AN EVALUATION OF SOIL IMPROVEMENT PRACTICES BEING USED ON IRRIGATED SOILS IN THE COLUMBIA BASIN

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For a general discussion of soil quality in the Columbia Basin, see the companion publication FS252E Improving Soil Quality on Irrigated Soils in the Columbia Basin.

Abstract

Farmers in the irrigated Columbia Basin of eastern Washington are using a variety of soil improvement practices: (1) organic amendments, (2) cover crops and green manures, and (3) high residue farming. To determine the effects of these practices, we compared the soils of fields managed under these practices to adjacent fields with no soil improvement practices. The soils were evaluated through an array of measurements in 2015. Results show that these practices can maintain or improve soils in this region, though each practice differs from the others in its specific effects. A parallel study estimated the economics of soil improvement and found that the improvement practices generated positive returns on investment.

Introduction

Many farmers in the Columbia Basin of Washington are applying soil improvement practices. However, it is not clear if these practices are changing soil quality or if the practices differ in their effects on the soil. To begin to answer these questions, this study assessed impacts of soil improvement practices in the Columbia Basin.

Methodology

Focus Groups

Farmers using soil improvement practices were invited to a series of three focus group discussions in June 2014. Each discussion focused on one practice: organic amendments, cover crops and green manures, or high residue farming. Farmers received a written survey prior to the meetings to help them describe their management and identify costs and benefits. A total of nine farmers attended the meetings. Each farmer used at least one of the soil improvement practices for periods ranging from three years to over 20 years. The crops they grew included timothy or alfalfa hay, potatoes, wheat, dry edible beans, canola seed, sweet corn, field corn, peas, carrots, lettuce, onions, and radish for seed. The goal of the survey and the focus group discussions was to collect qualitative data on the costs and benefits of soil improvement practices from the participating farmers. These same farmers were asked whether a field of theirs with the soil improvement practice might be sampled and compared with an adjacent one without the practice. Fields were identified, sampled, and analyzed, conducted as described below.

Soil Improvement Practices

As in our focus groups, for the field study we divided the soil improvement practices being used by farmers into three categories, each of which contains specific practices. The practices varied in terms of the source of added organic matter, tillage intensity, and frequency of application (Table 1).

Table 1. Differences in soil improvement practices.

Soil improvement practice	Source of added organic matter	Tillage intensity	Frequency of application
Organic amendments	Imported from livestock operations or composting facilities.	Medium to high	Ranged from every year to every other year, 4-5 ton/ac.
Green manures[1]	Grown in place.	Medium to high	Ranged from every other year to every 3-4 years.
High residue farming	Residues from cash crops only[2]. No imported organic materials, nor cover crops.	None[3] to low	Continuous, or two years out of every three.

[1]All cover crops were incorporated into the soil as green manures.
[2]Although combining cover crops and high residue farming has been shown to be a beneficial practice, farmers using high residue farming in this study did not also use cover crops.
[3]No-till or direct seeding with the only tillage occurring in planting the seed.

Field Selection

Fields were selected where the farmers either (1) had observed changes in the soil due to their soil improvement practices, or (2) had been using the practices the longest. Once the farmers' fields were chosen, adjacent fields (not receiving any soil improvement practices) were selected in the same soil series, based on NRCS soil survey maps. Nine pairs of fields were identified. Three pairs were fields with or without organic amendments. The organic amendments used were aged and screened compost from chicken and cow manure and waste from mint oil processing. Four pairs were fields with or without green manures consisting of mustard or mustard/arugula mixes. Two pairs were fields with or without high residue farming, which was either no-till (direct seeding) or strip till.

Paired with adjacent fields, a total of 18 fields were sampled in February 2015, at the end of winter when fields would be most similar regardless of management the previous season. Permission to sample all adjacent fields was obtained before sampling. In addition to not receiving soil improvement practices, these fields may have differed from farmers' fields in their specific crop rotations.

Soil Sampling

For soil sampling, parallel transects (~100 feet long) were selected near the common field boundary in each field (Figure 1). Along each transect, five sampling locations were flagged in each field (averaged before statistical analysis). Around each point, five 1-inch cores were taken to a 6-inch depth, composited, mixed, and resampled. The composite sample was bagged, refrigerated, and then either shipped on ice to the Cornell Soil Health lab or taken to a local soil lab. This soil was used for all laboratory measurements except texture and bulk density. For texture, one composite sample per field was made by taking 15 cores, mixing them, and then resampling from the mixed soil. Bulk density samples were taken from the undisturbed soil surface, one per sample location (total of five for each field).

