Subsoiling to Reduce Compaction

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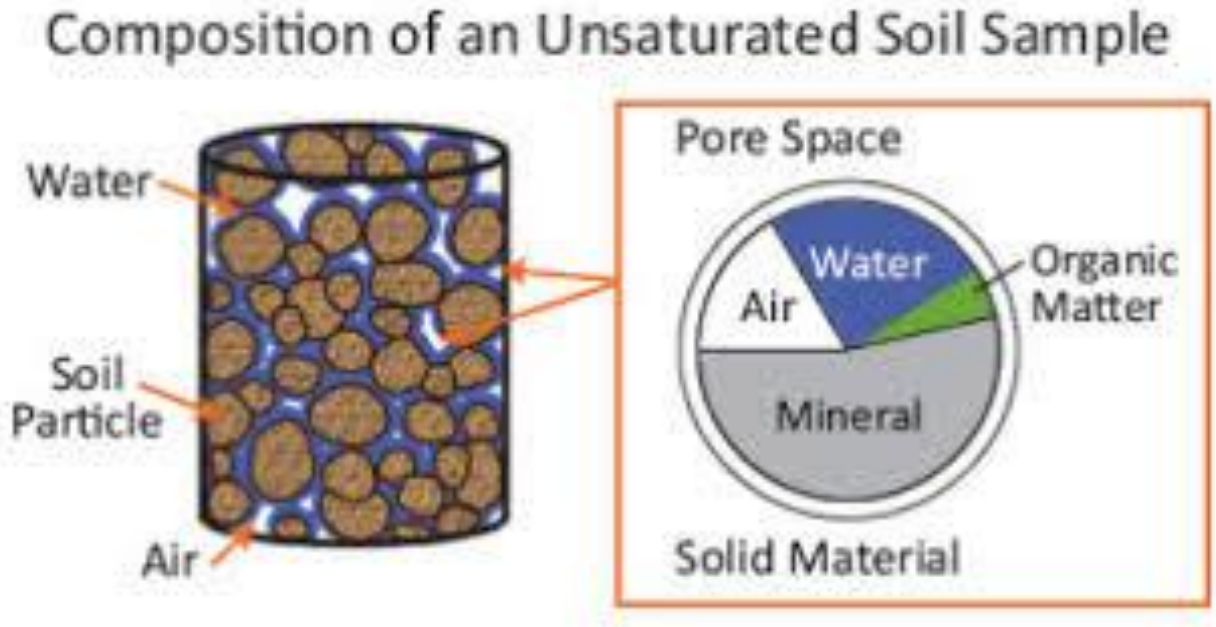
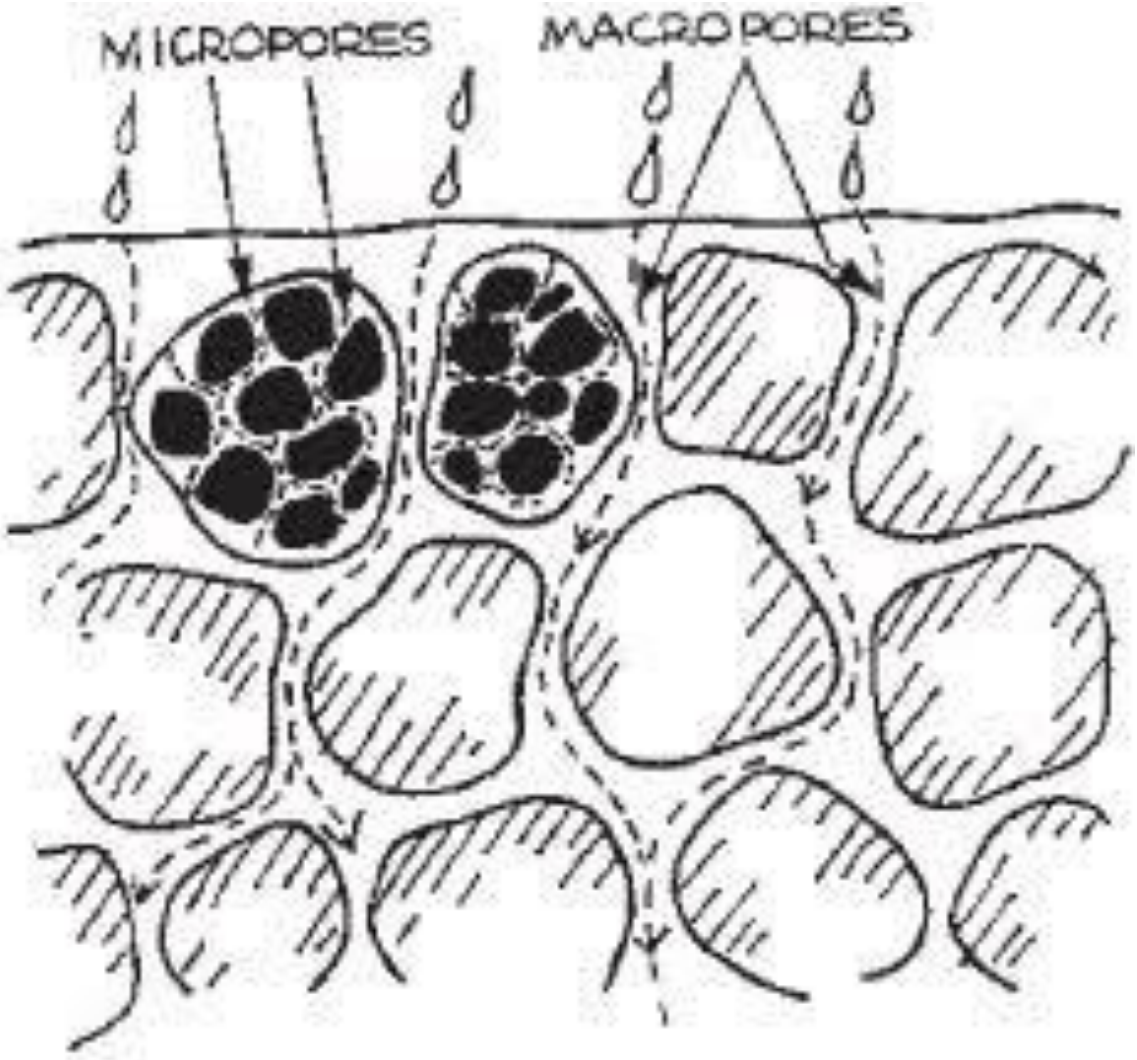
Soil Density

- This is an important soil characteristic to understand
- A soil is made up of the following:
  - Mineral particles
  - Humus particles
  - Soil pores that can be filled with air, water, or a combination of air and water



Pore Space is made up of Macropores and Micropores

- Macropores: are the large pores between soil peds from natural swelling and shrinking, and biopores (old root and soil animal channels)
- Micropores: are the small pores within soil peds or soil aggregates.



