TOOLS FOR SELECTING ORGANIC AMENDMENTS TO IMPROVE NUTRIENT CYCLING & OVERALL SOIL HEALTH ON YOUR FARM

Oahu Farmer Soil Health Cohort - Session 5

May 10th (Tuesday) 4-6pm

Thrive Family Farms, Halewia, HI

What is an organic amendment and how can I use it to improve nutrient cycling on my farm?

Organic (carbon-based) amendments include compost and vermicompost, biochar and biosolids, manures, minerals and meals (bone, blood, fish, feather and crustaceans). These amendments provide nutrients and trace minerals in various ratios, but in lower concentrations than synthetic fertilizers. The nutrients in organic amendments are also less volatile and become available to crops slower than synthetic fertilizers. This allows nutrient reserves to build-up in the soil and increases the amount of nutrients stored in the soil.

Organic amendments are also used to add and feed soil biology, which encourage the cycling of nutrients in the soil. Increasing biological activity in the soil increases the rate of mineralization, increasing the amount of nutrients available in a form that plants can uptake.

Unlike many synthetic fertilizers, organic amendments contain carbon and are sometimes referred to as 'carbon amendments'. The ratio of carbon and nitrogen vary in organic amendments along with their ratio of NPK and other nutrients.

Why should I add carbon to my soil?

Carbon is removed from a farm system during harvests, soil erosion, and typical management activities that occur on farms. Soil organic matter oxidizes (is lost to the atmosphere) when soils are broken apart by plows, hoes, and other implements. Forms of tillage can be necessary for productive food systems but land managers should ensure that soil organic matter is also being replenished. Hawaii's subtropical climate also lends itself to faster decomposition, increasing the need for organic inputs in farm systems. Incorporating carbon amendments into your system is one way to account for your soil's carbon losses.

Soil organic carbon can be considered in two broad categories, active and stable. Active carbon is readily usable by soil organisms and promotes biological activity. Stable carbon influences the long term CEC and buffer capacity of your soil.

WHY SHOULD I ADD CARBON TO MY SOIL?

Adding to your soil provides many benefits, including:

- Increase biological activity and diversity;
- Aeration,
- Improved tilth;
- Increased cation exchange capacity (CEC);
- Buffer against soil acidification;
- Increased soil water holding capacity;
- Enhanced nutrient cycling and mineralization

Choosing an organic amendment based on your test results from the UH Crow Lab

You will be receiving information on these indicators of soil health, from the soil samples we collected with you in the previous weeks. Your results will be provided alongside expected values of that soil type. When going over your results, consider the land's historical and current management to help identify if there are areas that can be improved to enhance a soil's capacity to function.

All of the indicators below have the potential to be impacted by the level of carbon in the soil. The deviation of Total organic carbon (TOC) from the average value can guide whether the soil would benefit from incorporating a high carbon amendment into your soil or if just maintenance additions are needed to offset potential losses.

Indicator	Function and Interpretation
Physical Properties	
Bulk density (g/cm^3)	Porosity and rooting environment; lower values are better; low bulk density soils are light, porous, and promote root growth
Water holding capacity (%)	Plant water relations; higher is better
Water stable aggregates (%)	Water infiltration, porosity, aeration; higher is better; soils with a high percentage of stable aggregates promote water infiltration, hold water, have high porosity, and promote root growth
Chemical Properties	
pH	Nutrient availability; 6.0—7.0 is ideal, this is the pH range where plant essential elements are most available and toxicities are negligible
Total organic carbon (%)	Natural resource reserve and overall soil function; higher is better; TOC is a measure of the amount of soil organic matter in soil, soil organic matter benefits all aspects of soil function
Hot water extractable organic C (mg kg^{-1})	Energy source for microbes and readily mineralizable N; higher is better; this pool of extractable C is involved in aggregate formation in addition to its bioavailability
Biological Properties	
CO_2 burst (mg C kg^{-1})	Metabolic activity of microbes; high equals active microbial community
Mineralizable nitrogen (mg kg^{-1})	Soil biological activity and available substrate for N mineralization; higher is better; this is a measure of the soil's natural capability to supply plant available N
β-glucosidase (mg kg^{-1})	Microbially produced enzyme associated with C decomposition; higher is better; a measure of soil's natural ability to cycle C
β-glucosiaminidase (mg kg^{-1})	Microbially produced enzyme associated with N mineralization; higher is better, a measure of soil's natural ability to cycle N

Image above: Soil health indicators tested through UH Crow Lab.

