Healthy Soils Hawaii Year 1 Final Report for Office of Planning and Hawaii State Greenhouse Gas Sequestration Task Force

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Healthy Soils Hawaii (HSH) is a one year pilot program that worked with farmers and ranchers to identify best management practices (BMPs) that sequester carbon in soil, increase soil health, and reduce greenhouse gas (GHG) emissions. The HSH team consisted of Jayme Barton of Hawaii Agriculture Research Center, PI, and Stephanie Mock of Oahu RC&D, Co-PI. The project was housed under the Hawaii Agriculture Research Center (HARC), a 120 year old organization with extensive experience in soil science research and agricultural outreach throughout the state of Hawaii.

HARC has partnered with the Natural Resources Conservation Service (NRCS) on several conservation related projects ranging from improvements in soil health to recommendations for new and improved BMPs in forestry systems and more for many years. Since 2014 the program PI has worked closely on soil health-related research and BMP improvements and outreach for farmers, ranchers and landowners in Hawaii. Through this partnership, she has traveled and taught soil health practices and principles to producers in Hawaii through educational workshops, presentations and field days. In 2018, the PI started working closely with NRCS, Colorado State University, and University of Hawaii Manoa College of Tropical Agriculture (CTAHR) to begin compiling data that will be used to update NRCS tools COMET Planner and COMET Farm. These tools are used in the continental 48 states to calculate GHG benefits of BMPs on working lands, but are not calibrated for use in the state of Hawaii yet.

The PI has also worked in collaboration with Oahu Resource Conservation and Development Council (Oʻahu RC&D) on conservation related projects since 2010. Collaboration has included research on crops to use for conservation cover, cover crops, erosion control, soil and water conservation, and several projects working with farmers & ranchers to implement climate-smart best management practices on their land. The HSH team has also been in attendance at most all of the Greenhouse Gas Sequestration Task Force meetings as active participants.

Purpose of Healthy Soils Hawaii

The goal of assessing soil health is to determine how land use changes and management practices impact the ability of soils to perform functions that support ecosystems and productivity. Management choices can either aggrade or degrade soil health over time as they impact the chemical, physical, and biological properties of soils. When each of these properties is functioning optimally an ecosystem will see positive changes and impacts that can lead to beneficial outcomes for air and water quality, ground water recharge, nearshore ecosystem resilience, increased drought tolerance, reduced impacts of flooding, crop and livestock productivity, and others. Building and measuring soil health has become an increasingly important task as we face global climate challenges such as drought, intense storms, increased greenhouse gas emissions, and limited resources needed for food production such as water and nutrients. Healthy soils are rich in carbon, the building block of soil organic matter that gives soil its structure, fertility and water holding capacity. Healthy soils provide ecosystem services and benefits that go far beyond the farm and can help Hawaii mitigate the stressful impacts of climate change from Mauka to Makai.

Our unique and beautiful state boasts nearly all soil types and microclimates. Some of our soils have incredibly high organic matter and carbon content, while others are depleted through years of intensive cultivation. A recent study through the University of Hawaii conducted at a Maui Ranch highlighted the immense amount of carbon tied up in their soils from excellent management of their grazing lands. Their use of best management practices was able to not only maintain the natural state of carbon in the soil, but potentially increase soil carbon content over time through good pasture management. There are nearly 900,000 acres of ranchland in production in the state of Hawaii. Many of these lands are well maintained and continue to provide ecosystem services for the state but may have the possibility of storing more carbon through enhanced management strategies aimed at improving soil health and increasing carbon storage in the soil. Additionally, some of Hawaii's farmlands reside on soils that commonly have lower organic matter content, and in some cases are very depleted of soil carbon due to years of intensive tillage. These highly degraded lands have huge potential to sequester carbon with the use of BMPs such as covering the soil with short- or long-term cover crops, agroforestry plantings, the use of compost, improved nutrient management, minimizing soil tillage and disturbance, and many others.

The impact of soil health improvement provides benefits that support farmers, ranchers, forests, watersheds, streams and waterways, and nearshore marine ecosystems. They provide better water quality and better air quality which is important for human health. The partnerships made during the pilot program include stakeholders representing each of these unique ecosystems in Hawaii, and the efforts of these organizations point to a collaborative opportunity to improve multiple ecosystem resources with a specific focus on soil health improvement.