Soil Porosity

- Soil pores are important for water and air storage and movement
- It can be calculated as follow:

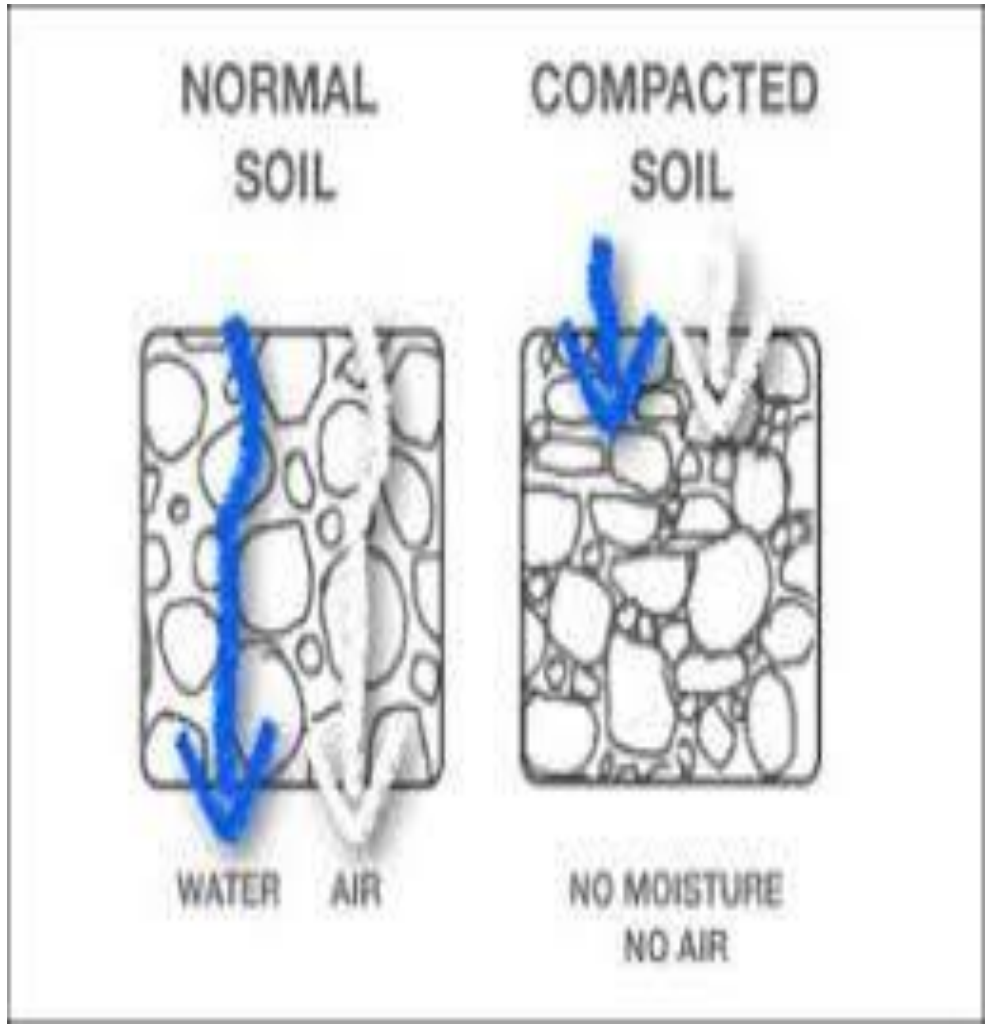
% pore space = 100% - [(Db of soil/density of soil minerals) x 100%]

Db of soil = 1.20; Db of most soil minerals = 2.65

% pore space = 100% - [(Db of 1.20/2.65) x 100%]

= 100 – 45.3

= 54.7% Pore Space



Soil Structure – Mineral Soils

- Soil mineral particles (sand, silt, and clay), combine together with organic materials or humus, to form complex aggregations
- Called aggregates, or peds
- The large scale structures are usually called peds
- Large peds can be broken into smaller peds or aggregates

Types of Soil Structure

- Single-grained
  - Loose sand particles
- Spheroidal
  - Granular structure, <1 up to 10 mm in diameter
- Platelike
  - Thin horizontal sheets or plates
- Blocky
  - Usually irregular cubelike aggregates, 5 to 50 mm in diameter
  - Angular blocky and subangular blocky
- Prismatic
  - Peds that are columnar or prismatic, arranged in vertically orientated peds

Spheroidal

Characteristic of surface (A) horizons. Subject to wide and rapid changes.

Granular (porous)

Crumb (very porous)

Plate-like

Common in E horizons, may occur in any part of the profile. Often inherited from parent material of soil, or caused by compaction.

Platy

Block-like

Common in B horizons, particularly in humid regions. May occur in A horizons.

