**Introduction**

Thank you for participating in the Healthy Soils for Productive Farms study conducted by the Gaudin Lab at UC Davis.

The goals of the project are to:

1. Identify the diversity of management approaches and practices on a gradient from conventional to ecological intensification for processing tomato farms in the Sacramento Valley
2. Assess soil multifunctionality (biological, chemical, physical indicators) of tomato fields across this management gradient
3. Understand the legacy effects (consistent management for 5+ years) of farm management on soil health and function

In 2023 we sampled soil from 18 fields planted to processing tomatoes. Sampling occurred during full bloom/early fruit development when we expect peak soil activity when the crop has high demand for water and nutrients. We sampled from two depths: 0-6 in where most of a soil's activity is concentrated; and from 6-12 in which covers some of the wet zone from subsurface drip irrigation (SSDI) with 14/18 fields under SSDI.

This report includes biophysical data from field (insert field name(s), management, and comparisons to study wide averages. In depth data analyzes to identify possible connections between management practices and soil indicators will be included in the next phase of our reporting. We greatly appreciate your patience and we're excited to share these results with you.

**Soil Health and Function**

Soil health is tied to function and processes that define a soil’s capacity to thrive as a living ecosystem that supports life. In this agricultural context, it is primarily important as it relates to the production of quality crops that supports human life, buffers against environmental stressors, and minimizes impact to semi-natural and natural habitat. Function includes physical, chemical, and biological properties governed by soil parent material and influenced by management.

- Soil aggregation for carbon and nutrient storage and root exploration

- pH (6--8) to maximize nutrient availability and minimize toxicity

- Sufficient---but not excessive---nutrient supply for crop growth

- Tight Carbon and nutrient cycling, to improve use efficiency, plant availability, and reduce harmful losses

- Adequate soil drainage, infiltration, and water holding capacity

- Diverse and active microbial and invertebrate communities important for carbon and nutrient cycling and pest suppression

- No residual chemicals or toxins that may harm the crop, including salts

- Resistance to degradation such as from erosion or surface runoff

**Physical Measurements**

**Soil Texture (modified from Wash State)** describes the mineral portion of sand, silt, and clay that is determined by the parent material and weathering of soil and is not affected by organic matter or management. This was measured by the hydrometer method.

**Bulk Density (modified from Wash State example)** is the mass of particles within a certain volume of soil used as an indicator of soil compaction. We use a bulk density hammer to measure this similar to this: [NRCS protocol](https://www.nrcs.usda.gov/sites/default/files/2022-10/Soil%20Bulk%20Density%20Moisture%20Aeration.pdf "NRCS bulk density protocol").

* Find a link to a bulk density hammer

**Wet Aggregate Stability (measured as MWD)** measures the resistance of soil aggregates to disintegration. Aggregates form when soil particles associate with organic matter, plant roots, fungal hyphae, and "glues" made by microbes. Stable aggregates can reduce erosion, and increase infiltration, drainage, and storage capacity. High clay soils tend to have higher aggregate stability, but increasing soil organic matter improves aggregate stability across all soil textures. We measured wet aggregate stability as mean weight diameter (MWD). This measures the proportion of soil weight that occurs in different particle size categories (8 mm - 2 mm, 2 mm - 250 um, 250 um - 52 um, > 52 um) after exposure to artificial rain. We took air-dried sieved soils and shook them on a stack of sieves while rewetting them. We take weights of the soil in each category to calculate a mean weight diameter. A higher MWD value means more stable and larger aggregates.

* Link to method

**Water Holding Capacity** (WHC) WHC varies by soil texture and bulk density, and can be greatly impacted by management. Generally, soils with finer textures, high organic matter, and low bulk density have higher WHC. WHC was measured on all soil samples by the pressure plates method, and we calculated it as the difference between field capacity (FC, water content at a pressure of -10 kPa) and permanent wilting point (PWP, water content at -1,500 kPa).

* Link to method

**Infiltration Rate and Unsaturated Hydraulic Conductivity** (K unsat) (modified from Wash State) measure the rate at which water enters the soil surface and the ease with which water is transmitted through the soil, respectively. In the case of processing tomatoes in Northern California, it may be particularly important in winter fallowed fields and fields with furrow irrigation systems. Texture, salinity, plow pans, and soil structure drive water movement in the soil. Infiltration is supported by bioturbation and aggregation by ecosystem engineers (ants, earthworms, enchytraeids) and plant roots and fungal hyphae. We measured infiltration rates and K unsat with [mini disk infiltrometers] (https://metergroup.com/products/mini-disk-infiltrometer/) in the field in the Winter of 2024. Some sites were tilled before they were dry enough to measure infiltration, and we could not report this variable for those fields. Infiltration rate can be also measured as outlined in this [NRCS protocol](https://www.nrcs.usda.gov/sites/default/files/2022-10/Infiltration.pdf "NRCS infiltration protocol").

**Biological Measurements**

**Soil Organic Matter** SOM can be slow to change as the

result of management. Because of this, many other indicators have been developed

to detect more sensitive components in SOM. Keep reading to learn more. SOM was measured by dry combustion.

