EFFECTS OF LONG-TERM BIOSOLIDS APPLICATIONS IN TWO DRYLAND AGROECOSYSTEMS ON PHYSICAL, BIOLOGICAL, AND CHEMICAL SOIL HEALTH PROPERTIES

M. Desjardins[1], A. Bary[2], J. Ippolito[3], S. Cappellazzi[4], D. Liptzin[5], D. Griffin-LaHue[1]
[1]Washington State University, Northwestern Washington Research and Extension Center
[2]Washington State University, Puyallup Research and Extension Center
[3]Colorado State University
[4]Grassland Oregon
[5]Soil Health Institute

ABSTRACT

Biosolids can be important sources of organic matter (OM) to semi-arid dryland grain systems and have the potential to mitigate some of the soil health challenges specific to these areas while providing an alternative to synthetic fertilizers. The objective of this research is to explore how long-term (20+ year) applications of biosolids at two field sites affected physical, biological, and chemical soil health properties in semi-arid dryland systems.

We collected our data from (i) a biosolids trial in a grain fallow rotation, located in Central Washington (WA), with three application rates of biosolids (2, 3, and 4.5 dry tons per acre) and (ii) a biosolids trial in a wheat-corn-fallow (WCF) and wheat-fallow (WF) rotation, located in Central-Eastern Colorado (CO), with biosolids applications occurring over ~ 20 years and based on agronomic nitrogen (N) needs of the crops.

At the WA site, we observed an increase in available water holding capacity (AWHC) and water-extractable carbon (C) and organic N concentrations with biosolids, while bulk density (BD) decreased in the two highest biosolids rates. Mineralizable C also increased at the highest biosolids rate. At the CO site, there was an increase in OM and n-acetyl-β-glucosaminidase (NAG) in biosolids-amended plots within the WCF rotation, but no changes within the WF rotation where biosolids were applied less frequently.

Our findings show that biosolids can improve aspects of soil health in dryland grain agroecosystems and that application rate matters when it comes to measurable improvements in soil health. Currently, biosolids are applied in agricultural settings based on the agronomic N needs of the crops, which is typically ~2-3 dry tons per acre; however, we saw greater changes to soil health indicators at higher application rates (3-4.5 dry tons per acre).

INTRODUCTION

Dryland agroecosystems rely on precipitation to meet the water needs of crops. While this practice is common in many different climates, it is particularly challenging within semi-arid and arid regions. Central Washington and Central-Eastern Colorado are semi-arid regions within the western United States where production challenges are often related to the low annual precipitation and the unpredictable timing and amount of precipitation, low plant-available water and slow decomposition of OM, which can limit nutrient cycling.

OM inputs are an effective way to improve soil health and function within these systems. OM can increase aggregation (Rieke et al., 2022) and water holding capacity (Bagnall et al., 2022), as well as stimulate biological activity, which can potentially improve nutrient mineralization and availability to plants. OM can be added in the form of cover crops, retained crop residue, and through external sources like amendments. In semi-arid systems, external sources of OM are necessary due to the difficulty to establish cover crops, the fallow period between crops, and the dry conditions that can limit the decomposition of crop residues. Finding cost-effective external sources of OM is a challenge within these systems.

Biosolids are cleaned and transformed products of the wastewater treatment process. They contain nutrients from food and are high in OM. Biosolids are applied as alternatives to synthetic nitrogen (N) fertilizers. Land application of biosolids is a way to close the nutrient cycle by recycling waste and redistributing nutrients and OM from densely populated areas where food is being consumed back into the less populated agricultural areas where food is being produced. This allows the nutrients being taken out of agricultural landscapes with crop harvests to be replaced.

Beyond their ability to be used as alternatives to synthetic N fertilizers, previous studies have also shown that biosolids can increase soil N and C (Cogger et al., 2013). The objective of this study is to explore how soil physical, biological, and chemical properties are influenced by long-term biosolids applications. We hypothesized that the high OM content in biosolids would result in improvements in soil health parameters that align with functions related to challenge areas for these systems. We were also interested in looking at how different application rates influenced soil health properties.

METHODS

This study was conducted on two sites, one located in Central Washington (WA) and the other in Central-Eastern Colorado (CO). Both trials have been receiving biosolids applications for 20+ years. The WA site was established in 1994 in Douglas County, WA, on a commercial farm in a grain-fallow rotation. The soil is classified as a Timentwa fine ashy sandy loam (ashy over loamy, glassy over mixed, superactive, mesic Vitrandic Haploxeroll) with 58.0% sand, 33.8% silt, and 8.2% clay. The mean annual precipitation for this site is ~10 inches per year.

