CAN CRP SERVE AS A SOIL HEALTH BENCHMARK: A MINNESOTA CASE STUDY UTILIZING SMAF

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ABSTRACT

Soil health is an important concept relating to sustainable agriculture and food security. However, the absence of a universally accepted benchmark for soil health complicates its application as a tool to measure soil functional capabilities. Here we propose the use of Conservation Reserve Program (CRP) soils as a potential benchmark for soil health in Southern Minnesota. The Soil Management Assessment Framework (SMAF) was used to evaluate soil health indicators and quantify the soil health gap (SHG) between corn-based agricultural and CRP systems. This case study featured three paired systems consisting of 22-year CRP tall grass prairie adjacent to long-term corn-based agriculture (AP). Soil samples were collected at a depth of 0-15cm, and SMAF scores were assigned to various soil health indicators. Results showed either greater soil health overall scores or trending towards greater soil health scores in CRP as compared to AP, primarily driven by soil biological indicators ($p < 0.001$). The CRP sites were statistically indicative or trended towards potentially being used as a benchmark for soil health, yet some data appeared to show limitations of SMAF as tool to characterize soil health at CRP sites. This suggests that more data is required and perhaps SMAF scoring functions need to be updated to more accurately reflect the conditions present in “benchmark” CRP locations.

INTRODUCTION

Agriculture plays a critical role in the production of food, feed, and fiber to meet the needs of a growing population. However, innovations in agricultural production in the early and mid-20th century have compromised environmental sustainability (Melsted., 1954). Over recent decades, the connection between agricultural production and environmental protection has gained significant scientific attention, with soil health emerging as a promising tool (Karlen et al., 2019). While soil health is recognized as a tool to bridge crop production and environmental stewardship, the scientific foundation of the topic is lagging behind the widespread implementation.

One prominent knowledge gap regarding soil health is a universally accepted benchmark to serve as a comparative tool for agricultural lands. Maharjan et al. (2020) proposed the concept of the soil health gap (SHG) as a way to understand the difference between untouched native soils and a test soil (benchmark soil – test soil = SHG). Native ecosystem soils were proposed as a reference point for soil health, but due to extensive conversion to agricultural and urban uses specifically in the Corn Belt region of the US, identifying representative native soils is a challenge. An alternative to using native soils as a benchmark could be soils within Conservation Reserve Program (CRP) locations, as they can be found extensively across the US with their aim to conserve environmentally sensitive land by restoring a semi-native ecosystem (Stubbs., 2014). Here we assess the use of CRP as a soil health benchmark in Faribault County, Minnesota, and quantified soil health using the Soil Management Assessment Framework (SMAF).

MATERIALS AND METHODS

Three agricultural production (AP) fields adjacent to three CRP sites were identified in Faribault County, Minnesota (farms H, E, and S). All CRP fields had been enrolled in the program for 22 years and managed as outlined by the NRCS county office. AP sites utilized different management systems, but all revolved around a corn-soybean rotation. In August of 2023, soil samples were collected from the top 15cm at each paired site and tested for the Soil Management Assessment Framework (SMAF) indicators. SMAF is a soil health quantification tool developed jointly by the USDA-NRCS and USDA-ARS at the Laboratory for Agriculture and the Environment in Ames, IA (Andrews et al., 2004). SMAF indicators included soil organic carbon (Nelson and Sommers., 1996;Sherrod et al., 2002), microbial biomass C (Beck et al., 1997), betaglucosidase activity (Green et al., 2007), mineralizable nitrogen (Mulvaney., 1996 and Curtain; McCallum., 2004), water stable aggregation (Kemper and Rosenau., 1986), bulk density, texture (Ashworth et al., 2001), pH (Thomas., 1996), electrical conductivity (Thomas., 1996), and plant-available P and K (Mehlich., 1984). SMAF then interprets the measured values using on-site characteristics to produce indicator scores and soil health scores ranging from 0 to 1 (0 being poor, and 1 being optimal). Pairwise comparisons from AP to CRP with each farm combined were performed utilizing the Mann-Whitney test while individual farm pairwise comparisons from AP to CRP were performed using the Kruskal-Wallis test. Significance levels were determined with an α of 0.05.

RESULTS AND DISCUSSION

The average soil health gap (SHG; presented in figure 1), calculated using SMAF overall scores, was 0.12 and proved significant. Notably, Farm H exhibited the largest and only significant SHG of 0.18, primarily driven by biological and physical indicators, all of which were significant. Farm S, although not significant, had a SHG of 0.09, trending towards the CRP sites having higher overall SMAF score, and was similarly influenced by biological and physical indicators. Interestingly, farm E had the smallest SHG of 0.01, likely a result of acidic pH conditions stressing the soil microbiome and reducing soil biological activity, a finding supported by previous research (Malik et al., 2018).