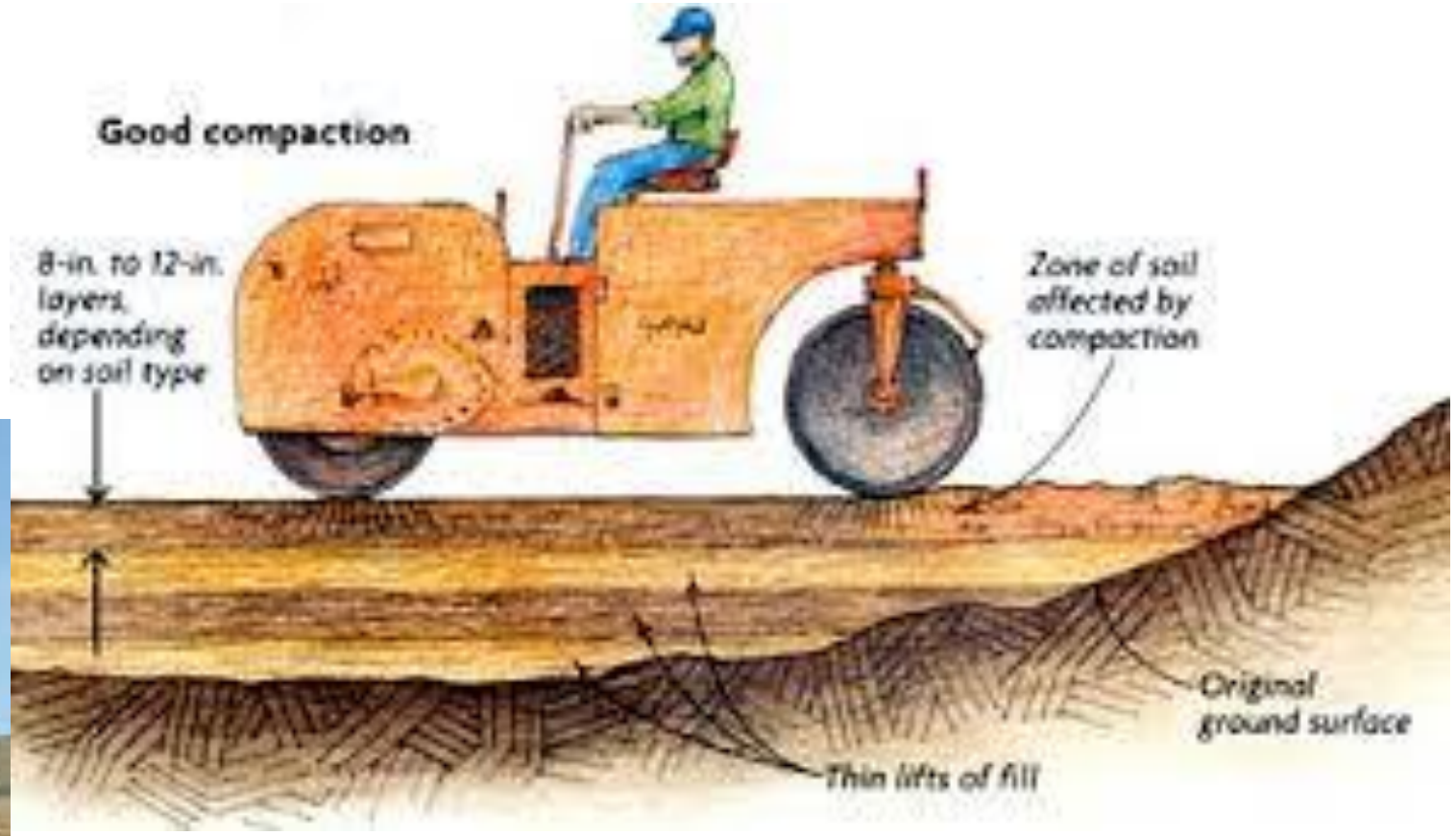
Angular blocky

Subangular blocky

Figure 4.21 Weil, Raymond R.; Brady, Late, Nyle C., Emeritus Professor. Nature and Properties of Soils, The (Page 147). Pearson Education. Kindle Edition.

Engineering- Soil Compaction for Road Foundations

- It is useful that subsoil materials can be compacted



Soil Properties Relevant to Engineering, cont.

- Compaction. Soils to be used for a foundation or roadbed are compacted on purpose using heavy rollers or vibrators. A Proctor test measures the bulk density of a soil at different moisture contents to determine the moisture content to achieve compaction.
- Compressibility. How much its volume will be reduced by a given applied force.

Weil, Raymond R.; Brady, Late, Nyle C., Emeritus Professor. Nature and Properties of Soils, The (Page 176). Pearson Education. Kindle Edition.

Influence of Tillage

- If the soil is too wet or too dry, tillage can destroy aggregation
- If soil is damp, neither too wet nor too dry, tillage can break large clods into smaller natural aggregates

Soil Tilth and Soil Friability

- A soil that can be cultivated and maintains a strong friable granular structure as large clods break apart is considered to have **good soil tilth**
  - The strength of the granular aggregate bonds is greater than the strength from tillage to break them apart

Soil Crusting

- Soil crusting is when the impact of raindrops breaks apart the surface soil aggregates, that are weakly held together, or poorly aggregated.
- The small soil particles, such as dispersed clay and silt, can clog surface soil pores
- When the soil dries, it can crust to the point that crop seedling shoots cannot grow through the crusted surface layer.

Density of Soil Portions

- Mineral particles 2.60 to 2.75 Mg/m^3
- Air 0.00 Mg/m^3
- Water 1.00 Mg/m^3
- Humus or organic matter 0.15 Mg/m3

http://www.sciencedirect.com/science/article/pii/S2214317315300093

Soil Bulk Density D_b

- But soils are a mix of mineral particles, air, water and humus
- Mineral soil bulk densities range between 1.0 and 2.0
- A granular topsoil with 6% organic matter can have a D_b of 1.2 to 1.3 Mg/m3

How to determine the Bulk Density of Soils (D_b)

- Collect a known volume of soil, using a core sample tube
- Dry it in an oven, e.g. 100 C for 24 hours
- Weigh the soil sample
- Calculate the D_b

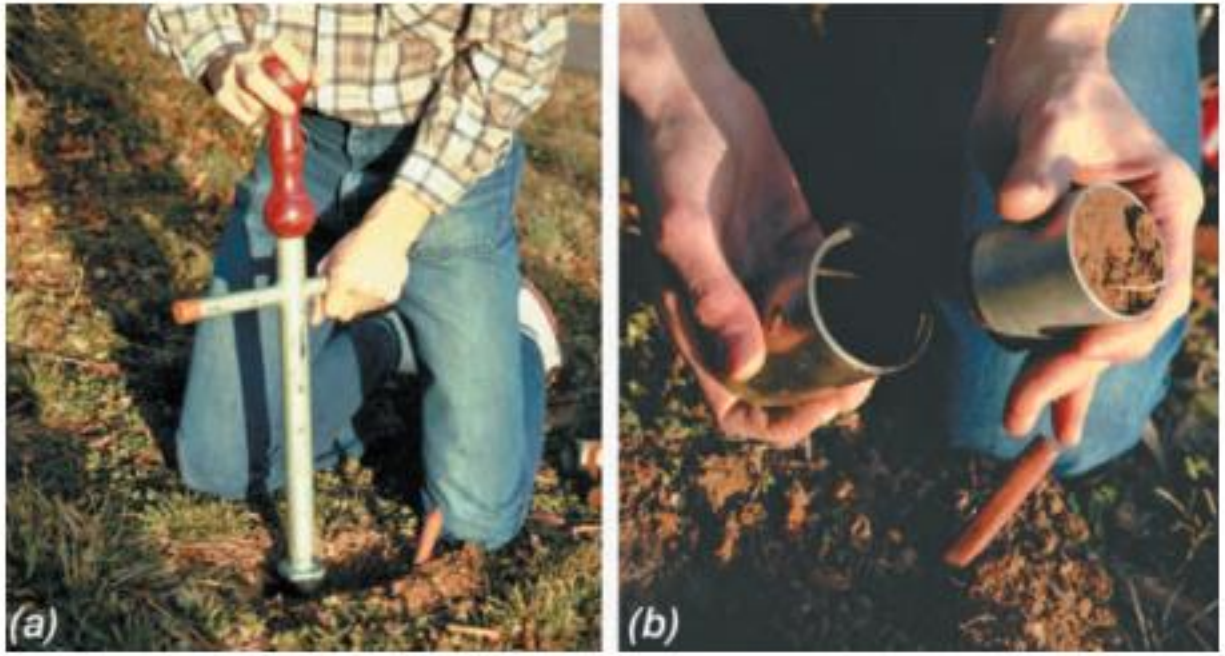


Figure 4.43 *A special sampler designed to remove a cylindrical core of soil without causing disturbance or compaction (a). The sampler head contains an inner cylinder and is driven into the soil with blows from a drop hammer. The inner cylinder (b) containing an undisturbed soil core is then removed and trimmed on the end with a knife to yield a core whose volume can easily be calculated from its length and diameter. The weight of this soil core is then determined after drying in an oven.* (Photos courtesy of Ray R. Weil)