Statewide Need for Soil Health BMPs

In 2018, Governor David Ige and the state of Hawaii signed into law House Bill 2182 which makes permanent the Greenhouse Gas Sequestration Task Force. This task force will focus on reduction of greenhouse gas emissions, carbon sequestration, and support best management practices that improve soil health which will directly impact farmers and ranchers. Many of the task force objectives require cooperation from large and small farms throughout the state in order to implement best practices to sequester carbon. A program in California called the California Healthy Soils Initiative is several years underway and supporting their farmers and ranchers through incentive payments to implement BMPs, and Soil Health improvement pilot programs are starting up in Colorado and several other states. The California program works directly with producers to implement BMPs that increase sequestration of carbon in soil, increase organic matter, reduce tillage, reduce other greenhouse gas emissions, and provide many other benefits on farms and ranches. The program works side by side with NRCS and other state agencies using their existing BMPs to promote healthy soils on California lands. Healthy Soils Hawaii learned from the California Healthy Soils Initiative, the Carbon Cycle Institute, and in-person meetings with California ranchers who participated in this program. HSH incorporated information based on successes and challenges reported and applied/adapted many of the same practices for the Hawaii pilot program. Funding to support Healthy Soils Hawaii came from both the Natural Resource Conservation Service and the State of Hawaii Office of Planning Greenhouse Gas Sequestration Task Force, which helped the program expand its reach to both Oahu and Maui and work with significantly larger operations.

In addition to outreach and education, this program looked at implementation of BMPs on farms that may otherwise not participate in traditional NRCS programs for various reasons. The management practice payments rates were identified as an area for future focus for adjustment as many of the rates for practices are best suited for large farms with very large acreage. Over 77% of Hawaiian farms are less than 20 acres, with the median farm size being closer to 5 acres. Many farms operate with short term leases which preclude them from participation in many NRCS cost-share programs that would otherwise provide some funding for BMP installation. With the high cost of farmland in Hawaii small-scale leases are expected to persist and one of the better ways to reach these farms is to offer incentives that make more financial sense for them and are accessible. Many of the large ranches in Hawaii are also precluded from traditional cost-share programs due to AGI restrictions, though this may have changed in the new iteration of the Farm Bill. There are limited or cost-share programs offered by the state of Hawaii. HSH used a combination of outreach and BMP installation using a flat rate honorarium payment for the first year to allow time to better identify costs associated with each BMP, increase adoption of soil health techniques on farms and ranches, and have greater impact on soil health and greenhouse gas reduction statewide.

Healthy Soils Hawaii Objectives for Year 1:

1. To work with at least 5 farmers and ranchers that collectively manage at least 20 acres on Oahu to implement best management practices (BMPs) that support soil health in Hawaii.
2. To make incentive payments available to producers that support installation of soil health BMPs.
3. To educate the farming community on the benefits of soil health practices for carbon sequestration, reduced greenhouse gas emissions, and improvement in ecosystems services.

Healthy Soils Hawaii Mission:

To highlight the ecosystem services provided by Hawaii's farmers and ranchers as stewards of the land, and to support their efforts to improve ecosystem services through improved land management.

Year 1 Deliverables:

Farms and ranches were invited to establish demonstration plantings and management strategies of BMPs known to improve soil health and sequester carbon. Farmers and ranchers were selected based on their proven track record of participation in soil health related projects to ensure completion of BMP installation and deliverables of this project. Technical assistance was provided to each producer as needed to identify and install various BMPs, and to identify other potential resource concerns. The HSH team conducted several site visits for each farm/ranch to discuss BMP location and take soil samples in the untreated control area (no BMP installation area) and the BMP installation site. Soil samples were sent for analysis to the University of Hawaii Crow Lab and reports were generated on the health of the soil, as discussed in further detail below.

Phase 1 of the project focused on contacting, interviewing, and/or partnering with various stakeholders both in Hawaii and nationally with similar objectives. The goal of this phase was to incorporate lessons learned from other organizations and states such as the California Healthy Soils Initiative, as well as involve non-traditional partners for production agriculture such as those working in marine conservation, various state offices, forestry and others. HSH networked and partnered with over 20 organizations in both Hawaii and California in order to bring the best available data, science, land managers, program managers, policy makers and more to the table in order to incorporate their knowledge and feedback to support this program.