Example: What type of organic amendment should I choose if my test results show my total organic carbon levels are low?

If your Total Organic Carbon (TOC) is lower than what is expected for your soil type, consider amending the soil with an organic amendment. Soil testing and carbon amending can be repeated annually. Web soil survey can also serve as a guide for information on the expected carbon values and your soils susceptibility to organic matter depletion.
Source: www.websoilsurvey.sc.egov.usda.gov/

In general, **compost** is carbon rich and may have high biological activating, depending on its production method. Nutrient values are going to vary with its parent material. **Biochar** is also carbon rich and very stable. It typically has a more basic, higher pH. Biosolid or manure based biochars can have significant nutrient content. Wood based biochar is lower in nutrients but can have excellent microstructure, providing habitat for microorganisms. Research has shown biochar to significantly enhance yields in sandy or acidic soils. **Manures** are also a good source of nutrients coupled with carbon. **Meals** (fish/bone/feather) or **Tankage** are nutrient rich while providing moderate sources of carbon. Locally produced tankage has been shown to average a C:N ratio of 5:1. These have the potential to result in nutrient loss to the environment if not incorporated or if over applied.

What farmers should understand about how the C:N ratio in their soil impacts nutrient cycling. - When materials are added into your soil system, whether from the breakdown of plant residue/mulches at the surface or incorporation of amendments into the subsurface, it becomes open season for all the organisms searching for nutrients. While microorganisms are essential to the retention and incorporation of nutrients, they can also compete with plants for these nutrients.

When making additions into your system, you may want to consider the C:N ratios to ensure that the new system you are promoting will not inhibit the nutrient demands of your crop. This can be achieved by trying to maintain a 24:1 ratio of your overall soil amendments, or by timing your amending to not interfere with your crop cycles. While microbes have the potential to "lock up" nutrients like nitrogen, the effect is only temporary and the nutrients will be released back in a plant-available, inorganic form.

Carbon to Nitrogen Ratios in Cropping Systems

- Soil microorganisms have a C:N ratio of approximately 8:1 in their bodies. To maintain themselves, they consume a 24:1 ratio of C:N from their environment.
- If the microbes are consuming substances with ratios of C:N greater than this, such as 563:1 measured in cardboard, the microbes will source additional nitrogen from the soil environment. This leads to nitrogen **immobilization**.
- If the microbes are consuming substances with ratios of C:N less than this, such as 4:1 measured in fish wastes , the microbes will release nitrogen back into the soil in a plant-available form. This leads to nitrogen **mineralization**.

Mineralization and Immobilization

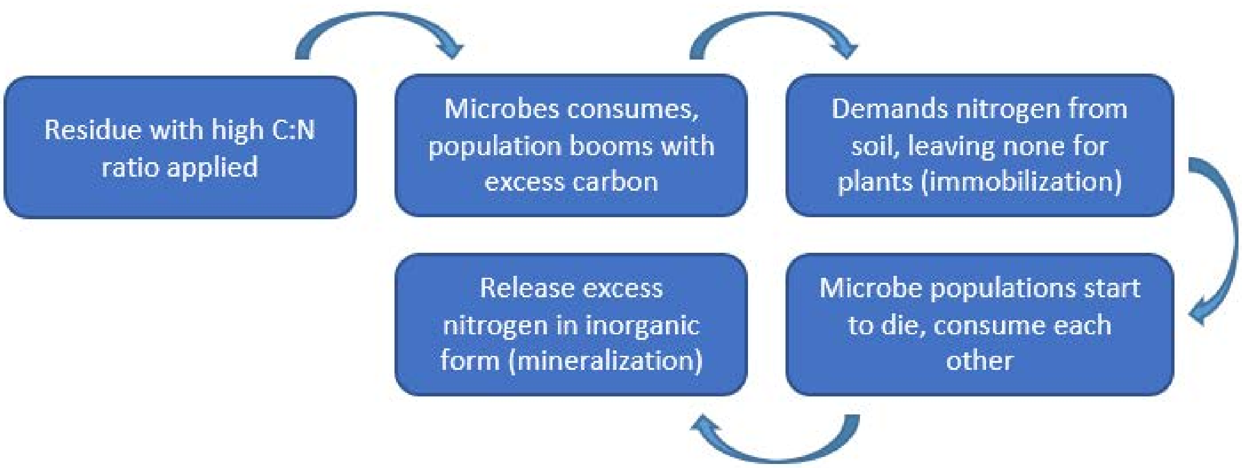
Nitrogen Mineralization is the process of microbes taking organic forms of nitrogen such as manure, organic matter, or crop residue and converting them to an inorganic forms of nitrogen, ammonium. Because it is a biological process, rates of mineralization vary with soil temperature, moisture and the amount of oxygen in the soil (aeration).