* Link to method and verify dry combustion
* Decide on including figure, or find one without POXC?

**Soil organic carbon (SOC)** represents the carbon tied up in organic matter and organisms (mainly microbes). This represents the vast majority of the carbon in your soils. Higher levels of SOC, particularly in the top 12 in of your soil profile can be thought of as the source of energy for your cropping system. This was measured with dry, ground soils via dry combustion on a Costech Elemental Analyzer.

* Link to method

**Microbial Biomass Carbon (MBC) and Microbial Biomass Nitrogen (MBN)** quantify micrograms of carbon and nitrogen contained in the microbes of each gram of soil. First, we extracted dissolved organic carbon (DOC) and nitrogen (DON) from all the samples. On replicated subsamples, we used fumigation with chloroform to kill all the microbes and have them release all their carbon and nitrogen. Microbial biomass is the difference between the fumigated samples and the basal dissolved organic carbon and nitrogen. MBC and MBN are indicators of easily available carbon and nitrogen, which determines faster cycling of nutrients.

* Include link to method

**Carbon mineralization:**

* **24hr CO2 burst test** is a measure of dissol that is readily available for microbes to utilize after soils are rewetted in the laboratory under “ideal” conditions. CO2 which is used to determine the amount of carbon being respired by microbes. Higher values signify more energy and more biological activity, a positive outcome for ecosystem function.
  + If this is not included in the report, be sure to include it in the raw data
* **Potentially mineralizable carbon (72hr CO2):** (PMC, referred to as "Soil Respiration") measures the release of carbon dioxide (CO₂) from soil after soils are rewetted in the laboratory under “ideal” conditions. The term mineralization refers to the process in which soil microbes produce CO₂ as they decompose SOM and plant residues. This process also mineralizes other nutrients, like nitrogen, which can be taken up by crops. Higher PMC represents greater potential biological activity. Soils with lower SOM tend to have lower PMC, while compacted soils may not provide adequate aeration for the mineralization process.
  + Include link to method

**Phospholipid fatty acids** (PLFAs) are found in the membranes of living organisms. They provide insights on the broad groups of microbes in your soil (e.g. bacteria and fungi) and total microbial biomass. Higher abundance of fungi can indicate reduced disturbance and slower but more efficient carbon and nutrient cycling, whereas the opposite is generally true for bacteria. A higher fungi:bacteria ratio can signify more efficient carbon and nutrient cycling of the microbial community. Higher biomass is a positive sign for improved ecosystem function. Similarly a higher score on the diversity index is a positive for ecosystem function.

* Include link to method
* If including this data, decide on including a fungi:bacteria ratio

**Enzymes** produced by microbes in soil are important for energy and nutrient cycling. They break down SOM, free nutrients bound in complex compounds, and release carbon as the soil’s energy source. We measured enzymes in the surface layer (0-6 in) where it is expected that

biological activity is highest.

* **β-Glucosidase (BG)** is crucial in the breakdown of cellulose, a major component of plant cell walls, into glucose, a simpler sugar. BG activity is an important indicator of carbon cycling and soil organic matter decomposition.
* **Cellobiohydrolase (CB)** is involved in cellulose degradation. CB works by cleaving cellobiose from the ends of cellulose chains, facilitating further breakdown by other enzymes. CB activity provides insight into the soil’s ability to decompose complex carbohydrates.
* **Phosphatases (PHOS)** are responsible for the release of phosphate from organic compounds, making phosphorus available for plant uptake. PHOS activity is a critical indicator of phosphorus cycling in the soil.
* **Leucine Aminopeptidase (LAP)** plays a role in N cycling by breaking down proteins into amino acids, specifically leucine. It is an indicator of N mineralization and the availability of organic N to plants and microorganisms.
* **N-acetyl-β-glucosaminidase (NAG)** is involved in the degradation of chitin, a major component of fungal cell walls and insect exoskeletons. NAG activity reflects the cycling of nitrogen and carbon within the soil.
  + Include link to the method

**Nematodes community** identification and quantification of nematodes is an indicator of the status of the ecological networks within a field. The analysis consists of extracting, concentrating, and counting up to 200 nematodes from a fresh soil subsample under a microscope. We analyzed only the 6-12 inch depth samples, because nematodes move towards moist soil. For this indicator, you will find specific genre quantification, its feeding habits, and a summary of the percentage of herbivores, fungivores, and bacterivores nematodes. The genre of particular concern for tomato growers is Meloidogyne or root-knot nematode. Please visit this website of UC ANR for more information (<https://ipm.ucanr.edu/agriculture/tomato/root-knot-nematodes/#gsc.tab=0>). If you need more information about any of the nematode’s indicators, please let us know or visit Nemaplex (<http://nemaplex.ucdavis.edu/Uppermnus/topmnu.htm>).