The science related to assessing soil health is evolving, as are the protocols and identified soil health indicators. Soils and ecosystems worldwide are diverse, and regionally based soil health indicators are being used throughout the United States. HSH networked with the University of Hawaii who is building out a Hawaii Soil Health Tool that will be available in the future to farmers and ranchers. The UH Soil Health Tool builds upon the best available global soil health research and provides a local context that is able to more accurately predict changes in soil health in Hawaii's unique volcanic soils, which currently can not be measured as accurately by other available soil health tools. HSH also began discussions with NRCS and Colorado State University to learn more about the COMET Planner and COMET Farm tools which account for management changes to productions systems and calculate GHG emissions, reductions, and carbon sequestration. HSH is committed to supporting NRCS in their efforts to update and make available these tools so that they may be reliably and accurately used in Hawaii.

HSH worked with producers in the program, as well as surveyed producers statewide, to identify possible barriers to implementation of soil health BMPs. This data will be discussed in detail later in this paper, however one of the barriers identified immediately was cost. HSH chose not to follow the California Healthy Soils Initiative incentive payment model based on feedback from producers interviewed in California, as well as applying local knowledge to the real costs of BMP installation in the islands. Due to limited budget, it was determined that a standard flat-rate honorarium would be paid to each participant in the program for this pilot program and that future work would need to focus more heavily on accounting for true costs associated with various BMPs.

Healthy Soils Hawaii Year 1 Results:

HSH was able to exceed its original proposal and partner with 5 producers on both Maui and Oahu which collectively manage over 41,000 acres. Our producers used over 10 climate-smart best management practices on their lands including but not limited to: no-till, reduced-tillage, cover crops, adaptive holistic grazing management, crop rotation, and compost additions, irrigation management and more.

Outreach:

Partnerships and outreach were identified as a very important component of running a successful program and HSH was able to network with over 20 organizations in HI and CA, as well as present on soil health at over 10 conferences or meetings including: a panel and presentation at the Hawaii Agriculture Conference, a digital poster at the Hawaii Conservation Conference, a presentation for the State of Hawaii Greenhouse Gas Sequestration Task Force, The Hawaii Cattleman’s Council, the HCA Ecosystem Services Committee meeting at Haleakala Ranch, The Carbon Cycle Institute and its California ranching partners, a Sustainable Agriculture Panel for Purple Mai’a Foundation, a Soil Health presentation for the Hawaii Coffee Association Annual Meeting, an agriculture advocate at the US Climate Alliance Natural and Working Lands Learning Lab, a publication in the Sierra Club of Hawaii newsletter, and organized a Climate-Smart Agriculture stakeholder meeting with participants from state and federal government agencies, non-profits, trade and industry groups, farmers, ranchers, and local politician staffers.

Soil Health Data

Soil health reports were generated by the University of Hawaii Crow Lab where Dr. Susan Crow, Dr. Johnathan Deenik and PhD Candidate Elaine Vizka ran samples through a beta version of their Hawaii Soil Health Tool. Due to the limited time of the project and the required time it takes to measure changes in soil health and soil carbon, measurements where taken from an area where producers were using some combination of BMPs for at least 2 years and compared with a control plot very nearby that was the same soil order and climatic zone but unmanaged. Most of the unmanaged sites were expected to be managed in the future, and both sites may be used as a baseline for future soil analysis of BMP potential on soil carbon and soil health. The following Hawaii Soil Health Tool reports and analysis were shared with producers, with discussion flowing each report:

Soil Health Report

University of Hawai'i
College of Tropical Agriculture and Human Resources

Farm: [redacted]
Site: Cultivated field and uncultivated grass area
Soil series: Kula series

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 tool that will enable farmers, ranchers, and land managers monitor the effects on land use. 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 the indicators best suited to characterizing soil health for Hawaii's diverse soils and landscapes. In Table 1 we present the indicators for soil physical, chemical, and biological properties and describe the significance of each indicator in relation to soil function.

