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Yuma Soil Health Survey 2022: A Discussion on POX-C, PMN, and Soil Protein

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Introduction

Improving soil health is gaining significant attention as we are facing extreme climatic adversities along with water scarcity, especially in the desert Southwest. Healthy soils are more resilient to biotic and abiotic stresses. There are several soil health indicators that are recognized by the United States Department of Agriculture (USDA), but to manage desert soils, we need to know how best to assess soil health in a desert ecosystem. Therefore, a pilot study was designed to identify soil health indicators that are contributing to 'soil health' in the desert ecosystems of Arizona.

Approach

To recruit producer collaborators, we took a strategy and asked growers in Yuma to indicate historically *healthy* and *less-healthy* fields that are adjacent to each other and managed similarly. This way we expect less variability in inherent soil and climatic parameters. We surveyed 10 pairs of historically *healthy* and *less-healthy* commercial fields in Yuma and collected soil samples during the summer and winter of 2022-23. These samples were then processed and analyzed at Sanyal lab for a suite of soil health indicators including permanganate oxidizable carbon (POX-C), potentially mineralizable N (PMN), and soil protein.

Surprisingly, among all the soil parameters tested, *we did not find statistically significant differences* between healthy and less-healthy fields. The most possible reason is the variation in the geospatial location of the fields surveyed, their existing soil conditions, and difference in crop rotations and other agronomic practices. However, when we averaged all data over 10 fields over two sampling times, we found that the average POX-C, PMN, and soil protein values were different between the healthy and less-healthy fields at different sampling times (Figure 1). While healthy soils had a 41% higher average POX-C value in summer, we measured 13% and 203% lower PMN and soil protein contents, respectively, under healthy fields in the winter season. As POX-C indicates a carbon source for soil microbes, higher POX-C values should indicate healthier soil during summer. The lack of difference in POX-C values during winter can be explained as depleted POX-C levels

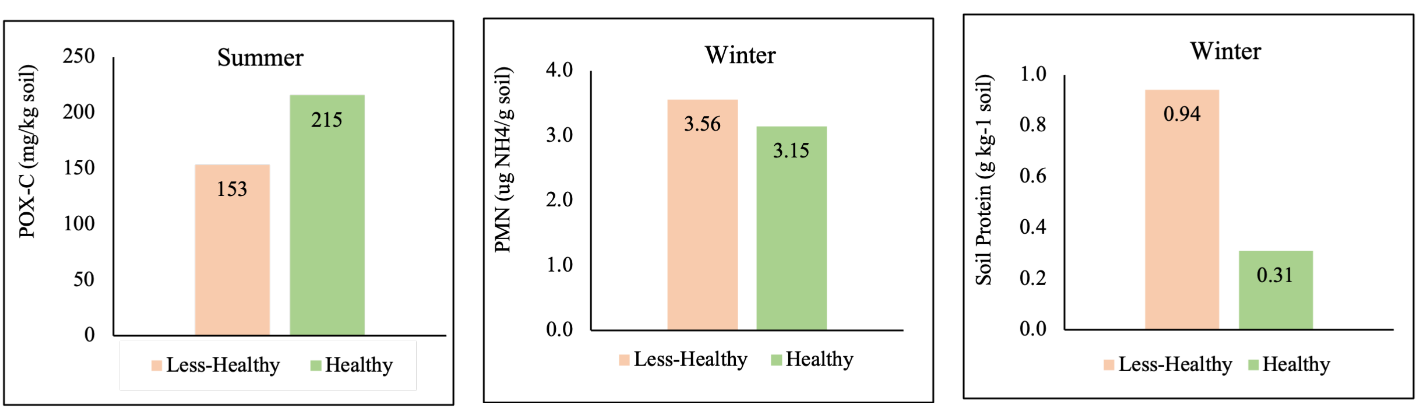

Figure 1. Average Summer POX-C values in healthier soils are higher than less-healthy field, while average PMN and soil protein values in winter were higher under less-healthy fields

due to microbial activities that consumed available POX-C sources. PMN and soil protein are both organic nitrogen sources and require microbial activity to release plant-available nitrogen from these complex sources. No difference in PMN and soil protein values in summer may indicate similar levels of these nitrogen sources*, and in healthier soils, these sources were utilized by microbes to release plant-available nitrogen, therefore creating a difference in PMN and soil protein levels in winter. This outcome pointed out that understanding and identifying the sensitive soil health indicators and their threshold levels are necessary to *diagnose* soil health in desert ecosystems. Our findings, therefore, emphasized the need to develop a comprehensive soil health assessment framework for desert ecosystems, which can be integrated into the decision-making process while aiming for sustainable soil management.

Why POX-C, PMN, and Soil Protein?