| Genre | Feeding habit |
| --- | --- |
| Panagrolaimus | Bacterial feeders |
| Rhabditis | Bacterial feeders |
| Cephalobus | Bacterial feeders |
| Eucephalobus | Bacterial feeders |
| Acrobeles | Bacterial feeders |
| Acrobeloides | Bacterial feeders |
| Plectus | Bacterial feeders |
| Prismatolaimus | Bacterial feeders |
| Aphelenchoides | Fungal feeders |
| Aphelenchus | Fungal feeders |
| Dorylaimus | Omnivores |
| Qudsianematidae | Omnivores (family) |
| Mononchidae | Predators |
| Microdorylaimus | Predators |
| Tylenchidae | Plant feeders (family) |
| Paratylenchus | Plant feeders |
| Tylenchorhynchus | Plant feeders |
| Pratylenchus | Plant feeders |
| Helicotylenchus | Plant feeders |
| Diphtherophora | Fungal feeders |
| Xiphinema | Plant feeders |
| Trichodorus | Plant feeders |
| Tylenchulus | Plant feeders |
| Meloidogyne | Plant feeders |
| Heterodera | Plant feeders |

**Chemical Measurements**

**Plant Essential Nutrients: Don’t include a description**

**Soil pH** greatly affects which microbial

populations can live in the soil. Soil pH is impacted by inherent qualities of

the soil such as its age, mineralogy, and rainfall zone. It is also impacted by

fertilization, irrigation water pH, and SOM content. Most agricultural crops

grow best in neutral soil pHs, within a range of 6 to 8.

**CEC:** Don't include description

**Total Nitrogen** is a measurement of both inorganic (plant-available nitrate and ammonium) and organic (typically not plant-available) nitrogen in the soil. Having sufficient total nitrogen in the soil is key for promoting mineralization, or the process of changing the organic nitrogen to a form that plants can use. This was measured with dry, ground soils via dry combustion on a Costech Elemental Analyzer.

* Include link to method

**Carbon to Nitrogen Ratio** in agricultural soils in annual systems generally have a C:N ratio of 10:1, which leads to faster cycling of N. This can be ideal for crops when demand for N is high. High C:N ratios tend to lead to N immobilization as microbes consume most of the available N, which can lead to crop deficiencies. Low C:N ratios can lead to harmful losses of N to the environment.

**Fruit Data**

Include in report and ask Selina/Shirley

**Raw Data** is included for plant essential nutrients and cation exchange capacity in the raw data provided separately.

***Indicators we may not need to explain***

* Bulk Density
* Texture
* SOM
* pH
* Macro/micro nutrients
* CEC

Include that we are still in the process of collecting management data, and will provide a follow up report which includes analyses for how management may impact soil outcomes.

* This will be the same report for everyone, across the study
* Including management scoring could be problematic

**Management Practices**

**Crop rotation:**

**Winter cash crop**

**Winter cover**

**Cover crop**

**Tillage**

Synthetic fertilizers

Organic fertilizers

Pest management

Livestock

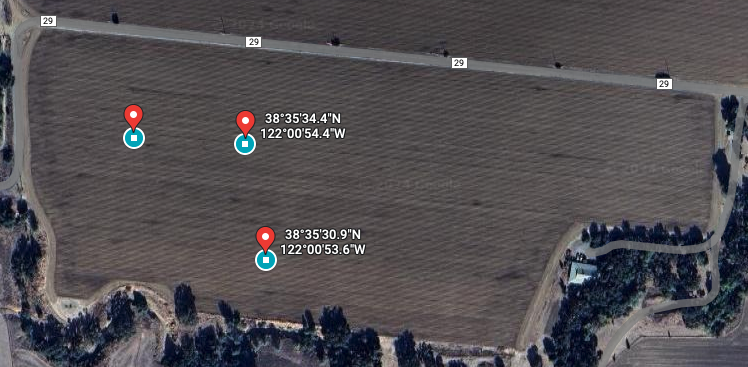
Field border management

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Practice | Description | Score (p | | | |
|  |  | 0 | 1 | 3 | 4 |
| Crop rotation |  | 2 crops but included back to back tomato | 2 crops without back to back tomato | 3 crops | 4 crops |
| Winter cash crop | Absence/presence of a winter cash crop | Absence of winter cash crop | Presence of wcc | - |  |
| Tillage | Based on the # of tractor passes | 20+ passes | 15-20 passes | 10-15 passes | <10 passes |
| Cover crops |  | No cover crop | Sometimes | Every other year | Every year |
| Synthetic fertilizers |  |  |  |  |  |
| Compost |  |  |  |  |  |
| Organic fertilizers |  |  |  |  |  |
| Pest management |  |  |  |  |  |
| Livestock |  | No grazing | Occasional grazing | Grazes every year |  |

* Create QMD file to include in report describing how these were scored

**Where and How We Measured**

To ensure a randomized, unbiased representation of soils in your field, three sampling points were randomly selected using GPS data. We exclude an area of 75 ft from the edge of your field(s) to avoid edge effects. Below is your field with the three points we collected soil cores from. At each sampling point we collected soils from six adjacent beds in a diagonal direction across the field, to capture a representative sample from each area. Soil was collected from the surface layer (0-6 in) and the first subsurface layer (6-12 in) which corresponds with the wetting zone in fields where subsurface drip irrigation is utilized.



**Project Results**

Below are tables and graphs representing results of the indicators we measured, with a comparison of your field(s) and study wide averages.