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, soil's ability to hold water
Water stable aggregates (%)	Water infiltration, porosity, aeration; higher is better; soil's ability to hold/transmit water, promote root growth, and resist erosion
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; measure of the amount of soil organic matter in soil, soil organic matter benefits all aspects of soil function
Carbon-to-nitrogen ratio (C:N)	Nutrient supply; higher is better for carbon sequestration; optimal plant growth range is 6-10
Biological Properties	
CO_2 burst (µg/g)	Metabolic activity and biomass of microbes; high equals active microbial community
Mineralizable nitrogen (µg/g)	Soil biological activity and available substrate for N mineralization; higher is better; measure of the soil's natural capability to supply plant available N

Results

Indicator	Site	
	Uncultivated	Cultivated
Physical Properties		
Bulk density (g/cm^3)	1.28(±0.03)	0.94(±0.05)
Water holding capacity (%)	73.26(±0.49)	83.23(±2.91)
Mega water stable aggregates (%)	6.72(±2.34)	12.98(±4.86)
Chemical Properties		
pH	5.85(±0.06)	7.16(±0.02)
Total organic carbon (%)	2.24(±0.48)	3.33(±0.42)
C:N	9.94(±0.44)	10.56(±0.15)
Biological Properties		
CO_2 burst (µg/g)	32.97(±9.81)	86.01(±23.69)
Mineralizable nitrogen (µg/g)	10.45(±5.22)	17.74(±10.30)

Interpretation

In order to interpret the results, we compare results of the tests from your cultivated field to a grassy area that has not been cultivated for an extended period in the same soil type, and is an example of the natural health of this soil type.

Physical Properties: Cover cropping and additions of organic matter has decreased soil bulk density with a positive effect on water holding capacity compared with the uncultivated soil. A lower bulk density means that the soil is "lighter" with more pore space to hold water and air. The increases in soil organic matter and decreases in bulk density associated with cover cropping and organic management has increase water stable aggregates.
Chemical Properties: Current soil management practices show a clear increase in soil pH, which, in this case, has positive impacts on nutrient availability. Soil carbon and C:N ratio were not affected by management and fall within the expected range for this soil type.
Biological Properties: Soil biology depends primarily on soil organic matter; as soil organic matter increases we expect increases in soil biological activity. We observe a clear increase in the CO_2 burst in the cultivated soil, accompanied by an increase in mineralizable N, which indicates higher biological activity.

Overall, current farmer practices have had a positive effect on soil health.

Recommendation

Current cultivated management practices has a general greater soil health than uncultivated. Continue as long crop productivity is maintained at desired level.

BMPS used: Cover cropping, crop rotation, compost additions, organic production, vermicompost, compost tea

Resource concerns: Ponding and flooding with heavy rains, Soil disturbance to make raised beds but otherwise not extensive disturbance, hard pan about 1ft depth

Limitations: Cost for amendments, time

Discussion: Recommendation to farmer to consider deep ripping soil at end of crop season and immediately incorporate a deep rooted cover crop to keep soil pore spaces filled with living roots. This may help to address ponding over time, although this soil and location is known for somewhat poor drainage it can be improved with better soil structure and addressing the compaction in the plow layer.

Soil Health Report

University of Hawai'i
College of Tropical Agriculture and Human Resources

Farm: [redacted]
Site: Rotational grazing and unmanaged
Soil series: Pā'ia series

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 tool that will enable farmers, ranchers, and land managers monitor the effects on land use. 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 the indicators best suited to characterizing soil health for Hawaii's diverse soils and landscapes. In Table 1 we present the indicators for soil physical, chemical, and biological properties and describe the significance of each indicator in relation to soil function.

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, soil's ability to hold water
Water stable aggregates (%)	Water infiltration, porosity, aeration; higher is better; soil's ability to hold/transmit water, promote root growth, and resist erosion
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; measure of the amount of soil organic matter in soil, soil organic matter benefits all aspects of soil function
Carbon-to-nitrogen ratio (C:N)	Nutrient supply; higher is better for carbon sequestration; optimal plant growth range is 6-10
Biological Properties	
CO_2 burst (µg/g)	Metabolic activity and biomass of microbes; high equals active microbial community
Mineralizable nitrogen (µg/g)	Soil biological activity and available substrate for N mineralization; higher is better; measure of the soil's natural capability to supply plant available N