Management Practices Affecting Bulk Density

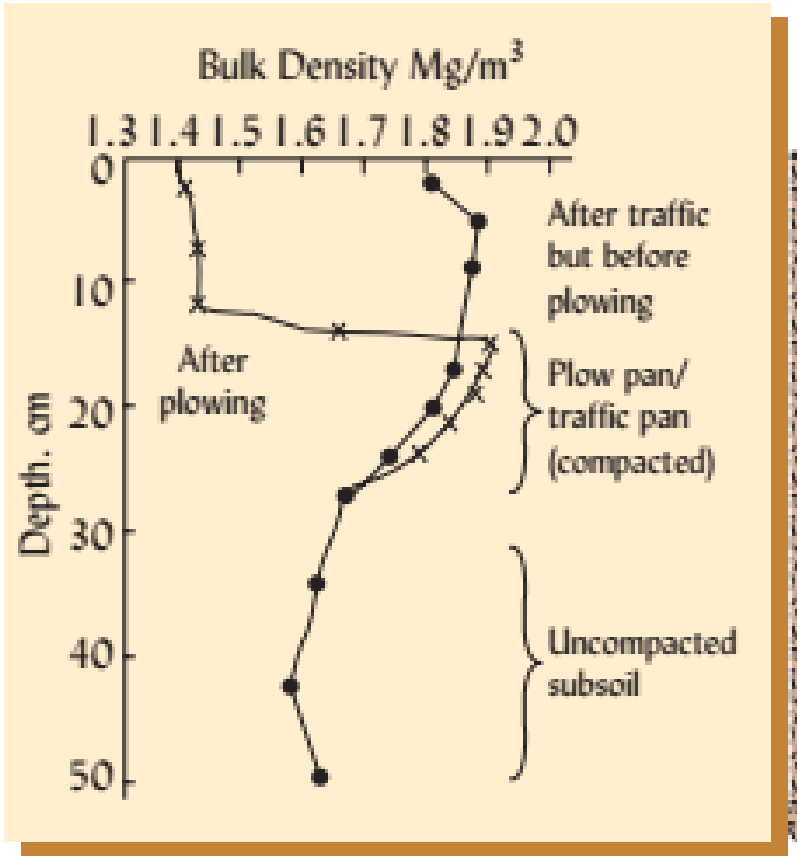
Forested Land, logging and skidder wheel traffic:

Time of Sampling	Bulk Density, Mg/m^3
Prehavest 0 to 8 cm	1.25
Postharvest, skidder trails 0 to 8 cm	1.47
Prehavest 8 to 15 cm	1.40
Postharvest, skidder trails 8 to 15 cm	1.71

Agriculture Land Affected by Tillage

Soil Management	D_b
Silt Loam, South Dakota Uncultivated grassland	1.10
Silt Loam, South Dakota, 80+ years **Cultivated**	**1.30**
Arid Clay Loam Soil, Turkey, uncultivated	1.25
Arid Clay Loam Soil, Turkey**, cultivated 12 years**	**1.34**
Zimbabwe Clay Soil, uncultivated	1.20
Zimbabwe Clay Soil, cultivated, **20-50 years**	**1.44**

Wheel Traffic and Ploughing of Soil



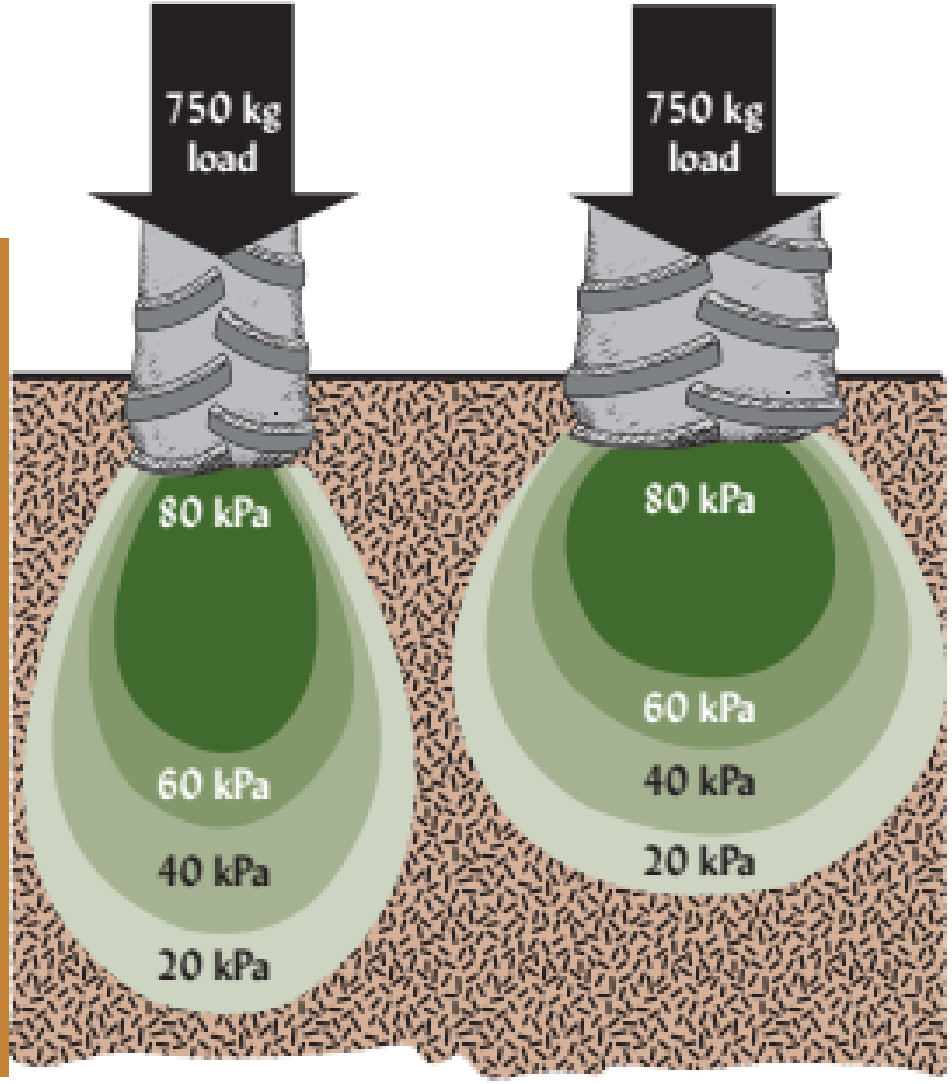


Figure 4.50 Vehicle tires compact soil to considerable depths. Plowing can temporarily loosen the compacted surface soil (plow layer), but usually increases compaction just below the plow layer.

