Title: Subsoil Quality in the inland Pacific Northwest

Taylor Beard, Megan Reese, Isaac Madsen, Lauren Port, Tai Maaz, William Pan; Department of Crop and Soil Sciences, Washington State University

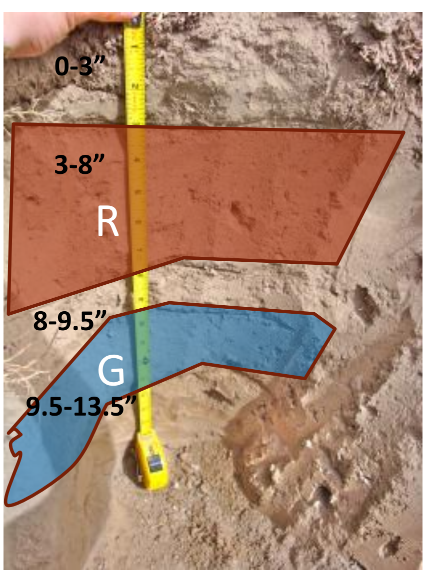
What is subsoil? It is the soil underneath the A horizon (topsoil). Like topsoil it is composed of a variable mixture of sand, silt, and clay, but is lower in organic matter and typically higher in clay sized particles and minerals. Factors that can influence subsoil quality include: soil formation processes, history of tillage and fertility management, pH, and crop rotation.

Figure 1. J-hooked canola root found in Mansfield area in the summer of 2014. J-hooking begins approximately 2.5" below

Why is it important to maximize subsoil quality?

- Enhance crop root growth and development by minimizing physical resistance and maximizing root channels.
- Maximize the storage and timing of nutrient and water availability for crop uptake to improve crop yield and quality.
- One of canola's best traits is the ability to mine nutrients from the soil, however if it cannot get down to those nutrients then more fertilizer may be required.
- Topsoil water is quickly used early in the season, and active roots locate in the subsoil during summer months.

Site 1



Site 2

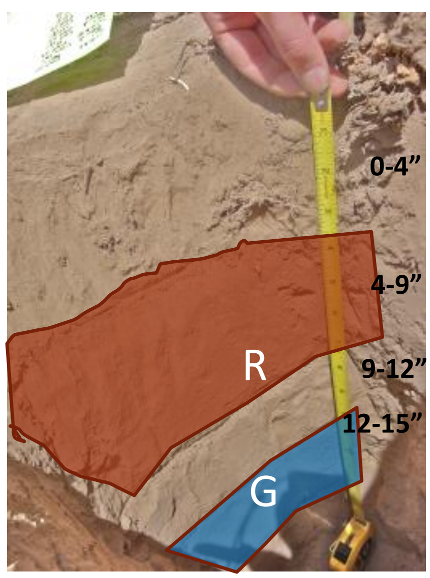


Figure 2. Two sites located in the Mansfield area displaying the impacts of soil formation processes and century long wheat rotations with consistent tillage. Total depth of both soil pits were approximately 17”. R = rodweeding layer, G = glacier layer.

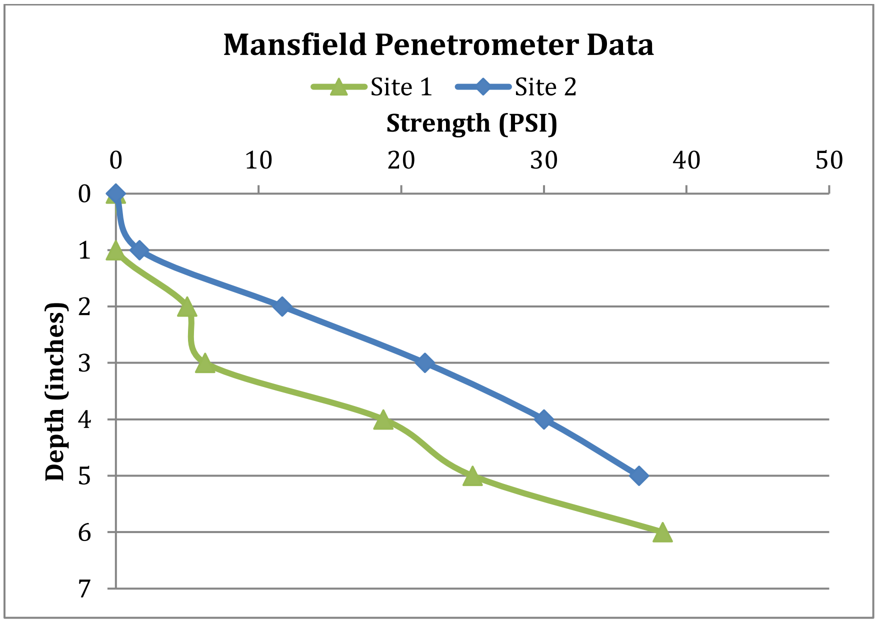


Figure 3. Penetrometer data for both sites.