Results

Indicator	Site	
	Rotational grazing	Unmanaged
Physical Properties		
Bulk density (g/cm^3)	1.20(±0.07)	1.12(±0.11)
Water holding capacity (%)	65.75(±2.36)	68.88(±1.63)
Mega water stable aggregates (%)	39.07(±7.17)	36.04(±15.69)
Chemical Properties		
pH	7.76(±0.17)	7.58(±0.12)
Total organic carbon (%)	1.83(±0.10)	1.51(±0.08)
C:N	9.51(±0.17)	9.98(±0.46)
Biological Properties		
CO_2 burst (μg/g)	37.78(±5.01)	39.01(±6.08)
Mineralizable nitrogen (μg/g)	16.96(±5.88)	6.81(±4.82)

Interpretation

In order to interpret the results, we compare results of the tests from your rotational grazing area to a grassy area that has not been managed for a short period in the same soil type.

Physical Properties: Bulk density, water holding capacity, and water stable aggregates have not been affected by current rotational grazing management.
Chemical Properties: pH and C:N have not been affected by current rotational grazing management. However, rotational grazing shows a small increase in organic carbon.
Biological Properties: CO_2 burst has not been affected by current rotational grazing management indicating no change in microbial activity. Mineralizable N has increased by the grazing practices, which is expected with the additions of animal manure from the presence of cattle.

Overall, current practices have had small effects on soil health. However, over time this management practice shows potential to improve soil health.

Recommendation

Continue rotational grazing practice while focusing on increased grass cover.

BMPS used: Multi-species forages, holistic adaptive grazing management, nutrient management, fencing, cover crops, irrigation management
Resource concerns: limited rain and rely on winter rains to irrigate forages, difficult to establish forages, invasive species, extreme soil compaction, poor soil structure, labor cost very high
Limitations: labor costs, fencing costs, rain, irrigation costs
Discussion: Soil structure is an issue in the field site sampled as seen when collecting soil samples. Previous land use was 120+ years of intensive sugarcane production, the land was transitioned to smaller perennial forage grasses with less substantial root system compared to sugarcane.

These smaller root systems appeared in the field to have an impact on soil structure and bulk density, though it was difficult to determine in the lab analysis. It possible that shallower root structure combined with potential for compaction when grazed in winter on wet soils has a negative impact on soil compaction and drainage but this was only base don visual observation and not confirmed in the lab. If drainage or run off issues are seen, or poor forage root structures with shallow depth, incorporation of a deeply rooted forage may help along with avoiding grazing fields when they are wet/saturated. Increased soil carbon and mineralizable N are encouraging and should hep to improve soil health over time.

Soil Health Report

University of Hawai'i
College of Tropical Agriculture and Human Resources

Farm: [redacted]
Site: Cultivated field and uncultivated grass area
Soil series: Haleiwa series

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 tool that will enable farmers, ranchers, and land managers monitor the effects on land use. 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 the indicators best suited to characterizing soil health for Hawaii's diverse soils and landscapes. In Table 1 we present the indicators for soil physical, chemical, and biological properties and describe the significance of each indicator in relation to soil function.

Indicator	Function and Interpretation
<u>Physical Properties</u>	
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, soil's ability to hold water
Water stable aggregates (%)	Water infiltration, porosity, aeration; higher is better; soil's ability to hold/transmit water, promote root growth, and resist erosion
<u>Chemical Properties</u>	
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; measure of the amount of soil organic matter in soil, soil organic matter benefits all aspects of soil function
Carbon-to-nitrogen ratio (C:N)	Nutrient supply; higher is better for carbon sequestration; optimal plant growth range is 6-10
<u>Biological Properties</u>	
CO_2 burst (μg/g)	Metabolic activity and biomass of microbes; high equals active microbial community
Mineralizable nitrogen (μg/g)	Soil biological activity and available substrate for N mineralization; higher is better; measure of the soil's natural capability to supply plant available N

Results

Indicator	Site	
	Cultivated	Uncultivated
Physical Properties		
Bulk density (g/cm^3)	0.94(±0.08)	0.96(±0.07)
Water holding capacity (%)	78.10(±1.79)	76.74(±2.07)
Mega water stable aggregates (%)	11.94(±6.13)	9.16(±3.24)
Chemical Properties		
pH	8.03(±0.10)	8.02(±0.13)
Total organic carbon (%)	4.10(±0.35)	2.61(±0.20)
C:N	10.59(±0.34)	9.97(±0.24)
Biological Properties		
CO_2 burst (μg/g)	50.25(±6.94)	55.55(±2.05)
Mineralizable nitrogen (μg/g)	7.35(±0.64)	25.41(±1.85)

Interpretation

In order to interpret the results, we compare results of the tests from your cultivated field to a grassy area that has not been cultivated for an extended period in the same soil type, and is an example of the natural health of this soil type.