The experiment is a randomized complete block design with three replications and five treatments: an unfertilized control, a synthetic N fertilizer and 2, 3, and 4.5 dry tons of biosolids per acre. The synthetic fertilizer is applied every crop year, and the biosolids were applied every four years. Biosolids are sourced from the Renton facility in King County, WA.

The CO site was established in 1999 in Arapahoe County, CO. The soil is classified as a Platner fine clay loam (fine, smectitic, mesic Aridic Paleustolls) with 25% sand, 44% silt, and 31% clay. This area of Colorado receives an average of 12 inches of precipitation per year. The experimental design is a split-plot design, with crop rotation as the main plot treatment (wheat-corn-fallow [WCF] or wheat-fallow [WF]) and fertility source as the subplot treatment (synthetic fertilizer or biosolids).

Biosolids were sourced from the South Platte Renew Facility. The rate and timing of biosolids applications were based on the agronomic N needs of the crop being grown. If the recommended application amount was less than 1.5 dry ton biosolids/acre, biosolids were not applied, due to the inability of equipment to accurately apply below this threshold.

In 2019, the Soil Health Institute (SHI) sampled both sites as a part of the North American Project to Evaluate Soil Health Measurements (NAPESHM). Physical, biological, and chemical soil health indicators were selected from the analyses run by the SHI (Norris et al., 2020) to be included in this study. We explored research questions by looking at soil health parameters related to soil functions that could mitigate some of the main challenge areas for these two agroecosystems. Within this context, we wanted to look at the functions of water regulation, soil resilience, and nutrient cycling in these systems. To do this, we looked at

AWHC, pore space, saturated hydraulic conductivity (K_{sat}), BD and aggregate stability, and C, N, and phosphorus (P) cycling enzymes, mineralizable C and N, and water-extractable C and N.

RESULTS AND DISCUSSION

We found improvements in several of the soil physical, chemical, and biological parameters at the WA site, but limited changes at the CO site. At the WA site, AWHC and BD improved with biosolids applications, while aggregate stability and K_{sat} did not change. At the WA and CO sites, we saw improvements in NAG, while phosphomonoesterase increased at the WA site. No change in β-glucosidase was observed at either site. At the WA site, we saw increases in mineralizable and water-extractable C and N.

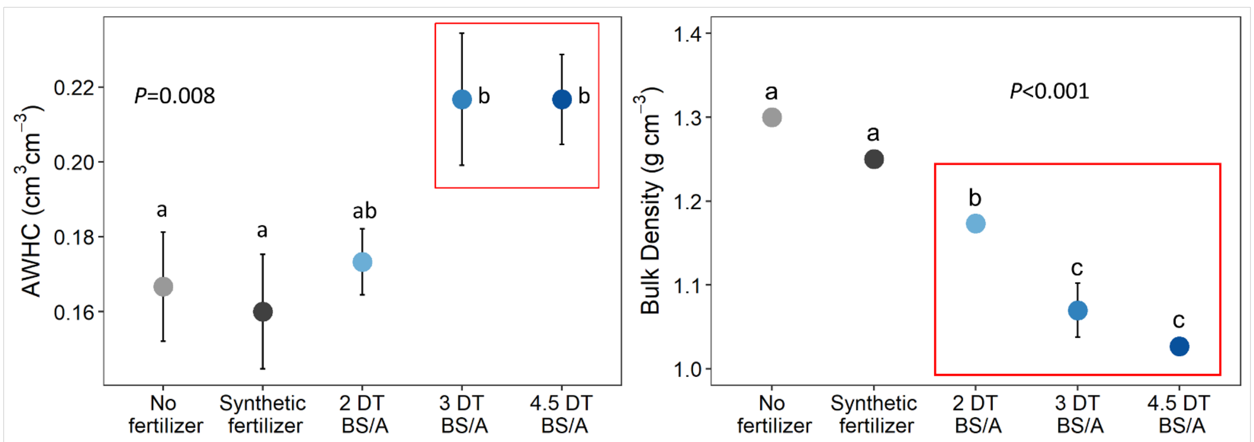


Figure 1a. At the WA site, available water holding capacity increased with the two highest biosolids applications rates.

Figure 2a. At the WA site, bulk density decreased at all biosolids application rates.