In addition to these 2015 measurements, this publication reports the results of soil measurements taken in 2009 from four cooperator fields receiving mustard green manures and four adjacent fields with no history of green manure crops. The rotation in all the green manure fields consisted of a two-year potato-wheat/mustard rotation with at least four previous cycles (see the Mustard Cover Cropping in Potatoes in Other Resources). Four sampling locations per field were selected near the common boundary, and 15 soil cores (0–6-inch depth) were taken and composited for each location. A complete soil health test was run on all soils by the Cornell Soil Health lab.

Figure 1. Conducting infiltration measurements along a field transect.

Measurement Selection

Seven soil quality measurements were selected based on relevance to farmers and their soil problems, and ease/cost of analysis such that growers might be able to have these tests done in the future. The selected measurements were total soil organic matter, active carbon, soil protein, soil respiration, available water-holding capacity, water infiltration rate, and bulk density. Soil texture and pH (1:1 soil-to-water ratio) were also measured to characterize the soils.

Soil Analysis

Infiltration was measured using a single-ring infiltrometer (6-inch diameter) pushed 5 inches into the soil. A plastic sheet was placed on the soil inside the ring. Then 1 inch of water was ponded and the plastic removed, and the time was recorded for the water to infiltrate. Three sequential runs were completed where feasible (i.e., when 1 inch of water infiltrated within 20 minutes).

Bulk density was measured with a 100cc volume bulk density sampler, representing the 2–4-inch depth of the soil. Intact cores were oven dried before weighing.

Soil organic matter (Walkley-Black method) and pH were analyzed by Best Test Analytical Services in Moses Lake, WA. All other measurements (active carbon, water-holding capacity, soil protein, soil respiration, and soil texture) were done by the Cornell Soil Health lab; methods can be found at http://soilhealth.cals.cornell.edu/.

All subsample data were averaged before statistical analysis. Data were analyzed statistically using paired t-tests with each farm as a replication (9 total replications). The comparisons for individual practices used the same analysis but included only the relevant fields.

Results

Soil texture classifications ranged from light-textured sands to sandy loams and silt loams. The ranges of percent sand, silt, and clay were 42–87%, 9–45%, and 4–13%, respectively. Overall, the textures did not differ between fields with and without soil improvement practices.

Table 2. Soil quality measurements with and without soil improvement practices. The high residue farming practice is not included because there were only two paired fields to compare.

Measured Soil Quality Characteristics

		Soil organic matter (%)	Active Carbon (ppm)	Soil protein (mg/g)	Soil respiration (mg/g)	Available water capacity (g/g)	Infiltration, first inch (minutes)	Infiltration, second inch (minutes)	Bulk density (g/cm3)
All Soil Improvement Practices Combined	With	2.2	461	5.3	0.5	0.182	12.5	16.5	1.34
	Without	1.8	374	4.0	0.4	0.165	14.9	22.0	1.34
	Effects and potential	☺	☺	☺	☺	☺	😐	😐	😐
Organic Amendments	With	2.6	566	6.4	0.6	0.184	27.0	27.2	1.39
	Without	2.2	480	4.6	0.4	0.184	17.0	18.2	1.41
	Effects and potential	☺	😐	☺	☺	😐	😐	😐	😐
Green Manures	With	1.9	364	4.6	0.4	0.185	3.0	7.9	1.23
	Without	1.5	329	3.6	0.3	0.168	19.6	16.3	1.27
	Effects and potential	☺	😐	☺	😐	😐	😐	☺	😐

Effects on soil

☺ Positive effect (P < 0.05 probability level)

😐 No effect

Overall Effects of Soil Improvement Practices

When the data from all nine pairs of fields were analyzed together, soil improvement practices had a measurable positive effect on available water capacity, soil organic matter, active carbon, soil protein levels, and soil respiration (Table 2). Neither bulk density nor water infiltration were significantly affected. In no case was a measured soil quality parameter significantly worse with soil improvement practices.

The results show that soil organic matter can be increased in Columbia Basin irrigated soils beyond current typical levels (Table 3). This occurred despite low clay content, high temperatures, low residue crops, and intensive tillage, all of which tend to result in lower soil organic matter levels. While this upward trend in soil organic matter is encouraging, it remains to be determined whether farmers should target a specific level of organic matter, as no threshold levels have been identified for these soils.

Table 3. Increases in soil organic matter levels due to soil improvement practices.

Soil improvement practice	Increase in soil organic matter levels over untreated fields (lb/ac)
Overall, all practices combined	7,974
Organic amendments	7,734
Green manures	6,649
High residue farming	No statistical difference

These increases in soil organic matter constitute the carbon stored in the soil from crop residues, composts and manures, and green manures. However, there is a cost to this build-up in that nutrients tied up in the stable organic matter are largely unavailable to plants and thus additional nutrient inputs may be needed in the short term. We estimate that the amount of nitrogen, phosphorus, and sulfur in the soil organic matter increase from using organic amendments at 345, 72, and 55 lb/ac, respectively.

