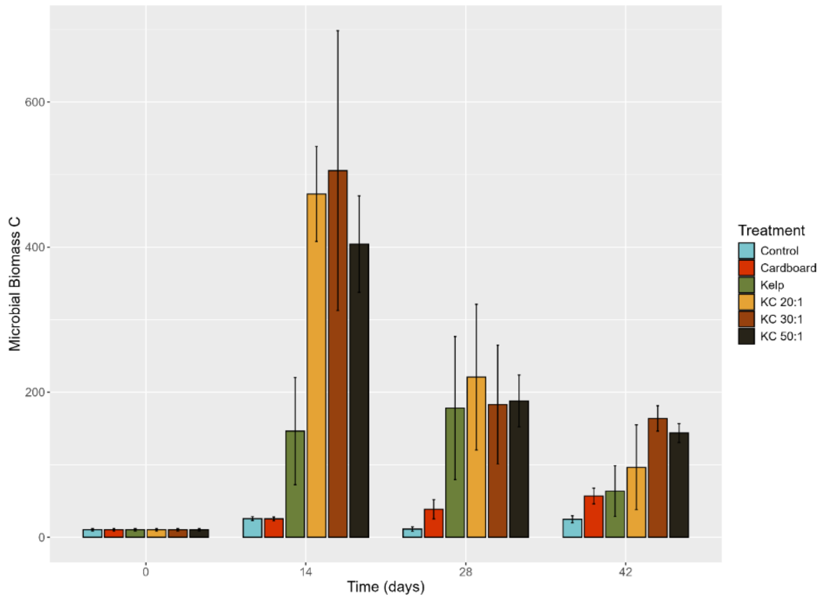

Figure 4: Microbial biomass carbon for each treatment throughout the 56-day incubation.

<u>Available N</u>

For all kelp amended treatments, available N increased relative to the control within the first week of incubation (Fig. 5). Most of this nitrogen was in the form of ammonium rather than nitrate. For the kelp only treatment there was rapid increase in nitrogen within the first week and then a steady increase throughout the rest of the experiment as the kelp was broken down and nitrogen released. The K + C (20:1) had the next highest nitrogen availability following a similar pattern to the kelp only treatment. K + C (30:1 and 50:1) both had initial increases and then less N was released throughout the rest of the experiment. This indicates that the kelp itself probably had a lot of available N already and the microbes did not need to convert it. This may be why we see an initial increase in all kelp treatments. The higher carbon content relative to nitrogen results in the immobilization of some of that N by the microbes to maintain an ideal C:N ratio. The cardboard only treatment did not release nitrogen with N availability being lower than the control throughout the experiment meaning that the microbes were completely immobilizing N in those

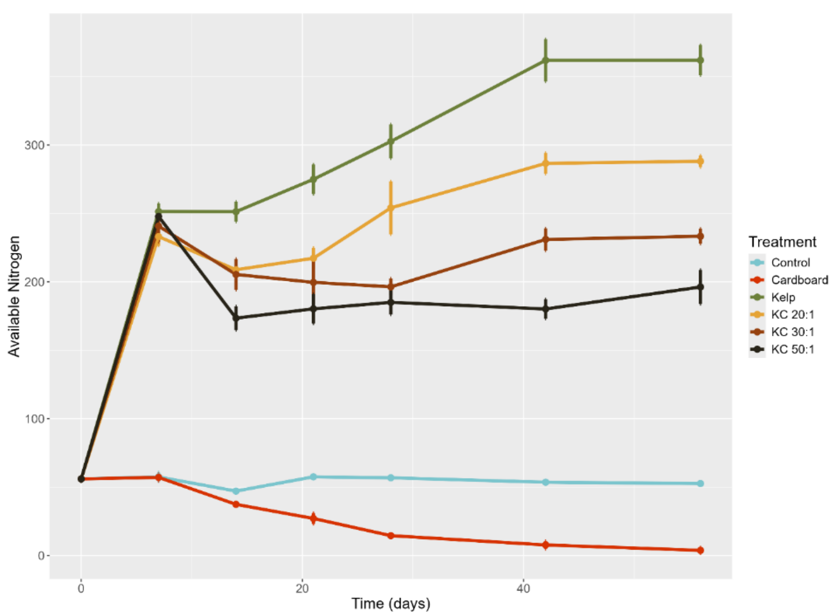

Figure 5: Available nitrogen (µg N/g soil) for each treatment throughout the incubation period. Available N is the sum of N in the forms of nitrate and ammonium.

treatments. In past experiments we have typically found that the microbes tend to immobilize nitrogen for the first 2-3 weeks after addition of kelp to the soil before releasing it. However, in this case the kelp appeared to have high concentrations of ammonium that provided available N immediately.