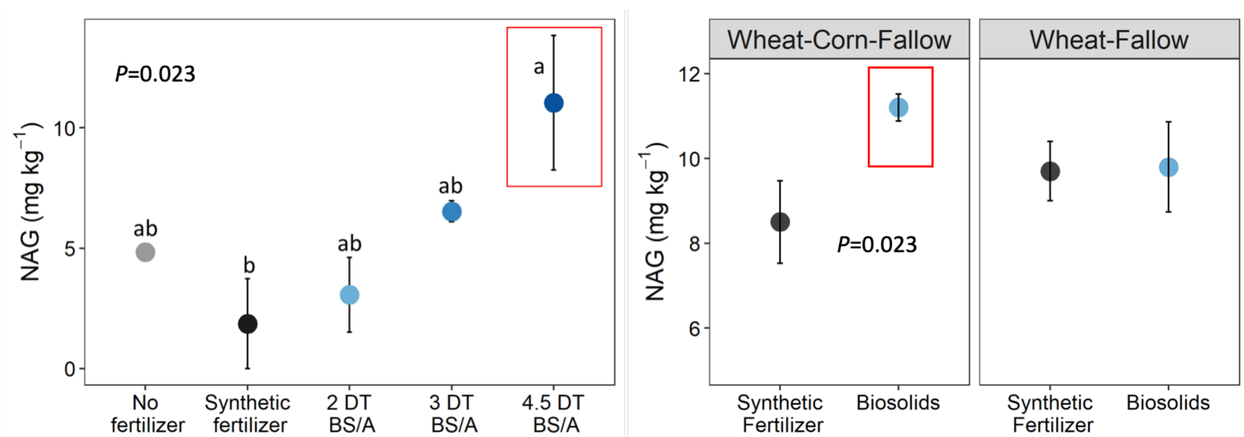
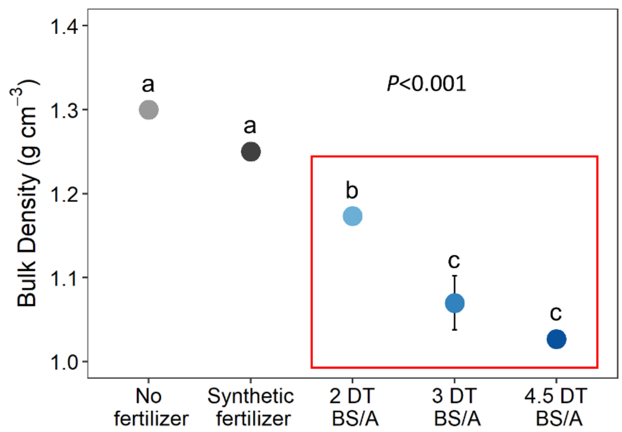


Figure 2a. NAG increased at the highest biosolids application rate at the WA site.

Figure 2b. NAG increased with biosolids in the WCF rotation at the CO site.



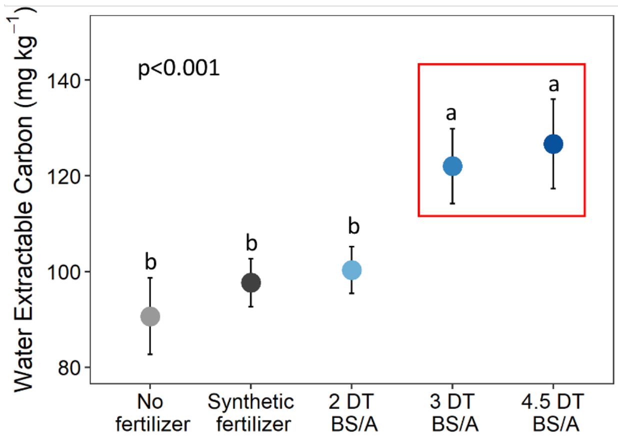


Figure 3a. CO_2-C increased at the highest biosolids application rate at the WA site.

Figure 3b. WEC increased at the two highest application rates at the WA site.

We hypothesize that the reason we did not see as many treatment effects at the CO site is due to the fact that the CO site plots received less cumulative biosolids than those at the WA site. At the CO site, biosolids are applied based on the agronomic N needs of the crops, which were usually in the 2 dry tons per acre range or below. Effects from biosolids observed at the CO site were in the cropping rotation that received greater biosolids applications (WCF). WCF rotation typically required more N than the WF due to the extra crop added to the rotation. At the WA site, we typically observed soil health indicator improvements at the 3 dry tons per acre rate, but not at the 2 dry tons per acre rate. Another factor that may be at play is that the WA site has a coarser soil texture, and sandy soils are more responsive to increases in OM inputs.