Mineralization

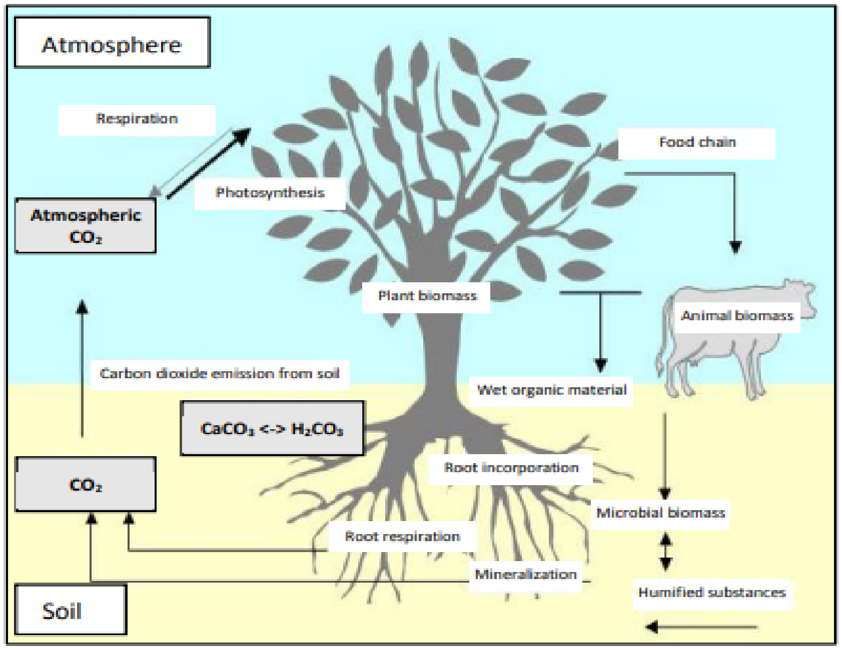
Nitrogen Immobilization is the process of soil organisms consuming nitrate and ammonium, therefore becoming unavailable to crops. Incorporation of materials with a high carbon to nitrogen ratio (e.g. sawdust, straw, etc.), will increase biological activity and cause a greater demand for N, and thus result in N immobilization.

Immobilization only temporarily locks up N. When the microorganisms die, the organic N contained in their cells is converted into ammonium through **mineralization** and then nitrification transforms it to nitrate. A good rule of thumb to reduce the risk of immobilization is to ensure the carbon to nitrogen ratio of an amendment is not higher than ~24:1

Immobilization



What farmers should understand about the nutrient cycling and compounds of carbon?



Carbon Cycling on your Farm

<u>Increasing nutrient cycling by increasing the supply of 'active' and 'stable' carbon in the soil:</u>

- Carbon is taken in from the atmosphere and assembled into plant biomass.
- Carbon is excreted through the respiration and exudates of living plants.
- Carbon from the biomass of non-living plants is released to the atmosphere or incorporated into the soil as organic matter.

<u>Increasing nutrient cycling by using carbon to improve the physical and chemical properties of soil:</u>

- Increasing the amount of carbon in soil results in increased soil aggregate stability;
- Increasing soil aggregate stability improves physical properties of the soil which improve soil aeration (oxygen in the soil), improves conditions for healthy plant roots and the production of root exudates, provides habitat for soil microbes and improves water drainage and retention.
- Soil organic carbon is also important to chemical composition and biological productivity. Adding carbon to the soil supports the growth of soil biology and increases the nutrient holding capacity and reduces nutrient leaching.