Weil, Raymond R.; Brady, Late, Nyle C., Emeritus Professor. Nature and Properties of Soils, The (Page 168). Pearson Education. Kindle Edition.

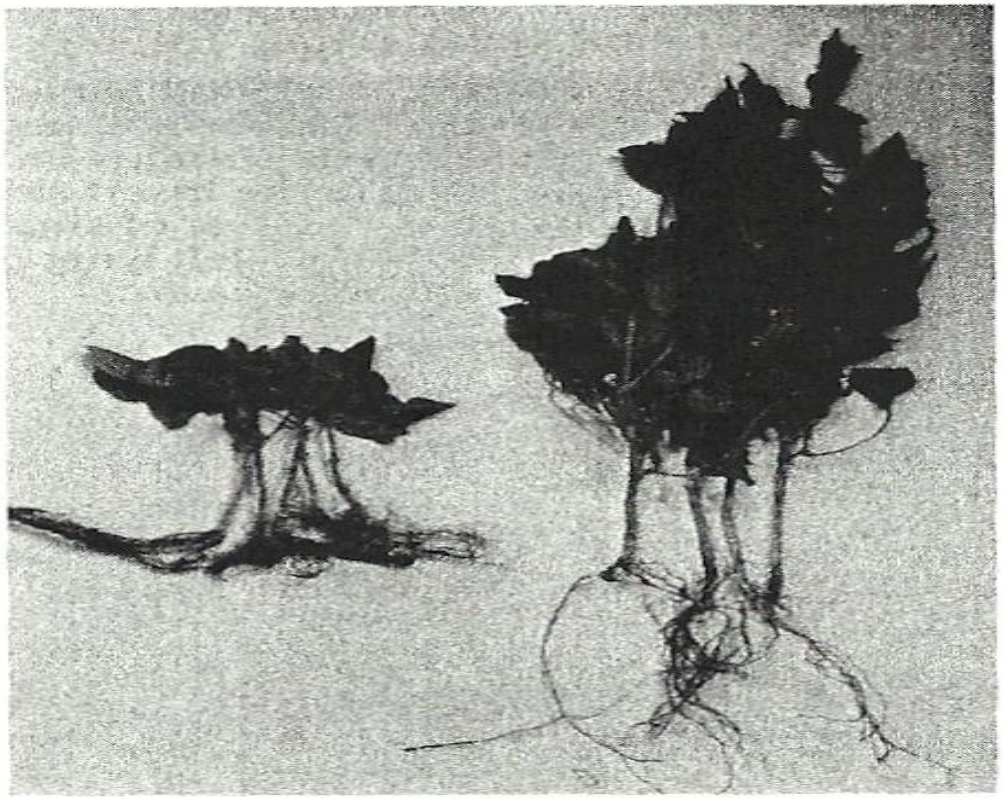
Effects of Compaction

- Reduced porosity, increased density of soil can **impede root growth**.

Soils with bulk density greater than about 1.6 to 1.8 grams per cc have problems with root penetration.

(Ideally like to have densities around 1.0 to 1.3 g/cc)

FIGURE 4.5 Bean root growth in compacted soil at 4-inch depth on left and no soil compaction on the right.



From Fundamentals
Of Soil Science, H. Foth

- Soils with **high clay, low organic matter**, limited aggregation (poor structure) most susceptible.
- **Excess moisture**: soil more easily deformed and particles forced together or smeared into dense layers: wheel ruts, tire slippage
- **Vehicle traffic** with high contact pressure: high weight, low footprint. Greater contact pressure and more passes = greater compaction.

Ways to Reduce Soil Compaction

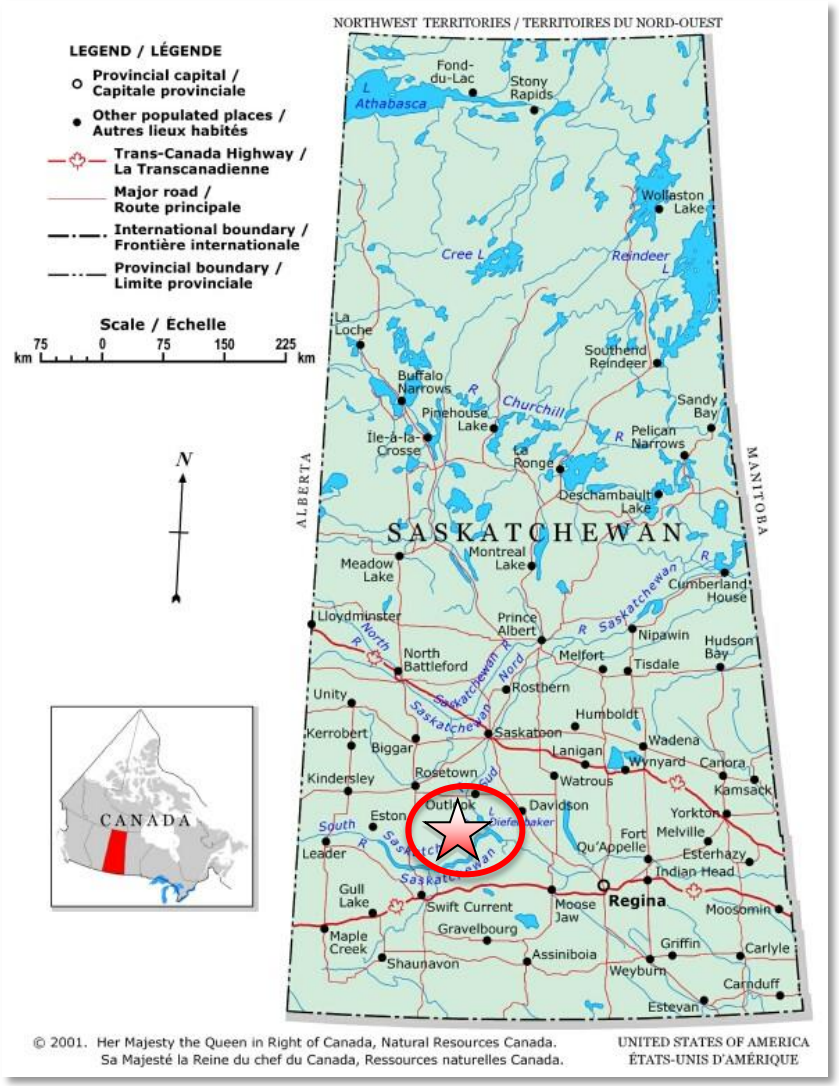
- Grow cover crop mixtures with some deep rooted crop species
- Use traffic tramlines in fields,
  - size equipment so that equipment wheel are always in the same track
  - The wheel track areas become compacted, but between tracks areas are uncompacted
- Use low tire pressure equipment
- Use soil subsoiling equipment