Table 1. %Moisture, bulk density, texture, pH, Si_{am}, and Si_{ws} for each depth at each site.

Depth (inches)	% Moisture	BD (g/cm^3)	% sand	% silt	% clay	pH	Si_{am}	Si_{ws}
Site 1								
0-3	3.4	1.1	58.4	30.2	11.4	8.2	6.9	0.8
3-8	5.2	1.6	53.3	34.4	12.3	9.3	6.3	1.1
8-9.5	5.0	1.3	56.2	32.9	10.9	9.5	3.3	1.1
9.5-13.5	7.5	1.5	54.8	34.1	11.1	9.6	2.6	1.0
13.5+	7.4	1.2	56.0	33.2	10.8	9.3	3.3	1.0
Site 2								
0-4	4.5	1.1	58.3	29.1	12.6	5.7	7.7	1.2
4-9	3.8	1.6	54.1	33.1	12.8	6.5	5.6	1.4
9-12	4.6	1.2	52.7	34.3	13.0	7.3	4.9	1.3
12-15	4.0	1.4	61.6	28.1	10.3	7.4	3.7	1.4
15+	4.0	1.2	57.9	30.4	11.7	7.1	4.6	1.4

High amounts of silicon (Si) have been linked to soil pan formation in previous studies. Silicon amounts can be influenced by many factors including crop type. Grass crops such as wheat can accumulate up to 10 times as much Si as broadleaf crops.

Soil pH affects the availability of Si within the soil. More acidic pH allows the Si to become available in the soil solution while higher pH levels cause Si to be adsorbed to soil particles.

Subsoil Quality in the PNW, Part 1: Physical and Chemical Root Restrictions

Taylor Beard, Megan Reese, Isaac Madsen, Lauren Port, Tai Maaz, William Pan; Department of Crop and Soil Sciences, Washington State University

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Figure 1. J-hooked canola root found in Mansfield area in the summer of 2014.

J-hooking begins approximately 2.5" below the surface.

Why is it important to maximize subsoil quality?

- Topsoil water is quickly used early in the semi-arid season, and active roots locate in the subsoil during summer months.
- Maximize root access, and the storage and timing of nutrient and water availability for crop uptake to improve crop yield and quality.

Physical Restrictions

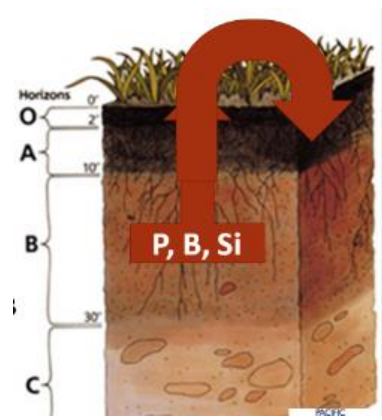
One of canola's best traits is the ability to mine nutrients from the soil, however if compaction (Figure 2) can restrict root development, causing J-hooking); more fertilizer may be required and yield potential declines. In order to enhance crop root growth and development we must minimize physical resistance.

Fertilizer Restrictions. We have become accustomed to banding ammonium based fertilizers below wheat seed rows in direct seed systems. The multiple axes wheat root systems are able to tolerate the high ammonia/ammonium conditions of the fertilizer band. But canola has a single tap root, which can be severely damaged by deep placed ammonium sources such as urea (figure 4). Adjustments in fertilizer placement, timing and form are required to avoid seedling damage and death.

Subsoil Quality, Part 2: Do our subsoils provide wheat and canola roots with ample water and nutrients during grain filling?