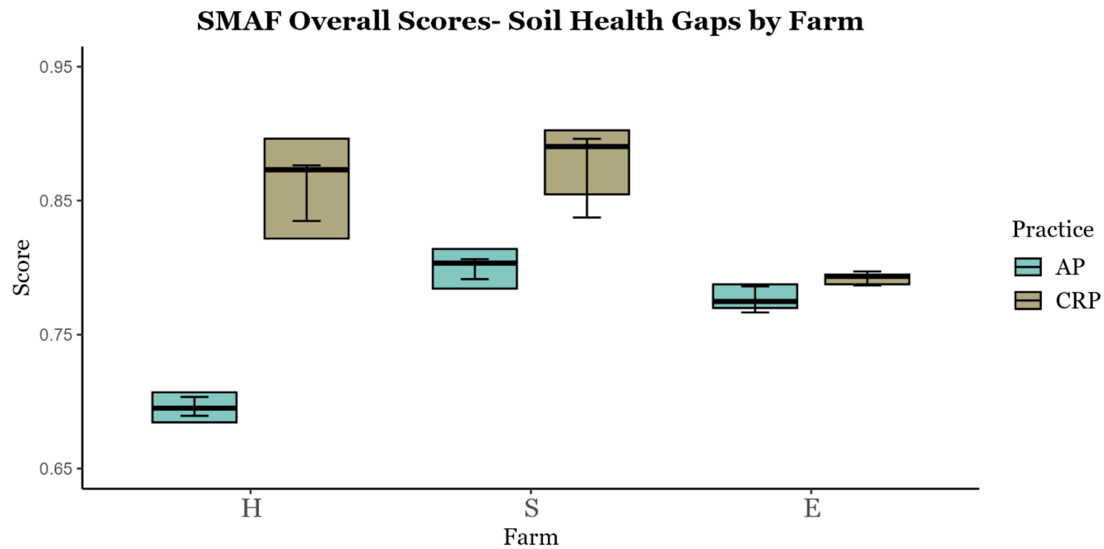

Figure 1: Average SMAF overall scores by individual farms comparing agricultural production (AP) site to Conservation Reserve Program (CRP) site.

The effect of pH on the soil microbiome was more pronounced in CRP sites and within SMAF biological indicators. This was likely because natural systems pH is a direct product of the environment while in AP sites, lime is often applied to manage for pH. Given that SMAF biological indicators were a significant driver of the overall soil health score, this pH effect likely drives the relatively small SHG found at farm E (figure 1). Specifically soil organic carbon (SOC), microbial biomass carbon (MBC), and betaglucosidase activity (BG) scores, and thus biological and overall soil health were impacted the most by pH (figure 2).

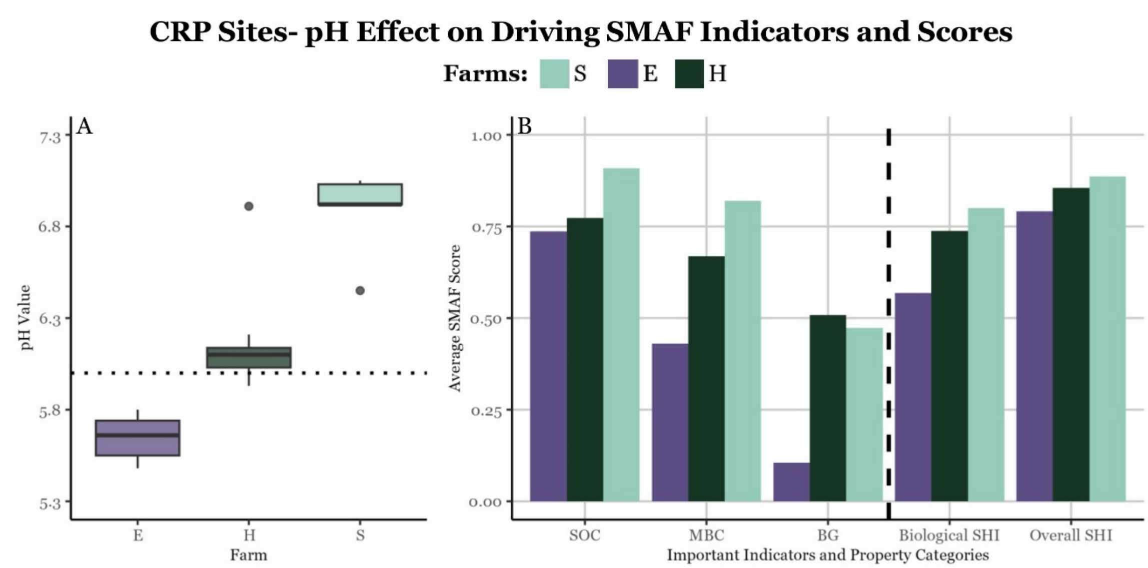

Figure 2: The influence of pH on SMAF biological indicator scores, biological soil health index (SHI) and overall SHI in CRP sites only. A) pH values for each individual farm

CRP site. B) Soil organic carbon (SOC), microbial biomass carbon (MBC), betaglucosidase activity (BG), biological SHI, and overall SHI by farm and only for CRP sites.