Research Project:
Effects of Sub-Soiling on Soil Bulk Density, Water Infiltration and Yield

Brett Ewen, Schoenau, J., Grevers, M. & Weiterman, G

University of Saskatchewan, Department of Soil Science, SMA Outlook

Site Location

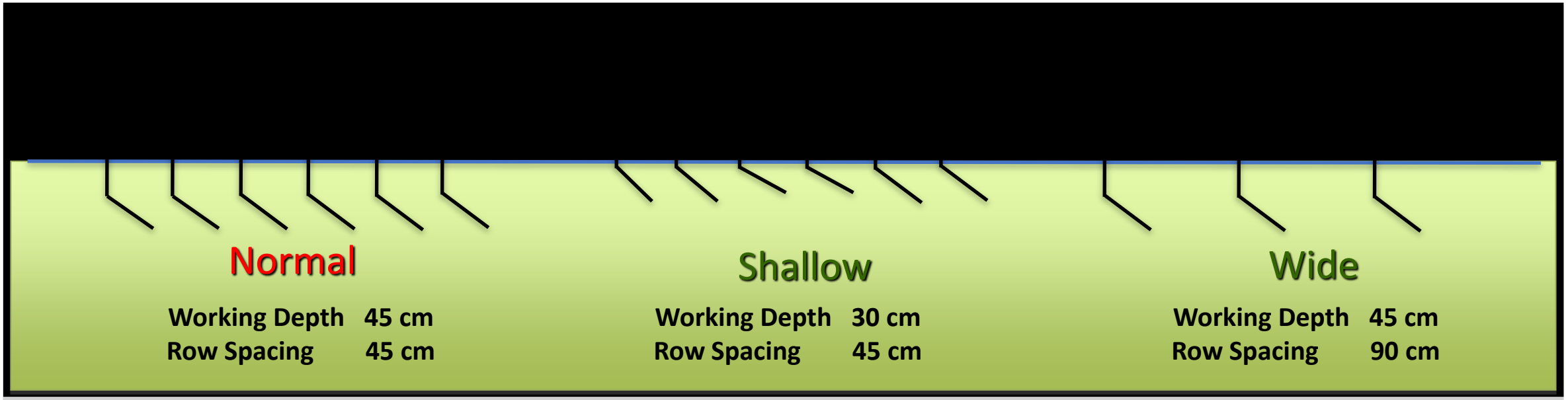


Two soil types:
Loamy Chernozem
Clayey Vertisol

Research Design

- Sites
  - 2010 – Chernozem, Vertisol, Solonetz (lost to flooding)
  - 2011- Chernozem 2, Chernozem Dryland
  - Seasonality
    Fall and Spring