<u>POXC</u>

The POXC concentration increased in all kelp amendments but not in the control or cardboard only amendment (Fig. 6). There were no distinguishable differences between the kelp or kelp + cardboard amendments. The increase in POXC indicates that the microbes are using the carbon from the kelp and the cardboard and turning it over in the soil rather than just respiring it off. *This is an indication that kelp could help to increase the organic carbon content in soil in the longer term.*

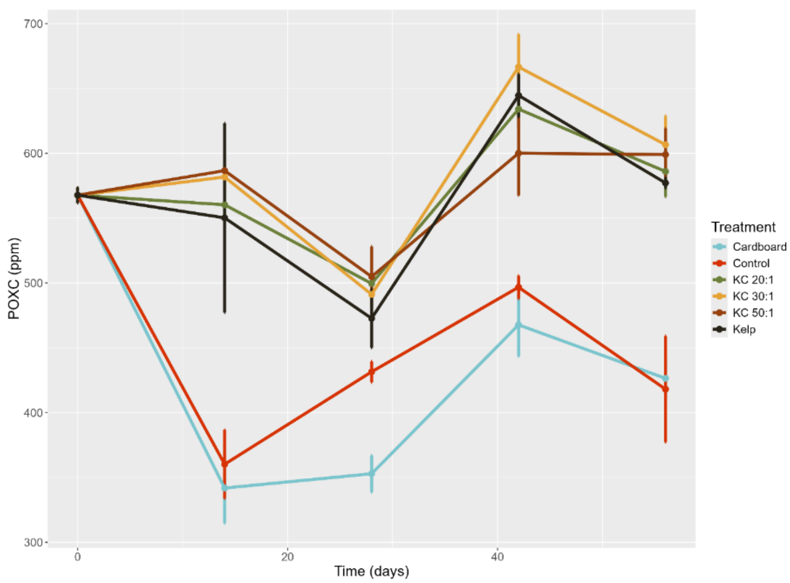

Figure 6: Permanganate oxidizable carbon (POXC) for each treatment throughout the 56-day incubation.

<u>Soil pH</u>

Both the kelp and the cardboard amendments increased soil pH from a baseline of about 5.6 to over 7 in the kelp amendments and up to 6.9 by day 56 in the cardboard only treatment (Fig. 7, Table 1). In last winter's lab experiments we saw a slight increase in pH with the kelp amended soils but we did not see this replicated in the field. Like salinity (below), it could be that the compounds that are increasing soil pH get washed out of the field. It should also be noted that when amending soils, pH can initially fluctuate. It is unclear what would occur in the long run. As microbes continue to break down these amendments, we may see pH go up and down.

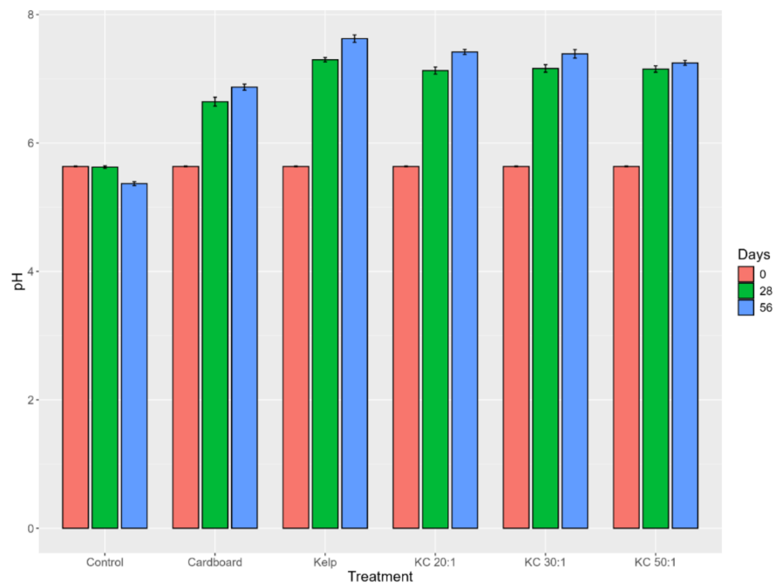

Figure 7: Soil pH for each treatment at 0, 28, and 56 days of incubation.