Physical Properties: Current soil management practices show no clear effect on soil physical properties. Bulk densities are relatively low for this soil type, which is desirable from a soil health stand point.
Chemical Properties: Current soil management practices show a clear increase in soil carbon, which has positive impacts on soil function. Soil pH is high under both management types, and is likely related to the influence of coral sand in the subsoil. C:N ratio was not affected by management and falls within the expected range for this soil type.
Biological Properties: Soil biology depends primarily on soil organic matter; as soil organic matter increases we expect increases in soil biological activity. However, we do not observe a change in the CO_2 burst in the cultivated soil with higher organic matter compared with the uncultivated soil. Increased soil organic matter in the cultivated soil depressed N mineralization potential, suggesting low quality carbon inputs (i.e., high C:N ratio input).

Overall, current farmer practices have not produced a clear change in soil health.

Recommendation

Although current soil management practices have increased soil orgaic matter content, the increase in soil C has had a negative effect on N mineralization potential. This condition may limit crop productivity due to potential for N deficiency. We recommend, that the farm consider applying high N organic soil amendments.

BMPS used: Cover cropping, crop rotation, compost additions, organic production, no-till,
Resource concerns: Some ponding and flooding with heavy rains
Limitations: Cost for amendments, time

Discussion: The field tested was the newest field addition to the farm with the least amount of time for BMPs to impact soil health. Its encouraging to see an increase in soil carbon, which is likely due to the use of no-till methods limiting disturbance as well as compost additions. High soil pH may cause some micronutrient deficiencies in crops and should be monitored. If pH is raising over time some irrigation management may help. Mineralizable N is low in the production site, some amendment may help to increase crop yields as well as stimulate more biological activity. When sampling, the bar soil between rows was quite hot as well, some mulch could also create a more favorable environment for biological activity, though may cause other unwanted pest pressure.

Soil Health Report

University of Hawai'i
College of Tropical Agriculture and Human Resources

Farm: [redacted]
Site: Cultivated field and uncultivated grass area
Soil series: Kula series

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 tool that will enable farmers, ranchers, and land managers monitor the effects on land use. 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 the indicators best suited to characterizing soil health for Hawaii's diverse soils and landscapes. In Table 1 we present the indicators for soil physical, chemical, and biological properties and describe the significance of each indicator in relation to soil function.

Indicator	Function and Interpretation
<u>Physical Properties</u>	
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, soil's ability to hold water
Water stable aggregates (%)	Water infiltration, porosity, aeration; higher is better; soil's ability to hold/transmit water, promote root growth, and resist erosion
<u>Chemical Properties</u>	
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; measure of the amount of soil organic matter in soil, soil organic matter benefits all aspects of soil function
Carbon-to-nitrogen ratio (C:N)	Nutrient supply; higher is better for carbon sequestration; optimal plant growth range is 6-10
<u>Biological Properties</u>	
CO_2 burst (μg/g)	Metabolic activity and biomass of microbes; high equals active microbial community
Mineralizable nitrogen (μg/g)	Soil biological activity and available substrate for N mineralization; higher is better; measure of the soil's natural capability to supply plant available N

Results

Indicator	Site	
	Uncultivated	Cultivated
Physical Properties		
Bulk density (g/cm^3)	1.50(±0.13)	0.96(±0.07)
Water holding capacity (%)	80.77(±2.35)	94.35(±0.87)
Mega water stable aggregates (%)	16.92(±6.18)	12.83(±6.08)
Chemical Properties		
pH	7.63(±0.17)	7.59(±0.09)
Total organic carbon (%)	0.99(±0.19)	2.19(±0.25)
C:N	9.64(±0.54)	10.47(±0.44)
Biological Properties		
CO_2 burst (μg/g)	30.99(±4.71)	64.24(±9.29)
Mineralizable nitrogen (μg/g)	7.52(±4.51)	15.50(±0.57)

Interpretation

In order to interpret the results, we compare results of the tests from your cultivated field to a grassy area that has not been cultivated for an extended period in the same soil type, and is an example of the natural health of this soil type.