- Three Configurations of Implement

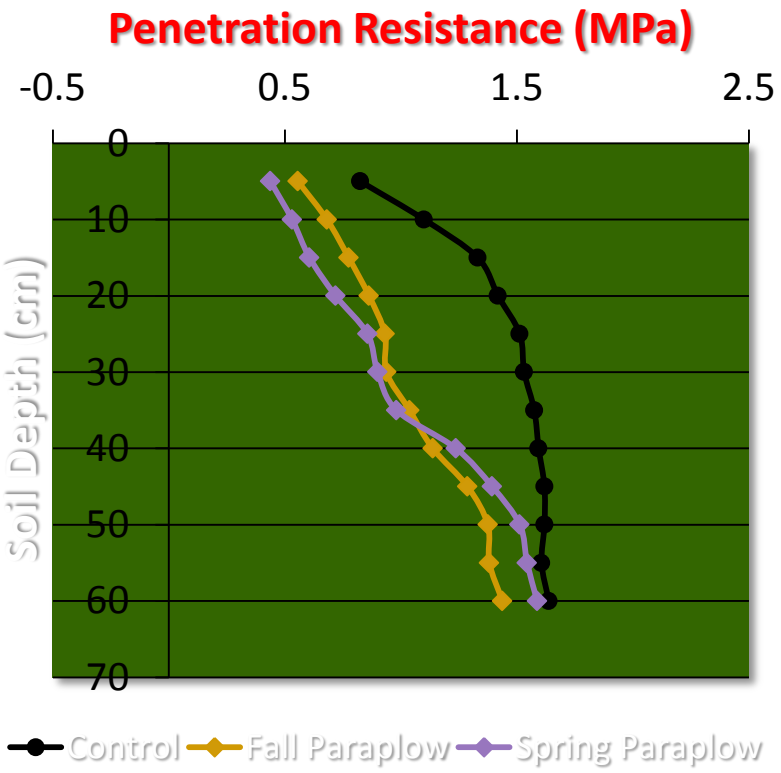


Treatments

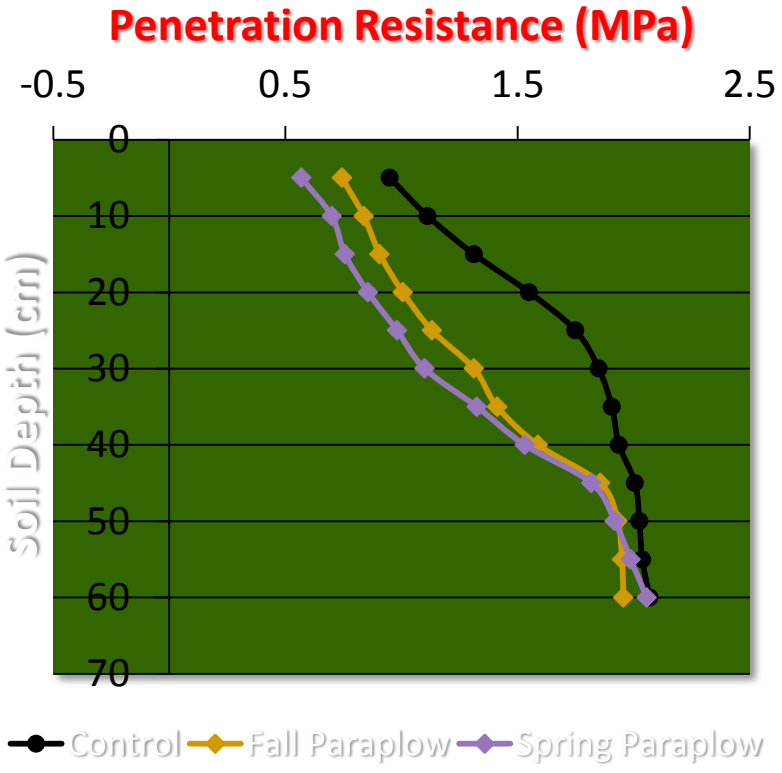
Penetration Resistance

Measured May 19, 2010

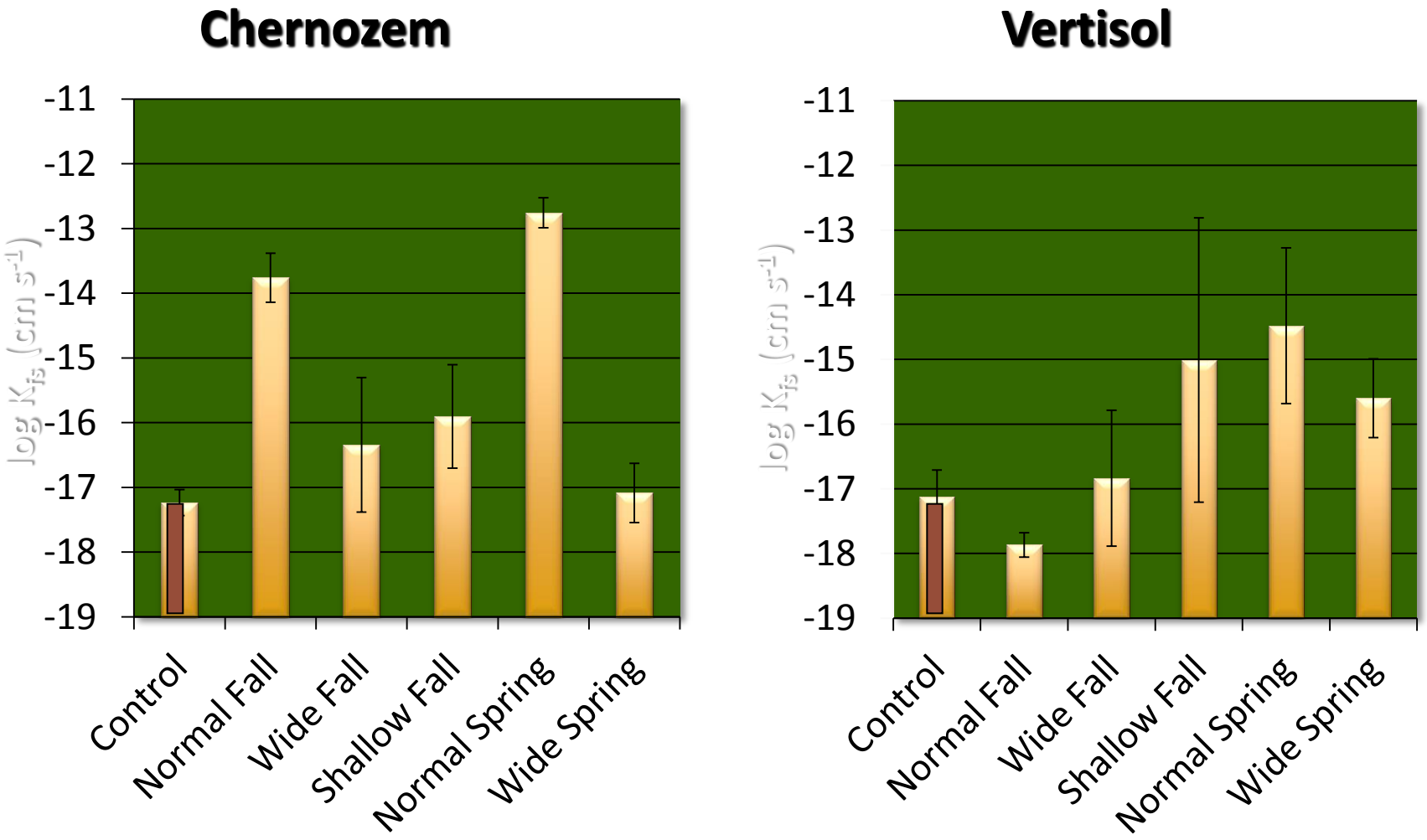
Vertisol

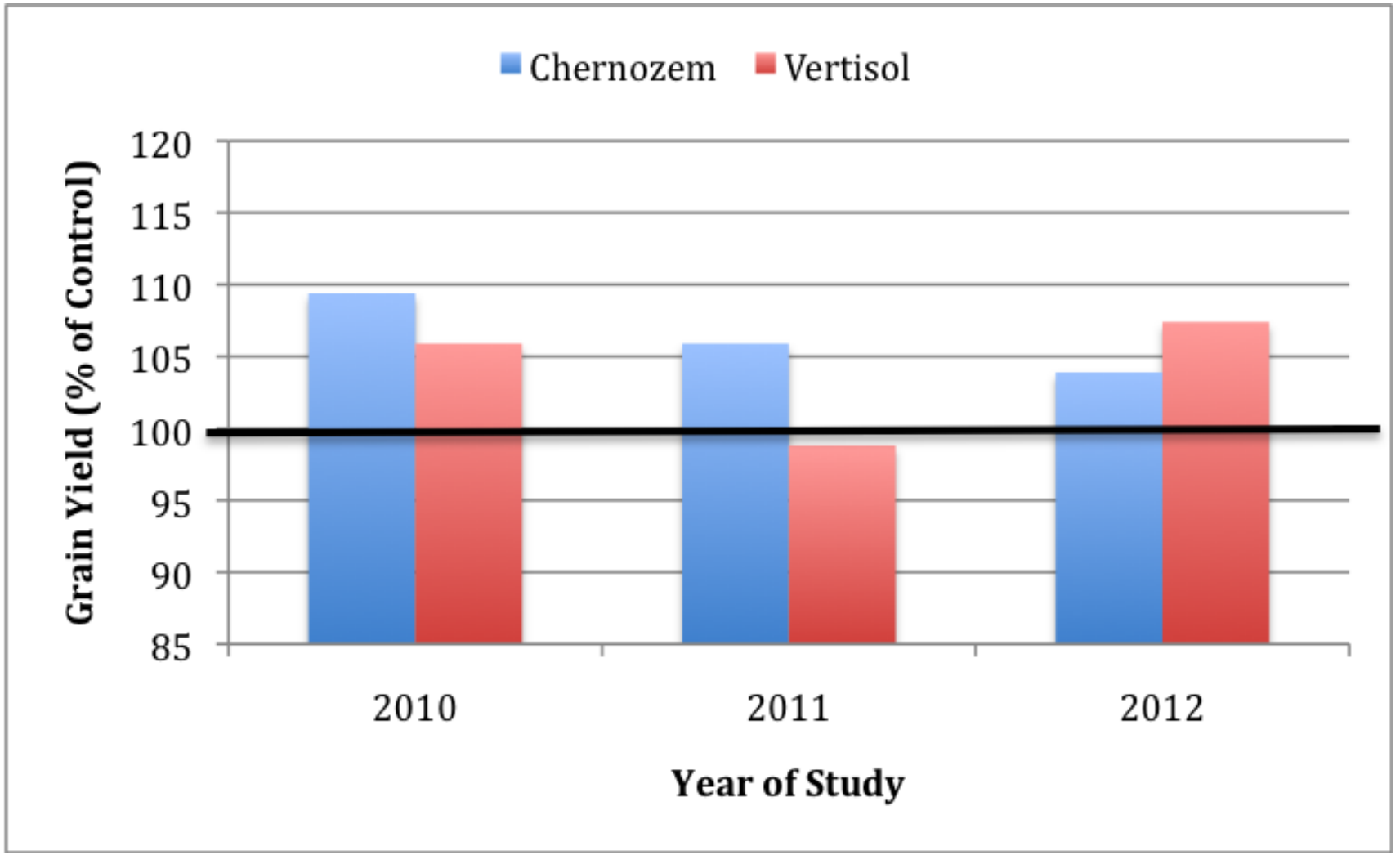


Chernozem



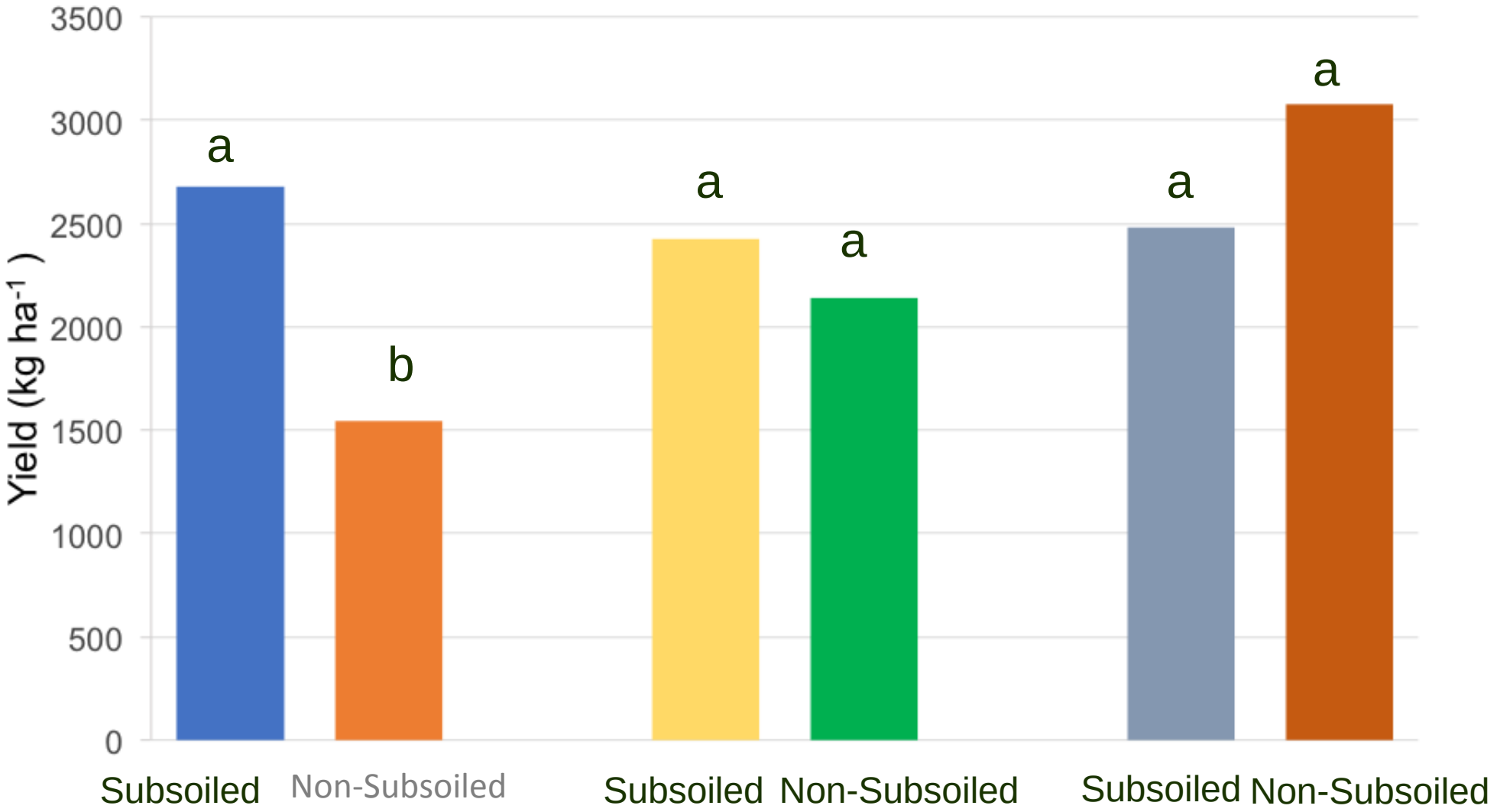
Water Infiltration Rate into Soil





Effect of sub-soiling on crop yield expressed as % of un-tilled control for each of the three years of the study

Raul Avila 2016 Tillage Study Canola Yields



Long-term compacted

Compacted after subsoiling

No compaction

Economics

- Calculated cost of sub-soiling with paraplow

~ $ 30 / acre (includes ownership and operating costs)

- Yield increase of 5% in first year = ~ 2 bushels per acre: means about break-even.
- Need to have larger benefits or benefits that persist longer than one year to provide significant positive economic return.

Conclusions

- Sub-soiling with paraplow reduced soil density and increased infiltration.
- Persistence of effects appears to be reduced in high clay content soils under wet conditions.
- Paraplowing had a limited effect on crop yield (~5% benefit) at the sites in this study.
- Drier conditions? Soils with more pronounced compacted layer?

- Compared to other parts of the world, we on the prairies are fortunate when it comes to compaction problems!

The many freeze-thaw and wet-dry cycles we experience in our environment, especially in spring and fall, are sources of contraction and expansion in the soil that help naturally break up compacted soil.

Questions