Active carbon aims to quantify the most biologically active (youngest) part of a soil's organic matter. Similarly, soil protein aims to quantify the protein (organic nitrogen compounds) part of the soil's organic matter. These two measurements, although they measure different components of the organic matter pool, tend to closely follow the direction of the total organic matter, whether it is increasing or decreasing. This is what we see with this study's data.

The increased respiration observed here is probably due to the inputs of organic materials, either compost or green manures, and therefore represents an increase in microbial activity which can benefit nutrient cycling, disease suppression, and other soil quality aspects.

The increase in available water content observed in study fields could reduce transient water stress on crops, particularly in sandy soils with low inherent available water content. In very hot weather, irrigation systems may not be able to replenish soil moisture fast enough to avoid some stress, and additional available water content can help buffer the system. The actual available water content difference between the treated and untreated fields, with all sites combined, was 0.14 inches of water per 6 inches of soil.

These measurements were made in the early spring to minimize the effects of past tillage on infiltration. However, fall tillage for incorporation of the mustard crop in green manure fields was probably still a factor. The dramatically higher infiltration rates after green manure may be the result of tillage in combination with the stabilizing effects (short term) of the breakdown of the green crop biomass in the tilled soil.

Overall, soil improvement practices had no effect on soil bulk density. This could be due to the tillage involved in these systems or because the soil organic matter levels are not high enough in these soils to support higher levels of aggregation which lead to lower bulk densities.

Effects of Specific Practices

In looking at the effects of specific practices, we reduce the number of fields in the analysis. In so doing, the confidence we have in the results is also correspondingly reduced.

Effects of Organic Amendments

Similar to the overall results, application of organic amendments on treated fields resulted in significant increases in soil organic matter, soil protein, and soil respiration but did not affect active carbon, bulk density, or infiltration. Nor was available water capacity changed compared to unamended fields.

The lack of effect of organic amendments on water infiltration and available water content may be due to relatively low overall amendment rates (not enough years of using the practice) or the use of already composted materials. While compost carbon tends to be more stable than that in green manure residues, for example, it does not undergo the microbial decomposition in the soil that green manure materials do. This decomposition process appears to contribute to the measurable benefit on infiltration from green manures, but may be a short-term change (Williams and Doneen 1960).

Effects of Green Manures

Green manures also increased soil organic matter and soil protein. Similar results were found in a previous study on green manures (McGuire 2003) where fields with a long-term history of green manure use were compared to adjacent fields not receiving green manures. The beneficial effects on infiltration are clear (Table 4).

In the 2015 study, green manures had beneficial effects on soil organic matter, soil protein levels, and water infiltration (second inch only; Table 2).

Table 4. Ponded infiltration time (minutes) for consecutive 1-inch applications of water to soil with and without green manure in Moses Lake, WA.

Field	1st inch of water	2nd inch of water	3rd inch of water
Long-term[1] green manure	0.3	3.1	6.4
No green manure	17.4	19.6	Not measurable[2]

[1]After ten green manure crops over twenty years of a wheat/green manure-potato rotation. See the Mustard Cover Cropping in Potatoes in Other Resources.
[2]Infiltration time exceeded the cutoff of 20 minutes.

Figure 2. Chopping and disking of a mustard green manure crop in the Columbia Basin.

Results from the 2009 study on fields with long-term history of green manures (Figure 2) also show the benefits of the practice (Table 5). Compared to untreated fields, fields receiving green manures had higher soil organic matter, more active carbon, and better root health ratings. The green manured fields also received a higher Cornell Soil Health rating than untreated fields. There were no measurable differences between fields for aggregate stability, available water capacity, and potentially mineralizable nitrogen.

The 2009 results also demonstrate that frequent use (every other year) of green manure crops can overcome the intensive tillage inherent in potato production and improve soils over time. The higher soil enzyme levels (Fluorescein diacetate and Glucosidase) indicate higher biological activity and may be correlated with soilborne disease suppression (Darby et al. 2004). This factor, along with improved soil tilth, are the major reasons why farmers in the Columbia Basin are using mustard green manures on about 30,000 acres per year (McGuire 2012).

Table 5. Comparison of soils from long-term green manure fields to soils from adjacent fields not receiving green manures (four paired fields, eight fields total) in the Columbia Basin.