Soil organic matter (SOM) is the major driver for soil functions and overall soil health and can be divided into passive, slow, and active pools (Figure 2). These pools have been identified to serve different ecosystem functions. The ***active pool*** provides food and energy sources to soil microbial communities. As microbes decompose this pool of SOM, nutrients are released in plant-available forms that were otherwise tied up to the SOM. POX-C, PMN, and soil protein are crucial parts of this active SOM pool and are indicators of nutrient cycling and soil health. POX-C is known as the ***microbially available carbon***; however, it was popularly termed as '*active carbon*'. In recent times, researchers prefer not to use the term 'active' as it is not clearly defined and instead use microbially available carbon or similar terms. POX-C is a small fraction, only ~2-4%, of the total soil organic carbon, which serves as a readily available food and energy source for the soil microbial community. It is, therefore, important to consider that having higher soil organic carbon content may not cater to the need of soil biological communities, and it is important to manage the sources of carbon input in soil.

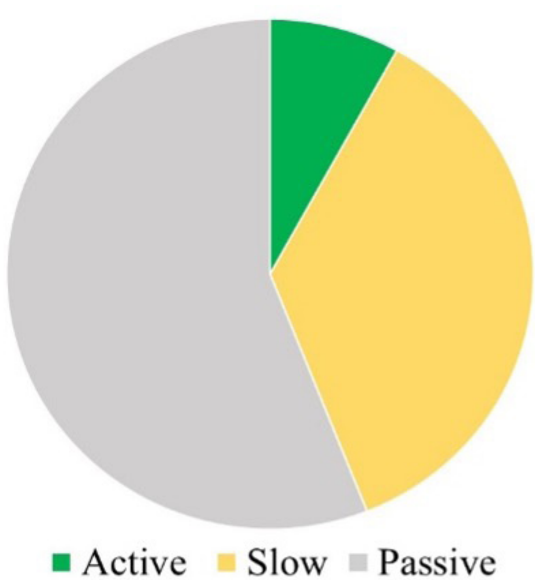

Figure 2. Soil Organic Matter pools: POX-C, soil protein, and PMN are the parts of the active pool

For example, the carbon composition of plant roots is different from that of plant leaves as plant roots have more stable organic carbon like lignin[1]. Incorporating only plant roots may add carbon to the soil, but not in the form of carbon that *feeds* the soil microbial community. As a result, nutrient cycling can get restricted, and soil health may be impaired. Therefore, it is necessary to manage the residue by controlling the amount and composition of the residue that is getting incorporated into the soil.

Mineralization is a microbial process of converting stable organic compounds in soil to more labile, plant-available forms of an element; ***immobilization*** is the opposite process. Nitrogen mineralization is a process of converting nitrogenous organic substances such as microbial biomass or protein-rich plant litter into simpler nitrogen forms such as ammonium or nitrate. PMN represents the fraction of nitrogen, generally ammonium, that can be easily decomposed by soil microorganisms and can be considered an indirect measure of plant nitrogen availability during the growing season. Soil protein content is calculated as the amount of protein-like substances in the SOM that can eventually be mineralized by soil microbes and PMN and subsequent plant-available nitrogen can be released. PMN and soil protein, therefore, indicate the capacity of the soil microbial communities to release the nitrogen tied up in organic matter and convert them into plant-available forms of nitrogen. Both PMN and soil protein serve as the ***precursors of biologically active, plant-available nitrogen*** in the soil[1].

POX-C, PMN, and soil protein are ***universally recognized soil health indicators*** that indicate if the soil microbial community has access to food and energy, and also if they can decompose SOM to release plant-available nutrients like nitrogen. Overall, we recorded very low POX-C values, only ~2.5% of the soil organic carbon values[2]. Our PMN values were also lower in comparison to the values reported from the central New Mexico desert region that ranged between

* Summer average values: PMN 5.2 and 4.8 (ug NH4/g soil), Protein 1.0 and 0.9 (g/kg soil) in less healthy and healthy soils respectively

7 and 14 (μg N/gram soil/ week)[3]. Therefore, we may need to design strategies to boost these values in desert soils. Simply, the higher the values, the *better the chances* that soil microbial communities can participate in efficient carbon and nutrient cycling, possibly contributing to higher crop productivity

Conclusion

Our results indicate that these soils need managed incorporation of crop residues and increased biodiversity through innovative and efficient crop rotations, which would contribute more to the active SOM pool and boost microbially available fractions like POX-C, PMN, and soil protein. A potential measure can be leaving more above-ground biomass and incorporating it into the soil, especially for the forage crops in rotation. This study is just the first step, and we need to collect more data to create an efficient soil health assessment framework for the desert. The University of Arizona Soil Health Extension team is designing research and education plans to find potential solutions and disseminate knowledge through outreach activities.

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