A high quality soil is a highly functioning soil that:

- Supports plant growth
- Recycles & buffers nutrients
- Accepts & stores water
- Exchanges gases with the atmosphere
- Regulates temperature
- Detoxifies & breaks down waste
- Is a reservoir of microorganisms & genetic diversity


"Soil health means soil quality. Healthy soils hold more moisture, are more productive and have higher microbial populations." Odell Raymond, NPARA, Peace River, AB

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Introduction

Part I or Forage Fact #95 provided some background about key Biological, Chemical, and Physical soil properties or indicators. Part II shows how these properties are integrated. Here we focus on the centre of the soil health diagram.

In addition to inherent soil properties, soil health is also a function of management.

Management objectives may be complementary or they may be mutually exclusive. For example, here we see bale grazing, which may have been aimed at providing a seed source for the pasture, increasing organic matter in selected spots, or reducing fuel costs or all three. Increased micro-site diversity is an unintended consequence, where the hay residue was thicker.

Soil variability is often easily visible in forage crops. It is not always as easy to diagnose, however. Here we see several different underlying soil conditions that affect the crop. Some may be chemical, some may be physical interacting with biological soil processes. Some may be simply varying degrees of the same condition.
Three Connectors For Discussing Interactions

Interactions among properties or indicators center on three connectors: **Aggregation**, **pH** and **Soil Organic Matter**. These connectors interact with other Biological, Chemical and Physical properties leading to outcomes that regulate plant growth, which in turn feeds back to them. We use 3 diagrams below to illustrate interactions involving each connector with examples of outcomes. **Red lines** represent progression and outcomes; **green lines** are feedback.

1. **Soil Aggregation**

**How do aggregates form?** They form in soils with more than 15% clay by physical and biological processes. In surface soils minerals and organic matter, e.g. polysaccharides, bind to soil clay particles to form micro-aggregates (< 0.25 mm diameter).

- **Aggregation** a physical property (blue in diagram on left) alters biological (yellow boxes in diagram), and physical (blue boxes in diagram) properties and is in turn regulated (green arrows) by stable properties such as Texture and Minerals, and by dynamic properties such as Fungal Hyphae and Soil Organic Matter (chemical or red boxes in left of diagram).

**What do they do?** Macro-aggregates bulk up soil (lower the bulk density). Bulkier soil allows air and water to enter and move more readily. That in turn enhances growth of micro-organisms and maintains aerobic processes. It favors root growth through soil to reach water and nutrients, while improved infiltration reduces erosion. All these outcomes improve crop growth. Feedback through the plant residues returns organic matter to soil, which supports growth of fungi and other organisms.

![Healthy soil aggregation](Image)

Healthy soil aggregation -> Healthy roots -> Healthy plants

![Unhealthy soil](Image)

Unhealthy soil: lack of stable aggregates leads to puddling, poor infiltration and erosion.

![Erosion of topsoil in the Peace](Image)

Erosion of topsoil in the Peace.

The nature of soils is derived from their profiles.

![L - F](Image)

Litter layers of soils in the Peace region are home to soil animals and to soil microorganisms.

Platy leached layers impede water infiltration and root growth.

Dense subsoil

Profile photo from J M Arocena UNBC; deceased.

Part of a Series: This forage fact is one of a series produced during the Soils & Forages Courses Project.
2. pH

**pH** is a master soil variable because it controls many other soil properties. It regulates plant growth both directly and indirectly.

**Soil pH** in the Peace region is normally between 5.5 and 7.5. Soil acidity can be toxic to plant roots and to soil animals and to many microorganisms (*yellow boxes in diagram to left*).

Such toxicity is due mostly to aluminum. Al becomes increasingly soluble as acidity increases (i.e. as pH drops, especially below 5).

In addition to direct toxicity of aluminum, low soil pH reduces availability of essential nutrients, especially phosphorus (*red in diagram*). Under highly acidic conditions, however, nitrogen, potassium, sulfur, manganese and molybdenum become deficient through reduced solubility and slower microbial transformations (which may also alter soil pH). Acidity prevents soil animals from modifying soil porosity.

3. Organic Matter

**Soil organic matter** is perhaps the single most important soil property. It is also one of only a few fundamental soil properties that can be altered by management.

**Soil Organic Matter** enters soil from plant roots, plant residues or external additions. It is stabilized in soil by adsorbing onto clays and by reaction with metals to produce insoluble complexes. The carbon in soil organic matter is slowly oxidized as an energy supply by soil microbes (*yellow in diagram*). During this process, nutrients they don't need, such as nitrogen, are discarded as a waste and used by plants.

Luvisolic soils are common in the Peace. They contain between 0.7 to 2.7 % carbon (based on data from the Breton plots). This equates to 13 to 53 metric tonnes of carbon / ha in the top 15 cm.

“**The smaller amounts of exchangeable Al that are present in the soils of higher organic matter content should result in less soil acidity damage to crops.**”


Because soil organic matter has many negative charges, it is highly effective at retaining nutrients and positively charged ions (such as Ca$^{2+}$, Mg$^{2+}$, K$^{+}$ etc.). In doing so, it prevents these and associated nutrients from being leached out of soil.

Organic matter also helps reduce Al solubility and hence the toxicity of highly acid soils (*3rd red box down on right side of diagram*).

By absorbing water and stabilizing aggregates, organic matter plays a very important role in water retention (*blue in diagram*).
“Most Luvisolic soils are strongly acid and low in nitrogen, phosphorus and organic matter.” Farstad et al., (1965). Soil Survey of the Peace River Area BC

“Distributed bale grazing is distributed manure spreading.” Bill Wilson Dawson Creek

**Bill’s On Line Favorites**
Dyck et al. The University of Alberta Breton Plots http://prairiesoilsandcrops.ca/articles/volume-5-10-screen.pdf


Forage Seeding Tool: http://www.peaceforagetool.ca/support-doc-types/bc-rangeland-seeding-manual

“Cattle hoofs are good for forages.” John Kendrew, Pouce Coupe

**Key Message**
The virtuous Cycle

Management (top tier above) improves forage & livestock productivity, which feeds back (green arrows in diagram) to improve aggregation; increase nutrient recycling and organic matter incorporation into soil; soil organism activity, mitigation on acidity, etc. Governed by inherited soil conditions, active processes supply nutrients, water and air (red arrows in diagram) for consumption by crops.

Long slopes, moderately high clay content, shallow acidic A horizons with low organic matter content and tough B horizons characterize many of the soils used in the Peace region for forage and livestock production. Slopes favor water runoff and erosion. High clay content and tough B horizons interfere with water infiltration and root penetration unless stable aggregates form. Acidic surface soils, which are low in organic matter (and hence nitrogen), phosphorus and often sulfur provide few nutrients for extraction by plants.

**Management Strategies**
Ranchers are meeting these challenges and developing integrated ways to manage soils for forage production and grazing that use perennial legumes and minimum tillage; stimulate nutrient recycling, add fertilizers as appropriate, and return manure during the entire year or by using innovative composting systems. The Soil Quality Field Kit is a tool to give report cards on how management improves the soil.

Healthy soil produces healthy crops, which beget healthy soil.

Composting manure before spreading returns more stabilized organic matter and nutrient, bases or cations to the soil (Glenn Hogberg).

Bale grazing distributes manure and increases soil organic matter cycling (Michael Nimitz).

Rotational grazing stimulates nutrient cycling & builds organic matter (John Kendrew).

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With Contributions from: station masters, mentors, participants of the soils & forages courses.

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