Bill Pan, Megan Reese, Taylor Beard, Isaac Madsen, Tai Maaz, Department of Crop and Soil Sciences, Washington State University, Pullman, WA

The inland Pacific Northwest is blessed with deep soils that are capable of storing water and nutrients that the crops can access over their life cycle in producing abundant grain. But 125 years of producing annual crops has extracted subsoil nutrients, and we now need to ask if we have a problem with subsoil deficiencies of the soil-immobile nutrients? These deficiencies are also exacerbated by alkaline subsoil conditions? Typically, routine **soil tests** are only conducted on **surface soil** samples. This approach was developed **for Midwestern and southern U.S.** where summer rains replenish topsoil moisture, thereby sustaining shallow root uptake of topsoil nutrients. The PNW adopted the same approach, but **does this make sense for us?** Currently we only test for subsoil mobile nutrient forms (nitrate and sulfate), replenished with vertical infiltration of water that carry these anions during soil recharge. **We decided to run soil tests on all root zone depths to begin assessment of subsoil fertility status. Here's what we found:**



- Most annual dryland crops remove subsoil nutrients, and those that are not removed by grain harvest are returned to the soil surface (see Figure).
- Wheat **recycles Si** to the soil surface more than canola. This may increase soil crusting.
- Many nutrients are not soluble enough to be carried in high concentrations back into the subsoil, and mainly remain in the surface soils that receive these nutrients. **Soil immobile nutrients include P, Zn, Mn, Fe, B.**
- Over years of crop extraction, these soil-immobile nutrients have reached very low levels, and high subsoil pHs render some of these even more unavailable.
- But wheat and canola **root systems rely on subsoil water and nutrients** mid to late season as surface soils dry in our semi-arid climate.
- Topsoils dry out in our systems and shallow roots become inactive. **Do our subsoils provide wheat and canola roots with ample nutrients during grain filling?**
- With our unique patterns of winter precipitation and dry summers, **improving subsoil fertility subsoils** may be crucial to achieving full soil productivity potential.
- What are ways to improve subsoil fertility? For example deep phosphorus movement is only achieved when P fixation sites are saturated during P overfertilization. It will be tough. However, organically bound nutrient forms are more mobile. Green cover crops, animal manures, biosolids, and perennial forages may all provide more organic compounds such as organic acids that solubilize soil-immobile nutrients.

	Seasonal Availability of Immobile Nutrients ←--early-----→ ←-mid-season→←------late------→ Soil Depth (ft)				
OKANOGAN composite B	0_1'	1_2'	2_3'	3_4'	4_5'
pH 1:1	6.7	7.5	8.8	9.3	9
E.C. 1:1 m.mhos/cm	0.28	0.17	0.22	0.28	0.27
E.C. saturated paste m.mhos/cm	0.68	0.44	0.57	0.73	0.7
Effervescence	Low	Low	Med	Med	Med
Organic Matter W.B.	1.3	0.9	0.4	0.5	0.004
Ammonium - N mg/kg	4.1	2.7	0.6	0.8	1.6
Nitrate – N mg/kg	1.7	3.6	0.9	0.8	1.7
Sulfate – S mg/kg	7	6	6	6	7
Phosphorus Olsen mg/kg	16	9	4	7	7
Potassium Olsen mg/kg	449	406	350	365	324
Boron DTPA mg/kg	0.15	0.21	0.2	0.13	0.07
Zinc DTPA mg/kg	0.9	0.2	0.1	0.1	0.1
Manganese DTPA mg/kg	2.8	0.9	0.5	0.8	0.7
Copper DTPA mg/kg	0.6	0.6	0.5	0.7	1.1
Iron DTPA mg/kg	26	8	5	7	6
Calcium NH4OAc meq/100g	6.1	6.4	11.4	6.6	12.8
Magnesium NH4OAc meq/100g	1.1	1.5	2.2	2.3	2.4
Sodium NH4OAc meq/100g	0.1	0.15	0.72	1.23	1.15
Total Bases NH4OAc meq/100g	8.5	9.1	15.1	11.1	17.2

Holy Grail of semi-arid systems: Improve and sustain soil productivity by increasing SUBsoil organic matter, macropore channels, nutrient availability. It is not happening with tilled monoculture wheat.

- Perennial crops
- Cover crops
- Large taprooted crops
- Earthworms
- No Tillage

Let's do it.