To better understand the effect of pH on biological indicators, diving into measured values is prudent. For the CRP sites, farm H had an average pH value of 6.2 while farm S was 6.9 (figure 2), both within neutral range minimizing the effects of pH on the soil microbiome. Whereas at farm E, the measured pH value for the CRP site was 5.6. When combining sites H-CRP and S-CRP for betaglucosidase activity (BG), the average measured value was 288 mg PNP/kg/hr while at site E-CRP the average BG measured value was 115 mg PNP/kg/hr, a 60% reduction in C cycling enzyme activity (figure 3). Similarly, microbial biomass carbon (MBC) was reduced by 42% and potentially mineralizable nitrogen (PMN) was reduced by 49% (figure 3). These results for biological indicators support our observation of acidic pH impacting C and N cycling in these soils.

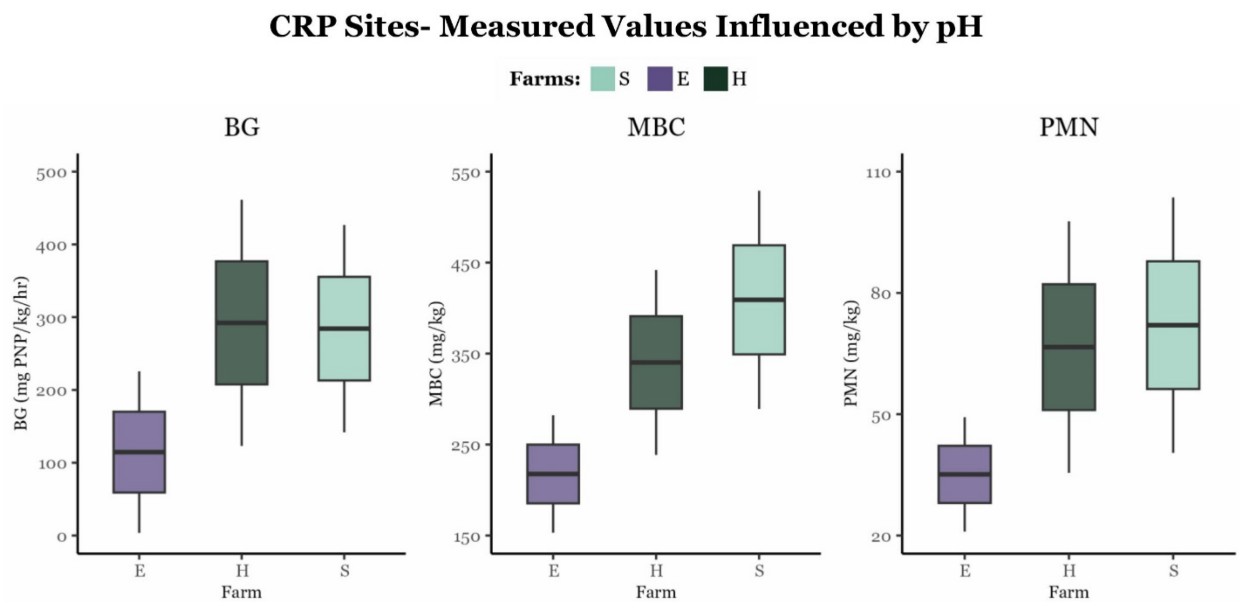

Figure 3: Raw values by individual farm for only the CRP sites. BG: betaglucosidase activity (mg PNP/kg/hr). MBC: microbial biomass carbon (mg/kg). PMN: potentially mineralizable nitrogen (mg/kg).

The observed effect of pH on soil biological indicators raises concerns regarding the applicability of SMAF within natural systems. For agricultural systems, where the goal is to produce commodity crops, soil pH is managed with lime to maintain optimal levels of nutrient availability. However, in natural systems, pH is a direct result of environmental conditions and therefore becomes an inherent soil factor. Within SMAF, pH is treated as a manageable indicator with a direct score given, yet it seems more apropos to be treated as a factor class influencing soil biological interpretations for natural systems. Despite the effects of pH on SMAF scores and the SHG, CRP does appear to show potential as a benchmark for soil health. Farms H and S are examples of this, an informative SHG was derived and differences in the SHG appear to be tied to agricultural management strategies.

CONCLUSIONS

The need for a soil health benchmark remains, however this case study identified facets of soil health that must be understood before a true benchmark can be implemented. Specifically, the mechanisms by which SMAF and soil health frameworks in general interpret pH when assessing natural systems. CRP does show promise to serve as a nation-wide soil health benchmark and appears to have elevated biological activity and physical structure. Results from this project suggest future work assess the potential of CRP on a larger scale and the updating of soil health frameworks to more accurately reflect natural systems. Data from a larger scale project can potentially inform what agricultural management practices have the greatest potential to decrease the soil health gap and increase regional agricultural sustainability.

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