Physical Properties: Cover cropping and additions of organic matter has decreased soil bulk density with a positive effect on water holding capacity compared with the uncultivated soil. A lower bulk density means that the soil is "lighter" with more pore space to hold water and air. While increases in soil organic matter and decreases in bulk density associated with cover cropping and organic management tend to increase water stable aggregates, in this case we have no evidence of a strong effect on water stable aggregates.
Chemical Properties: Current soil management practices show a clear increase in soil carbon, which has positive impacts on soil function. Soil pH and C:N ratio were not affected by management and fall within the expected range for this soil type.
Biological Properties: Soil biology depends primarily on soil organic matter; as soil organic matter increases we expect increases in soil biological activity. We observe a clear increase in the CO_2 burst in the cultivated soil, accompanied by an increase in mineralizable N, which indicates higher biological activity.

Overall, current farmer practices have had a positive effect on soil health.

Recommendation

Current cultivated management practices has a general greater soil health than uncultivated. Continue as long as crop productivity is maintained at desired level.

BMPS used: Cover cropping, crop rotation, compost additions, organic production, irrigation system micro irrigation, sprinkler irrigation,
Resource concerns: interested in no-till but haven't had luck due to soil structure when wet, shrink/swell clay which cracks when dry and exposed to sun
Limitations: Cost for amendments, heat stress, soil structure
Discussion: This Vertisol soil has interesting shrink/swell properties that make it challenging to attempt no-till or minimal soil disturbance due to soil cracks that appear when dry and exposed to sun. One option to attempt no-till practices would be to use a keyline plow or ripper and incorporate deeply rooted cover crops at the end of each season to maintain poor spaces in deeper soil structure and see is this helps with drainage. This is unlikely to address the soil surface cracking which makes seed germination a challenge. Overall production practices have a positive impact on soil health.

Soil Health Report

University of Hawai'i
College of Tropical Agriculture and Human Resources

Farm: [redacted]
Site: Cultivated field and uncultivated grass area
Soil series: Alaeloa series

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 tool that will enable farmers, ranchers, and land managers monitor the effects on land use. 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 the indicators best suited to characterizing soil health for Hawaii's diverse soils and landscapes. In Table 1 we present the indicators for soil physical, chemical, and biological properties and describe the significance of each indicator in relation to soil function.

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, soil's ability to hold water
Water stable aggregates (%)	Water infiltration, porosity, aeration; higher is better; soil's ability to hold/transmit water, promote root growth, and resist erosion
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; measure of the amount of soil organic matter in soil, soil organic matter benefits all aspects of soil function
Carbon-to-nitrogen ratio (C:N)	Nutrient supply; higher is better for carbon sequestration; optimal plant growth range is 6-10
Biological Properties	
CO_2 burst (µg/g)	Metabolic activity and biomass of microbes; high equals active microbial community
Mineralizable nitrogen (µg/g)	Soil biological activity and available substrate for N mineralization; higher is better; measure of the soil's natural capability to supply plant available N

Results

Indicator	Site	
	Cultivated	Uncultivated
Physical Properties		
Bulk density (g/cm^3)	0.84(±0.06)	0.99(±0.04)
Water holding capacity (%)	93.65(±4.06)	95.84(±2.96)
Mega water stable aggregates (%)	23.55(±1.66)	43.01(±13.28)
Chemical Properties		
pH	8.36(±0.06)	6.50(±0.20)
Total organic carbon (%)	4.33(±0.27)	2.62(±0.40)
C:N	12.09(±0.47)	11.38(±0.13)
Biological Properties		
CO_2 burst (μg/g)	89.02(±3.90)	66.07(±6.64)
Mineralizable nitrogen (μg/g)	13.22(±0.48)	10.43(±5.51)

Interpretation

In order to interpret the results, we compare results of the tests from your cultivated field to a grassy area that has not been cultivated for an extended period in the same soil type, and is an example of the natural health of this soil type.

