Background. The 2014 USDA NRCS campaign promoting cover crops as a viable option for improving soil health stimulated active discussions among agronomists and producers across the semi-arid iPNW. Water was the number one driving concern. Circulating opinions centered on luxurious water use and how water invested in soil health could negatively impact grain yields and profits.

Objectives. In response to the question of water consumption by cover crops, we implemented an observational field trial at five locations across a rainfall gradient from low to moderately high precipitation. We quantified soil profile water loss/use: i) as evaporation (E) under three fallow systems; and ii) as evapotranspiration (ET) for cover crop biomass production.

Results. We documented the amount of water consumed by a mature cover crop (allowed to achieve senescence) to be the same as that of a spring cereal crop. We observed a highly significant (P-value < 0.01) relationship between changes in soil water status and the amount of above-ground biomass produced by a cover crop. We also recorded soil temperatures at three depths for each treatment (bare soil, residue cover, and artificial shade as fallow effects and under the cover crop). Our data showed that the magnitude of change in daily temperatures (both daily max and daily min) decreased with depth (0-6, inch 6-12 inch, and 12-18 inch) and with increasing cover. The magnitude of season average daily change by depth was typically lowest under artificial shade (7.1°F, 2.2°F, and 0.9°F) followed by high residue fallow (6.5°F, 3.4°F, 1.0°F) and cover crop (10.7°F, 3.0°F, 1.1°F). The magnitude of average daily change in temperature under bare soil was consistently highest across all sites (17.7°F, 5.4°F, 2.1°F). Note that as surface soil temperatures increase, so does the rate of water loss by evaporation – supporting findings that soil water conservation under high residue fallow systems is more efficient than under bare soil fallow systems.

In 2015 we decreased the number of sites to three and increased soil moisture and biomass sampling frequency to a three-week interval (refer to 2015 cover crop report). The increased sampling frequency allowed us to more accurately track changes due to evapotranspiration (ET) in soil profile water under a cover cropping system, and as evaporative water loss (E) under fallow. 2015 measurements provided data that significantly strengthened our 2014 conclusions, specifically for two dominant species - tillage radish and winter wheat.

Conclusion. *We can effectively manage cover crop water consumption by judiciously monitoring above-ground biomass accumulation, and terminating growth (biomass accumulation) of the cover crop at a predetermined point on a water-use curve (see attached preliminary report).*

Considerations. A cover crop root system and above-ground biomass, if terminated when succulent (e.g., prior to jointing and/or well before flowering), will retain moisture, and high concentrations of nutrients and soluble sugars. This condition supports soil fauna and soil microbial activity and promotes rapid conversion of crop biomass to soil humus. This condition is much unlike the soil status at grain harvest when mature dry straw and roots are denuded of most nutrients and soluble sugars. Mature grain of a crop contains most of the energy and nutrients. Removal of nutrients and soluble carbohydrates combined with a dry soil condition impose significant limitations on microbial activity and the conversion of biomass (roots, leaves and stems) to humus.

Biomass accumulation rates and water use efficiency vary among plant species and crop varieties. Characterization of multiple species under mixed systems could help us better understand the biological, physical and chemical interactions affecting improved humus formation, nutrient cycling, water-holding capacity, aggregate stability, and soil buffering capacity (ability to resist change). For example if the need for more nitrogen to favor organic matter decomposition is observed, would it be effective to include nitrogen accumulators such as tillage radish and legumes in a cover crop mix? Or, if organic material decomposition rates are too high, should nitrogen-rich species be excluded from a subsequent cover crop mix?

Additional Considerations and Effects. Soil nutrient and acid stratification was observed at all sites as minimum tillage was the common practice for ten or more years. Severe acidification, pH below 5.2, occurred at the depth of fertilizer placement (Fig 1). As soil acidifies, soluble ionic species of iron, manganese, and aluminum dominate, trivalent = 3+ charged ions, (Fig 2). These acid-forming cations displace base-forming cations that occupy cation exchange sites in solution, on clay particles, soil aggregates and humified soil organic matter (Fig 3).

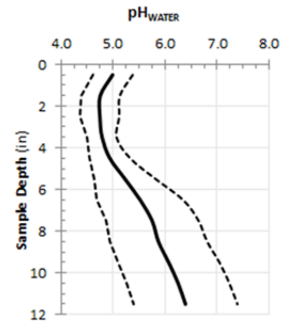

Fig 1. Changes in soil pH by soil depth, means (solid line) ± std dev (dashed line).