CARBON CATEGORIES

Active (days-years)

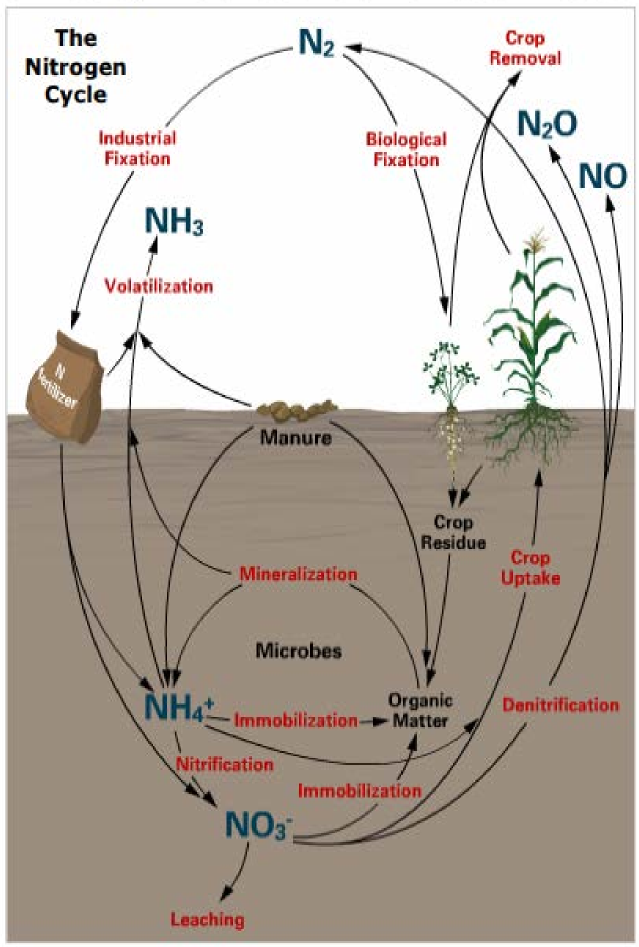
Dead organisms, root exudates, dissolved organic carbon, particulate soil organic matter

Stable (decades-centuries)

Mineral- associated –adsorbed onto mineral soil particles (e.g. clay)

What farmers should understand about the nutrient cycling and compounds of nitrogen?

Nitrogen Cycle



Nitrogen Cycling on your Farm

<u>Increasing nutrient cycling by increasing the supply of nitrogen in the soil:</u> Bacteria and algae 'fix' nitrogen by pulling it from the air and storing it in the soil. As plant biomass break down to form organic matter, nitrogen and carbon are stored in the soil. Farmers can use practices that create greater biomass in the field and build up organic matter. These practices include leaving crop residues in the field, cover cropping, and adding green mulch. Sources of organic matter vary in the amount of nitrogen and carbon they store in the soil. Wood chips are a source of organic matter that provide higher levels of carbon, while grass provides higher levels of nitrogen.

<u>Increasing nutrient cycling by increasing the mineralization of nitrogen into compounds plants can uptake:</u> Soil biology mineralize nitrogen in the soil and make it available in a form that plants can uptake. Increasing the amount of biological activity increases the amount of nitrogen that can be broken into compounds of nitrogen (nitrate and ammonium) that plants can use.

Organic amendments with low C:N ratios, such as manure, can have both readily available forms of nitrogen (nitrates and ammonium). Manures also contain soil biology which can increase the mineralization of nitrogen into compounds that plants can uptake.