Measurement	Green manured soils	Non-green manured soils	Effects and potential
Aggregate stability (%)	29.6	26.3	😐
Available water capacity (m/m)	0.081	0.099	😐
Soil organic matter (%)	1.2	0.9	☺
Active carbon (ppm)	235.0	135.2	☺
Potentially mineralizable N (ugN/g dw soil/week)	21.9	13.0	😐
Snap bean root health rating (1-9, 1=best)	3.5	4.9	☺
Fluorescein diacetate (ug FDA/g OD soil)	15.7	7.2	☺
Glucosidase (ug p-nitrophenol/g soil/hour)	636.7	282.2	☺
Cornell soil health rating	68.7	59.9	☺

Effects on soil	
☺	Positive effect
😐	No effect
☹	Negative effect

Potential for similar results on other fields

(dark blue)	Highest (significant at the 0.001 probability level)
(light blue)	High (significant at the 0.01 probability level)

When compared to the effects of the other practices, the increase in infiltration rates is most striking with green manure use. Although research indicates that this is a relatively short-term effect (Williams and Doneen 1960), it is a valuable one for irrigated agriculture where runoff from sprinkler irrigation can be a problem.

Effects of High Residue Farming

Because we compared only two pairs of fields under high residue farming, our ability to detect differences in the soils of the paired fields was much reduced. However, other long-term studies have found that these systems result in improved soil quality (Karlen et al. 1994) and reduced erosion (Seta et al. 1993). In cropping systems similar to those in the Columbia Basin (irrigated vegetables), Veenstra et al. (2007) found that the combination of conservation tillage (e.g., high residue farming) and cover cropping resulted in increased soil organic matter levels, with most of the benefit coming from the cover cropping.

Wind Erosion

Reducing the losses of small soil particles (silt, clay, and organic matter) and minimizing the sand blasting of tender seedlings associated with wind erosion was the goal of nearly all cooperating farmers. While we did not directly measure the effects of practices on wind erosion, our results indicate that wind erosion should be reduced through increased soil organic matter and associated changes in the soil, especially increased aggregation. In a previous study (McGuire, unpublished), we found that long-term use of green manures improved resistance to wind erosion (required wind velocity to begin to move soil particles) in a sandy soil but not in a sandy loam. In addition, high residue farming's crop residue cover directly protects the soil from wind erosion. Most farmers reported less crop loss due to sand blasting, a direct reflection of less wind erosion, and preventing this crop damage provided a large economic benefit.

Conclusions

The use of three different soil improvement practices on commercial farms in the Columbia Basin led to measurable improvements in select soil properties generally considered to indicate higher soil quality. All practices increased soil organic matter content, a key characteristic that influences other biological, chemical, and physical properties. Raising soil organic matter levels in the region has been considered difficult due to low clay content, well-aerated and hot soils, intensive tillage, and rotations with various low residue crops. The farmers involved in this study indicated that soil physical problems, such as poor aggregation, wind erosion and sand blasting of seedlings, surface sealing, and poor water infiltration tended to be their primary soil quality concerns. The three practices being used addressed these problems to different degrees and with different economic impacts. Farmers involved in the study observed enough benefits, both economic and environmental, to continue using these soil improvement practices.

Other Resources

Mustard Cover Cropping in Potatoes. REACCH Case Studies, Dale Gies System profile.

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References

Darby, H.M., A.G. Stone, and R.P. Dick. 2004. Compost and Manure Mediated Impacts on Soilborne Pathogens and Soil Quality. *Soil Science Society of America Journal* 70: 347–358.

Karlen, D.L., N.C. Wollenhaupt, D.C. Erbach, E.C. Berry, J.B. Swan, N.S. Eash, and J.L. Jordahl. 1994. Long-Term Tillage Effects on Soil Quality. *Soil and Tillage Research* 32(4): 313–327.

McGuire, A.M. 2003. Mustard Green Manures Replace Fumigant and Improve Infiltration in Potato Cropping System. *Crop Management*.

McGuire, A.M. 2012. Mustard Green Manure Use in Eastern Washington State. P. 117-130. In: Z. He, R. Larkin, and W. Honeycutt, eds. Sustainable Potato Production: Global Case Studies. Springer, Netherlands.

Seta, A.K., R.L. Blevins, W.W. Frye, and B.J. Barfield. 1993. Reducing Soil Erosion and Agricultural Chemical Losses with Conservation Tillage. *Journal of Environment Quality* 22(4): 661.

Veenstra, J.J., W.R. Horwath, and J.P. Mitchell. 2007. Tillage and Cover Cropping Effects on Aggregate-Protected Carbon in Cotton and Tomato. *Soil Science Society of America Journal* 71(2): 362.

Williams, W.A., and L.D. Doneen. 1960. Field Infiltration Studies with Green Manures and Crop Residues on Irrigated Soils. *Soil Science Society of America Journal* 24(1): 58.

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