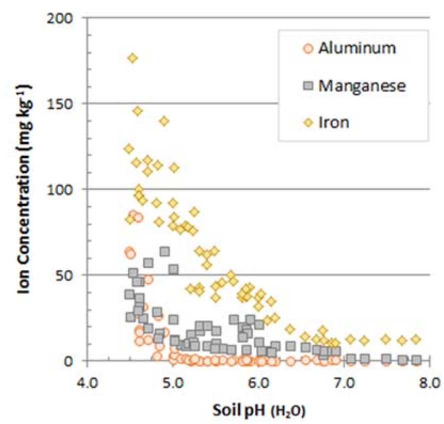

Fig 2. Effect of soil pH on concentrations of three acid-forming cations.

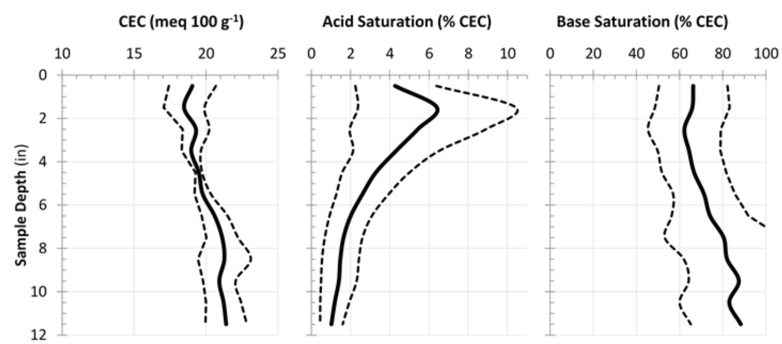

Fig 3. Changes in cation exchange capacity (CEC), acid saturation and base saturation by depth. Acid saturation = ([Al] + [Mn] + [Fe]) ÷ CEC; Base saturation = ([Ca] + [Mg] + [Na] + [K]) ÷ CEC. Solid lines = sample means for four sites, dashed lines = standard deviations.

As a soil acidifies, base cations calcium and magnesium become more water-soluble. Effects of this this phenomenon were observed within the zone or strata of acidification where our data shows depletions of calcium within the acidified zone, followed by increases in base saturation with depth, below the zone of acidification (Fig 3).

Additionally, we observed higher concentrations of mineral nitrogen and sulfur associated with surface concentrations of soil organic materials (Fig 4). It is known that soluble nitrate nitrogen, sulfate sulfur and chloride attach to free calcium to form a relatively soluble molecule. As soluble anions leach to positions below the acidified strata, solubilized calcium and magnesium are carried to lower soil profile positions (Fig 3).

Soil pH amendments including calcium and magnesium carbonates, and organic acids effectively decrease the availability and solubility of acid cations aluminum, manganese, and iron. Cover crops can significantly promote the accumulation of low molecular weight organic acids (citric, malic and oxalic acid) through release from live and during decomposition of terminated succulent plant roots. This process defines one of the principal benefits of cover crops, the production and release of organic acids deep in the rooting zone well below the soil surface. Decomposition of deep penetrating