<u>Salinity</u>

Kelp amendments increased the salinity of the soil significantly (Fig. 8). This was also the case in the 2025 lab experiments. Even with rinsing kelp with freshwater it is difficult to completely desalinate it. We have observed that salts tend to build up in the soils of closed systems (mason jars) when kelp is added. However, our field experiments did not have the same issue as the salt washed out of the soil. Salinity is an issue to consider when working in closed systems (e.g. potted plants, hydroponics) as it can inhibit plant growth.

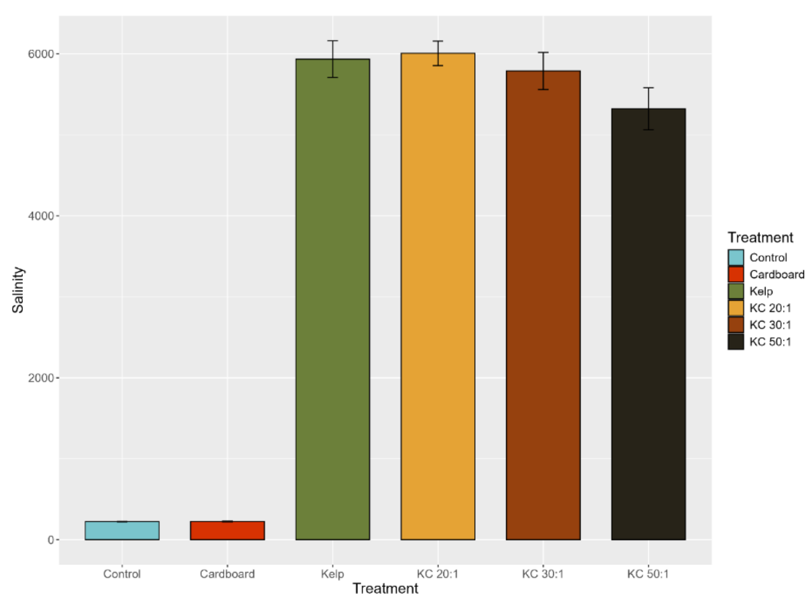

Figure 8: Salinity ($EC_{1:5}$, µS/cm) at Day 7 for each treatment

Conclusions

- Overall these experiments show that the combination of kelp and cardboard is an effective way to boost microbial activity (respiration and biomass production). The kelp only treatments also boosted these metrics but the combination of the two materials resulted in a significantly greater increase in both metrics.

- The kelp only treatment provided the greatest amount of available N but the kelp and cardboard amendments also provided increased N relative to the control and the lower N availability may result in keeping more N in the system in the long-term. These experiments were done in a closed system so the available N builds up throughout the experiments but in a field setting the excess N will either be taken up by plants or lost from the soil via leaching out.

- *All kelp treatments (with and without cardboard) increased POXC concentrations relative to the control and the cardboard only treatments indicating that these amendments are increasing the amount of carbon in the soil. Though it will likely require longer time scales to see larger and long-lasting changes in this pool of C.*

- Cardboard on its own is not an effective soil amendment though it is often used for weed control in home gardens.

- This summer we will test these treatments in field trials using zucchini as the test crop. Results in the field will likely differ from the lab as these results only give us an idea of the potential of these amendments to boost soil health.

Task 2: Field Trials

Planning for the 2026 field season is underway. Experimental design is currently under refinement based on the above laboratory findings including the selection of amendment types and carbon to nitrogen ratios for testing under field conditions. Crop selection has also been informed by previous trials with a shift toward more nutrient-demanding crops to better evaluate treatment effects like zucchini.

Site preparation planning is ongoing. We are currently coordinating with Dr. Oliver and the Matanuska Experimental Farm where they are developing sampling protocols for soil and crop measurements. Field trials will begin in late May/early June and will build directly on both our previous work in 2025 and the 2026 laboratory results.

Task 3: Support Prince William Sound Kelp Farmers

Coordination with Prince William Sound kelp farmers has continued throughout the reporting period. Requests have been sent to three local farms to secure 4,000 pounds of sugar kelp for use in the project. These three farms include Royal Ocean Kelp Company, WildBlue Mariculture, and Noble Ocean Farms. Follow-up communication has focused on confirming availability, harvest timing, and logistics for processing and transport.

This work supports local mariculture operations while ensuring a consistent supply of material for research.