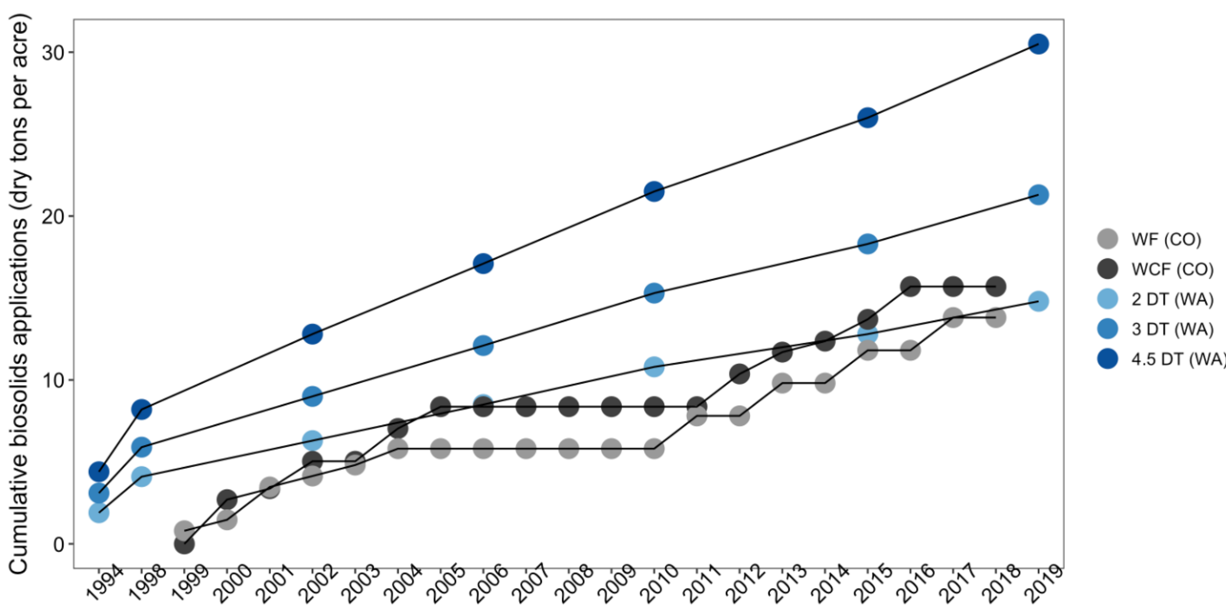


Figure 4. Cumulative biosolids applications for different treatments and cropping systems at WA and CO sites.

Overall, our results indicate that biosolids provide improvements in soil functions relevant to our challenge areas, but that application rate matters when it comes to measurable improvements in soil health. Currently, biosolids are applied in agricultural settings based on the agronomic N needs of crops, as they are at the CO site. Biosolids can increase soil P levels, which is one important reason for growers to ensure they are not overapplying biosolids. However, our research shows that in semi-arid dryland systems, particularly with coarse soils, the rate at which we can typically expect to see changes in soil health is higher than agronomic N rates being applied in some cases.

REFERENCES

Bagnall, D. K., Morgan, C. L.S., Cope, M., Bean, G. M., Cappellazzi, S., Greub, K., Liptzin, D., Norris, C. L., Rieke, E., Tracy, P., Aberle, E., Ashworth, A., Bañuelos Tavarez, O., Bary, A., Baumhardt, R. L., Borbón Gracia, A., Brainard, D., Brennan, J., Briones Reyes, D., … Honeycutt, C. W. (2022). Carbon-sensitive pedotransfer functions for plant available water. Soil Science Society of America Journal, 86, 612– 629. https://doi.org/10.1002/saj2.20395

Cogger, C. G., Bary, A. I., Myhre, E. A., & Fortuna, A.-M. (2013). Biosolids Applications to Tall Fescue Have Long-Term Influence on Soil Nitrogen, Carbon, and Phosphorus. Journal of Environmental Quality, 42(2), 516–522. https://doi.org/10.2134/jeq2012.0269

Norris, C. E., Bean, G. M., Cappellazzi, S. B., Cope, M., Greub, K. L., Liptzin, D., ... & Honeycutt, C. W. (2020). Introducing the North American project to evaluate soil health measurements. Agronomy Journal, 112(4), 3195-3215. https://doi.org/10.1002/agj2.20234

Rieke, E.L., Bagnall, D.K., Morgan, C.L.S., Flynn, K.D., Howe, J.A., Greub, K.L.H., Mac Bean, G., Cappellazzi, S.B., Cope, M., Liptzin, D., Norris, C.E., Tracy, P.W., Aberle, E., Ashworth, A., Bañuelos Tavarez, O., Bary, A.I., Baumhardt, R.L., Borbón Gracia, A., Brainard, D.C., Brennan, J.R., Briones Reyes, D., … Honeycutt, C.W., 2022. Evaluation of aggregate stability methods for soil health. Geoderma 428. https://doi.org/10.1016/j.geoderma.2022.116156