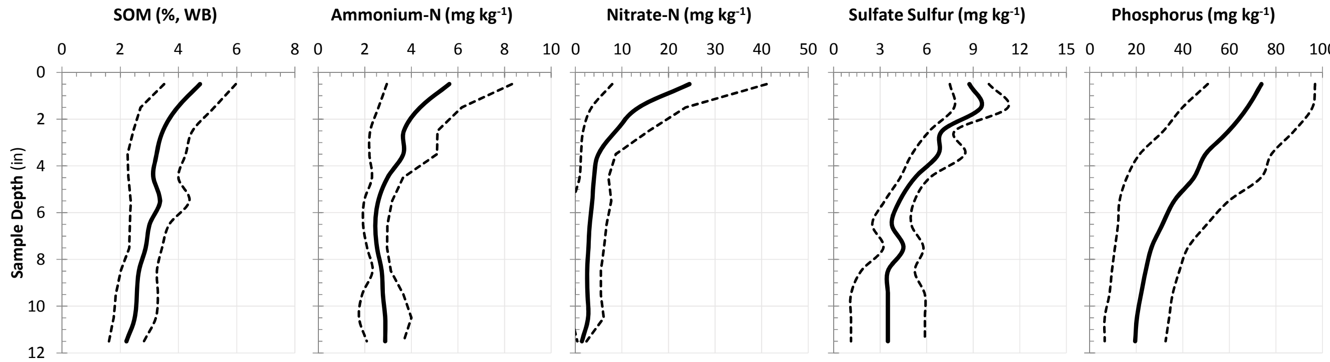

Fig 4. Decreasing soil organic matter (SOM, Walkley Black oxidizable carbon) by depth and concentrations of closely associated nutrients: mineral nitrogen (nitrate and ammonium), sulfate sulfur, and phosphorus. Solid lines represent sample means for four sites, and dashed lines indicate standard deviation.

succulent roots can promote soil organic matter and humus formation deep soil strata, well below conventional surface residue cover conditions promoted by minimum tillage systems alone.

Summary.

Cereal grain harvest residues are dry, relatively nutrient denuded, and much more resistant to decomposition than succulent plant materials of a herbaceous cover crop. Amendments of ag lime to manage low soil pH and correspondingly higher levels of aluminum, iron and/or manganese can further stimulate or enhance microbial activity. Seed box applications of low rate pelletized agricultural liming material directly with cover crop seed may provide a beneficial increase in base cations in cover crop roots and over time with repeated use could effectively sustain increased microbial activity, thereby accelerating the formation of beneficial humic substances deeper in a soil profile.

Soil moisture conditions vary from year to year, and across the iPNW rainfall gradient. For this reason, levels of risks with planting a cover crop mix will vary from year to year. Because we can estimate the amount of water consumed by a cover crop, risk assessment becomes practical. Soil water status measurements combined with projected precipitation rates (low, medium, high probabilities) can provide ample data to reliably assess season-specific risks associated with cover crop water use.

Even though we see promises of known positives that we are beginning to understand and consider, we still ponder both known and unknown negatives that challenge many people and may beg and/or deserve deeper review. I am confident that with continued well-coordinated collaborative efforts, all will soon understand when and where cover cropping strategies can be successfully employed to improve both iPNW cereal and pulse grain production and soil health.

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2015 Research Update. WATER USE BY COVER CROP VS. FALLOW

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Driving Question: What is the water balance trade-off of building soil quality with a cover cropping system versus allowing for increased water storage with a conventional dryland fallow system?

Determine amount of soil water utilized by cover crop versus amount of moisture lost as evaporative water under fallow systems.

Concept Overview:

ET = Evapotranspiration (in)

soil water lost as vapor, plus
consumed by crop to produce biomass

E = Evaporative Water Loss (in)

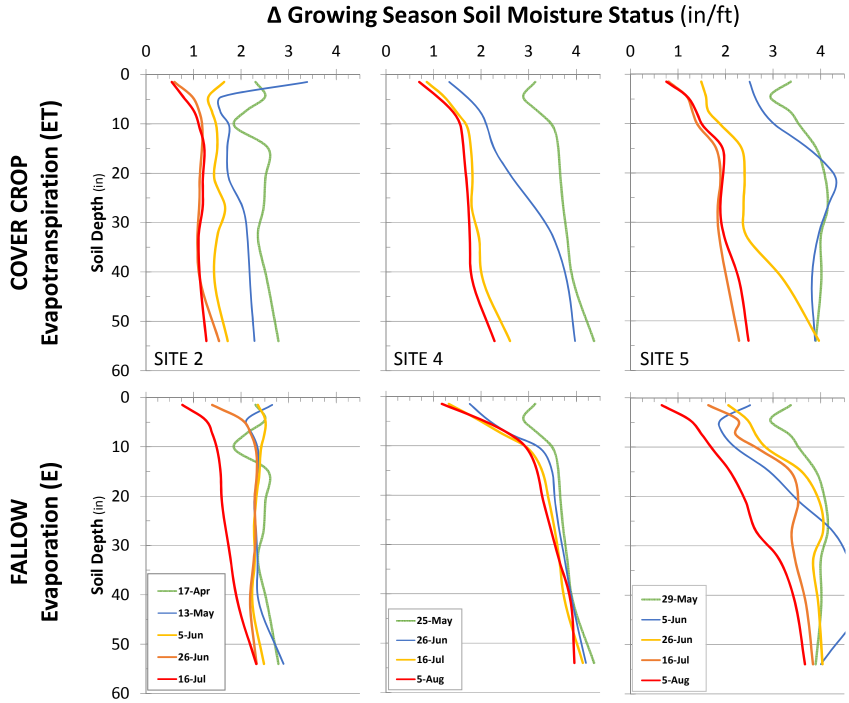
water lost as vapor

T = Transpired Water (in)

consumed by crop to produce biomass,
soil profile water consumed by crop (ET)
relative to water lost under dryland fallow as evaporated water (E)