Questions? Contact Bill Pan wlpan@wsu.edu

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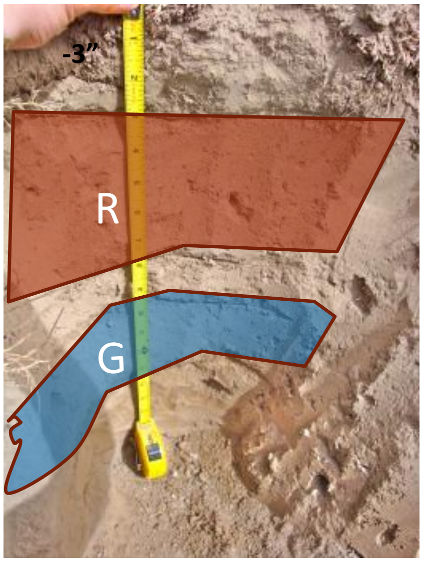
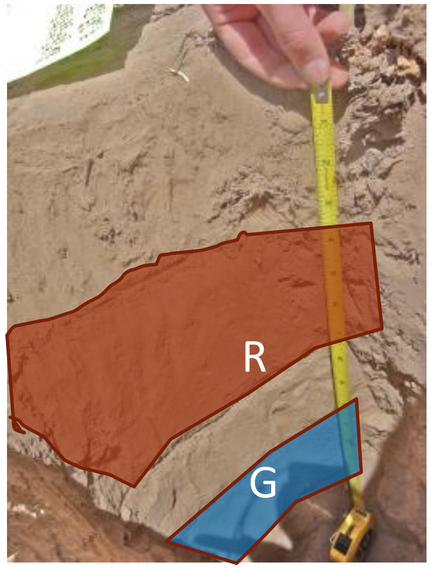


Site 2



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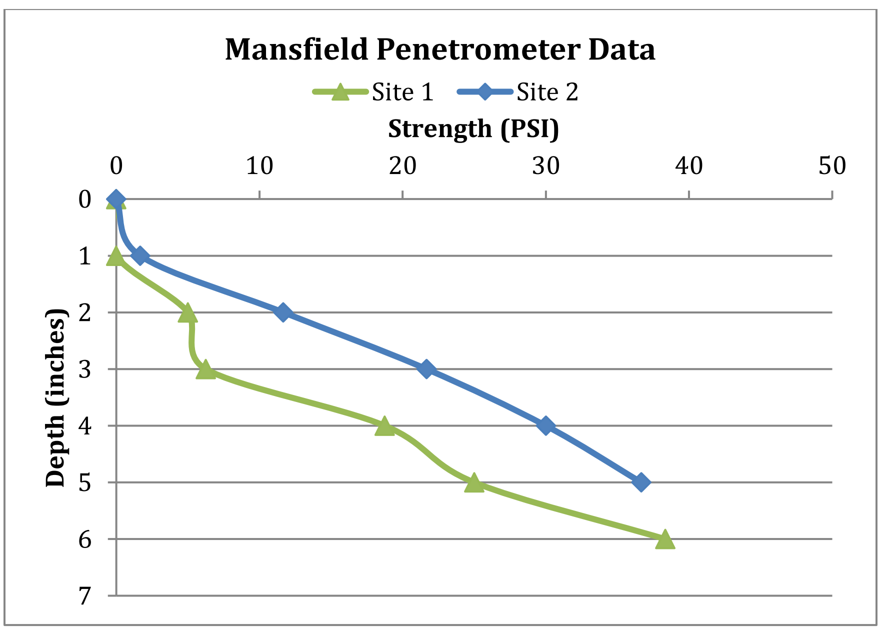

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Soil pH affects the availability of Si within the soil. More acidic pH allows the Si to become available in the soil solution while higher pH levels cause Si to be adsorbed to soil particles. All of these factors can contribute to greater soil crusting and compaction.

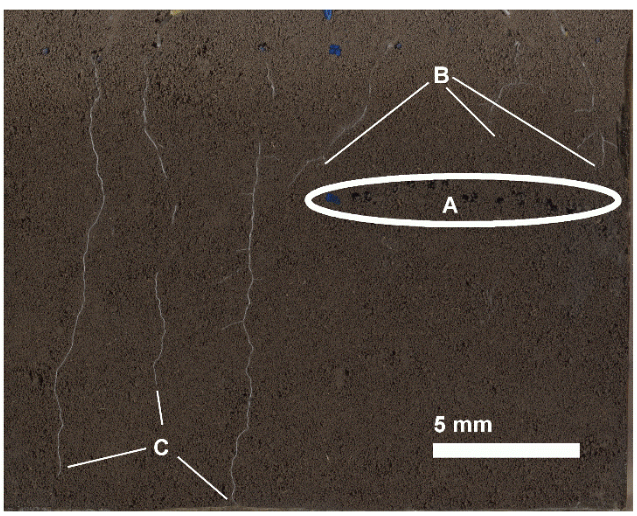

Figure 4. Canola seeds planted 2.5 cm soil below the soil surface and 5 cm above a fertilizer band (A). The tap roots of the seeds placed above the fertilizer band stopped short of the fertilizer band and prematurely developed lateral roots (B). The tap roots of the plants without the fertilizer band proliferated towards the bottom of the container (C).