NITROGEN COMPOUND CHEAT SHEET

NH_4^+ AMMONIUM: PLANT AVAILABLE, DIRECTLY USED IN PLANT PROTEINS; RETAINED IN THE SOIL

NO_3- NITRATE: PLANT AVAILABLE, USED IN GROWTH AND DEVELOPMENT; EASILY LOST TO GROUNDWATER

N2 ATMOSPHERIC N: CANNOT BE DIRECTLY USED BY PLANTS

2NH4+ ORGANIC N: STORED IN LIVING ORGNAISMS AND ORGANIC MATTER

Soil Health Report

University of Hawai'i

College of Tropical Agriculture and Human Resources

Client: __________

Sites: __________

Soil series: Wahiawa series (Wahiawa series—Very-fine, kaolinitic, isohyperthermic Rhodic Haplustox) **Soil health** is defined as "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans" (NRCS, 2018). Healthy soils ensure that the following critical services are provided: clean air and water, productive crop and grazing lands, thriving forests, diverse wildlife and scenic landscapes." Assessing soil health requires an evaluation of the physical, chemical, and biological state of the soil. CTAHR is currently developing a soil health test that will enable farmers, ranchers, and land managers monitor the effects of land use on soil health. The first step in this process is to select a suite of indicators (measurements) that best describe the physical, chemical, and biological state of a soil. This report presents results of a preliminary set of indicators best suited to characterizing soil health for Hawaii's diverse soils and landscapes. In Table 1 we present these indicators for soil physical, chemical, and biological properties and describe the significance of each indicator in relation to soil function.

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Field size (acres)	Rate	CuYd needed	Location	Delivery cost (HI Earth)	Delivery cost (Island TS)	Compost cost (Island TS)	Compost Cost (HI Earth)	Total Costs (Island TS)	Total Cost / CuYD (Island TS)	Total Costs (HI Earth)	Total Cost / CuYd (HI Earth)
0.125	Low (2 tons/acre)	0.5	North Shore Region	$125	$200	$19	$20	$219	$437	$145	$290
0.125	Medium (5 tons/acre)	1.25	North Shore Region	$125	$200	$46	$50	$246	$197	$175	$140
0.125	High (10 tons/acre)	2.5	North Shore Region	$125	$200	$93	$100	$293	$117	$225	$90
0.125	Xtra High (20 tons/acre)	5	North Shore Region	$125	$200	$185	$200	$385	$77	$325	$65
1	Low (2 tons/acre)	4	North Shore Region	$125	$200	$148	$160	$348	$87	$285	$71
1	Medium (5 tons/acre)	10	North Shore Region	$193	$400	$370	$400	$770	$77	$593	$59
1	High (10 tons/acre)	20	North Shore Region	$213	$450	$740	$800	$1,190	$60	$1,013	$51
1	Xtra High (20 tons/acre)	40	North Shore Region	$406	$950	$1,480	$1,600	$2,430	$61	$2,006	$50
2	Low (2 tons/acre)	8	North Shore Region	$193	$400	$296	$320	$696	$87	$513	$64
2	Medium (5 tons/acre)	20	North Shore Region	$213	$450	$740	$800	$1,190	$60	$1,013	$51
2	High (10 tons/acre)	40	North Shore Region	$406	$950	$1,480	$1,600	$2,430	$61	$2,006	$50
2	Xtra High (20 tons/acre)	80	North Shore Region	$639	$1,550	$2,960	$3,200	$4,510	$56	$3,839	$48
2.5	Low (2 tons/acre)	10	North Shore Region	$193	$400	$370	$400	$770	$77	$593	$59
2.5	Medium (5 tons/acre)	25	North Shore Region	$213	$450	$925	$1,000	$1,375	$55	$1,213	$49
2.5	High (10 tons/acre)	50	North Shore Region	$406	$900	$1,850	$2,000	$2,750	$55	$2,406	$48
2.5	Xtra High (20 tons/acre)	100	North Shore Region	$832	$1,800	$3,700	$4,000	$5,500	$55	$4,832	$48
5	Low (2 tons/acre)	20	North Shore Region	$213	$450	$740	$800	$1,190	$60	$1,013	$51
5	Medium (5 tons/acre)	50	North Shore Region	$426	$900	$1,850	$2,000	$2,750	$55	$2,426	$49
5	High (10 tons/acre)	100	North Shore Region	$832	$1,800	$3,700	$4,000	$5,500	$55	$4,832	$48
5	Xtra High (20 tons/acre)	200	North Shore Region	$1,491	$3,600	$7,400	$8,000	$11,000	$55	$9,491	$47