Physical Properties: Current soil management practices show no clear effect on soil physical properties. Bulk densities are relatively low for this soil type, which is desirable from a soil health stand point.
Chemical Properties: Current soil management practices show a clear increase in soil carbon, which has positive impacts on soil function. Soil pH is high under both management types, and is likely related to the influence of coral sand in the subsoil. C:N ratio was not affected by management and falls within the expected range for this soil type.
Biological Properties: Soil biology depends primarily on soil organic matter; as soil organic matter increases we expect increases in soil biological activity. However, we do not observe a change in the CO_2 burst in the cultivated soil with higher organic matter compared with the uncultivated soil. Increased soil organic matter in the cultivated soil depressed N mineralization potential, suggesting low quality carbon inputs (i.e., high C:N ratio input).

Overall, current farmer practices have not produced a clear change in soil health.

Recommendation

Although current soil management practices have increased soil organic matter content, the increase in soil C has had a negative effect on N mineralization potential. This condition may limit crop productivity due to potential for N deficiency. We recommend, that the farm consider applying high N (low C:N) organic soil amendments.

BMPS used: Cover cropping, crop rotation, compost additions, organic production, tree-trimmers mulch, Limu (algae from Kaneohe bay)

Resource concerns: Severe ponding and flooding with rains, soil disturbance to make raised beds but stopped making raised beds recently, subsoil brough in from up slope to build elevation to deal with flooding, low pH

Limitations: Cost for amendments, time, labor, flooding, poor soil

Discussion: soil sample were difficult to gather, soil was compact despite low bulk density number in the lab. The pH is very high in the cultivated soil, likely due to amendments the farmer applied and not flooding as mentioned in report, uncultivated area was not amended still floods and has a low pH. Higher carbon content likely due to BMP use and an increase in diverse living roots. Contrary to the Soil Health Tool Report Interpretation section there does appear to be in increase in soil biological activity in the cultivated plot as shown in the Results section. This is likely due to increased use of BMPs at this location.

Survey Results

Producers were surveyed to identify the limitations to BMP installation, and a statewide survey was sent out to gauge the desire for producers to participate in a program that focuses on soil health improvement. Responses to the survey were received from Hawaii Island, Oahu, Maui, Molokai, and Kauai and came from several farming regions on each of these islands. Responses were received from both beginning farmers with less than 10 years of experience, as well as seasoned farmers some of whom had over 40 years farming experience. Both small and large producer responded with some as small and an acre, and others over 41,000 acres. Producers represented large and small ranching operations, both conventional and organic farming production methods, and less commonly identified farming methods such as agroforestry, mixed ranching and agricultural production, permaculture, beekeeping, nursery operations and more.

The diversity of survey respondents in size, location, and methods of production highlight the statewide interest and need for improved soil health on producers' lands. A 2015 FAO report *The Status of the World's Soil Resources* highlighted that a majority of the world's soils are in fair, poor or very poor condition and that conditions are getting worse far more often than they are improving. About 33% of the worlds land is moderately to highly degraded due to erosion, salinization, compaction, acidification, and chemical pollution. Hawaii's legacy of plantation agriculture has left many of the most highly productive soils in the state in a degraded condition, however many producers are interested in reversing this trend. Over 87% of survey respondents highlighted Soil Health as their primary resource concern, 99% said either Soil Health, Soil erosion or both, and many cited Technical Assistance as a limiting factor to adoption of BMPS. Outreach and education combined with financial incentives to support best management practices has potential to support soil health improvement rather than continue soil degradation.

Lastly the survey asked what the top limitations to BMP implementation were and in order the respondents reported: Labor 99%, Time 86%, and Money 72%. Financial incentives can help with all of these barriers if implemented in a way that accounts for the high costs of production and BMP implementation in an island setting. The labor shortage may be a challenging barrier to overcome as it can be tied to limited financial resources as well as a limited labor pool of affordable and reliable workers in many of the agricultural regions on the state. An increase in incentive payments may allow producer to offer more competitive salaries which could help recruit more reliable labor.

The Healthy Soils Hawaii team thanks the Natural resource Conservation Service and the State of Hawaii Office of Planning Greenhouse Gas Sequestration Task Force for your support of this program, and we look forward to future collaboration.