Task 4: Project Administration and Reporting

Project management and coordination have continued throughout the reporting period. This includes financial tracking, procurement, partner coordination, and reporting. Communication between NVE and Washington State University has supported successful completion of laboratory trials and preparation for field work.

Administrative work has ensured that the project remains on schedule and aligned with contract requirements. Reporting and invoicing have been completed in accordance with Southeast Conference guidelines.

Collaboration with UAF Alaska Center for Energy and Power

We coordinated with the UAF Alaska Center for Energy and Power through direct information sharing and technical support. During this reporting period, their project team reached out following challenges with greenhouse trials. We met with the project fellow responsible for implementation to review their methods and results. They presented their approach and unsuccessful outcomes using kelp and glacial silt to grow butterhead lettuce. We shared findings from our kelp soil amendment work conducted previously. Based on our experience and existing data, we provided technical guidance on kelp processing methods and appropriate amendment rates for different laboratory treatments that would yield successful results for their study. This coordination has helped inform their ongoing work and supports broader understanding of kelp-based soil amendments across projects.

Next Steps

- Complete kelp purchasing, processing, and transport to Palmer
- Begin field trials during the summer 2026 growing season
- Apply kelp and kelp and cardboard amendments to field plots
- Monitor soil health, nutrient availability, and crop growth
- Continue coordination with project partners
- Prepare next quarterly report with field data

Appendix

Soil health results (average values) for each treatment

Metric	Treatment	Day						
		0	7	14	21	28	42	56
Respiration Rate (µg C-CO_2/g soil/hr)	Control	0.07	0.08	0.09	0.05	0.05	0.03	0.05
	Cardboard	0.07	0.38	0.82	1.39	1.28	0.85	0.53
	Kelp	0.07	4.19	2.99	1.63	1.54	1.01	0.80
	K + C (20:1)	0.07	3.80	3.48	2.04	2.09	1.80	1.50
	K + C (30:1)	0.07	3.80	3.45	3.46	2.00	2.01	1.84
	K + C (50:1)	0.07	3.75	5.15	3.76	2.50	2.35	2.51
Microbial Biomass (µg C/g soil)	Control	10.28	-	25.67	-	11.33	24.81	-
	Cardboard	10.28	-	25.40	-	38.56	56.84	-
	Kelp	10.28	-	146.35	-	178.08	63.46	-
	K + C (20:1)	10.28	-	473.32	-	220.79	96.39	-
	K + C (30:1)	10.28	-	505.56	-	183.04	163.81	-
	K + C (50:1)	10.28	-	404.22	-	188.00	143.69	-
Available N (µg N/g soil)	Control	56.02	57.47	47.14	57.56	56.85	53.63	52.65
	Cardboard	56.02	57.14	37.44	27.15	14.58	7.79	3.84
	Kelp	56.02	251.39	251.31	274.95	302.61	361.92	361.97
	K + C (20:1)	56.02	233.08	208.88	217.29	254.08	286.61	288.12
	K + C (30:1)	56.02	240.76	205.44	199.66	196.38	231.01	233.33
	K + C (50:1)	56.02	247.80	173.43	180.30	185.06	180.21	196.25
POXC (ppm)	Control	567.75	-	360.24	-	431.54	496.75	418.13
	Cardboard	567.75	-	341.89	-	352.92	467.73	426.49
	Kelp	567.75	-	550.26	-	472.76	644.69	577.17
	K + C (20:1)	567.75	-	560.36	-	499.61	634.15	586.02
	K + C (30:1)	567.75	-	581.76	-	491.22	666.64	606.69
	K + C (50:1)	567.75	-	586.67	-	504.89	600.11	599.07
Soil pH	Control	5.64	-	-	-	5.63	-	5.37
	Cardboard	5.64	-	-	-	6.64	-	6.87
	Kelp	5.64	-	-	-	7.30	-	7.63
	K + C (20:1)	5.64	-	-	-	7.13	-	7.42
	K + C (30:1)	5.64	-	-	-	7.16	-	7.39
	K + C (50:1)	5.64	-	-	-	7.15	-	7.25
Salinity ($EC_{1:5}$, µS/cm)	Control	266.09	223.83	-	-	-	-	-
	Cardboard	266.09	224.98	-	-	-	-	-
	Kelp	266.09	5935	-	-	-	-	-
	K + C (20:1)	266.09	6007	-	-	-	-	-
	K + C (30:1)	266.09	5788.8	-	-	-	-	-
	K + C (50:1)	266.09	5321.3	-	-	-	-	-