Assumption:

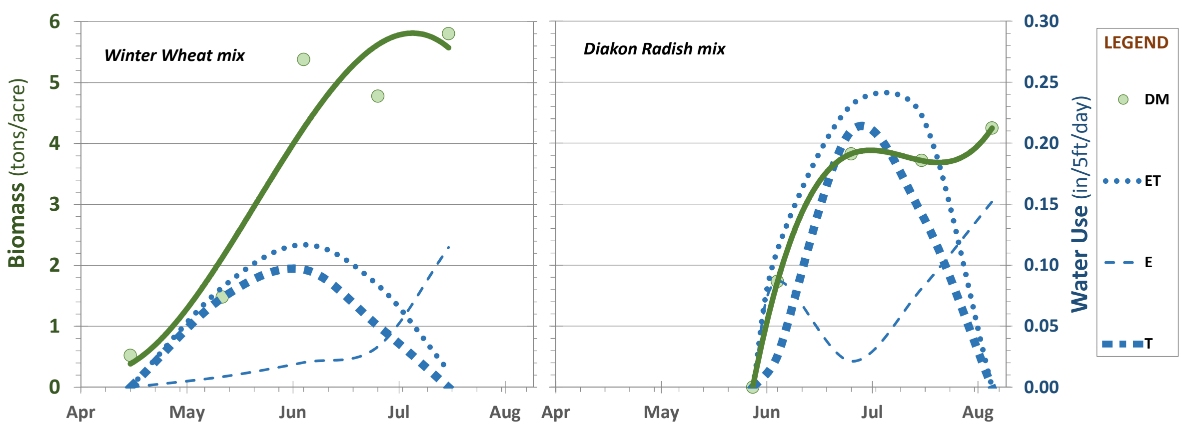
T ≡ Δ (soil moisture crop, ET) – Δ (soil moisture fallow, E)

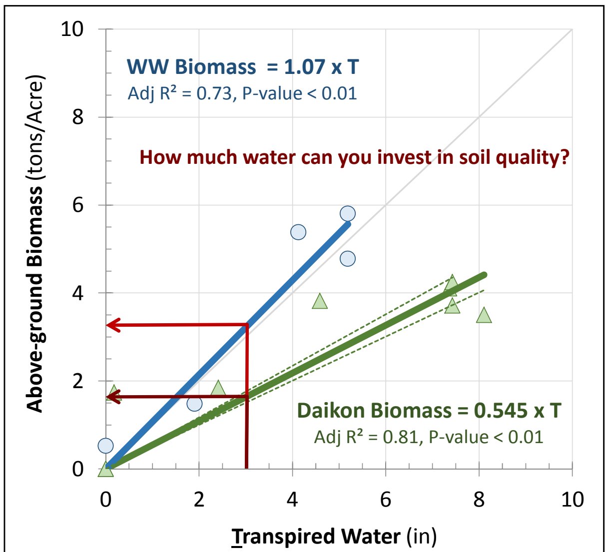


Water use analysis: Cover Crop Dry Matter (DM) Accumulation versus Daily Water Use

Plant tissue samples (dry matter) and 5-ft gravimetric soil moisture samples were collected at ~3-week interval. ET *(cover crop)*, E *(fallow)* and T were calculated as described above (*right*).

Water Use Efficiency was then determined for each CC mix (*below*).





Considerations:

- *Question.* Can we schedule Cover Crop (CC) termination by specifying a limit on CC water use? Consider amount of transpired water per unit CC biomass produced (*left*).
- *Cover Crop Termination Decision Aid.* Should we develop a species-specific soil moisture consumption database for dryland cover cropping systems? Could this minimize risk?
- *Terminated cover crop residues improve soil shading.* Will cover crop residues provide ample shading to moderate soil temperatures and decrease evaporative water loss from termination to subsequent crop planting date?