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Soil Health: A Definition

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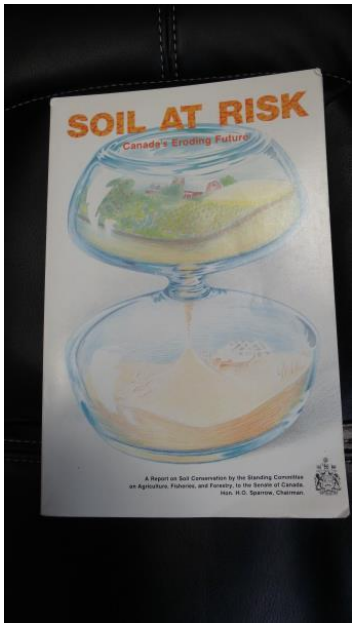
Canada

Outline

- Canadian history of soil quality/health concerns
- US history of soil quality/health concerns
- Soil quality vs soil health definitions
- Current understanding of soil health
- Human Microbiome Project – parallels with soil health

Canadian History

- 1980s: Decade of awareness of soil degradation:-
  - Erosion (wind and water), salinization, OM loss, urban encroachment.
  - 1984: Senate report “Soil at risk: Canada’s eroding future”.



  - Other reports: Federal and provincial departments of agriculture, universities, Agric. Institute of Canada (AIC).

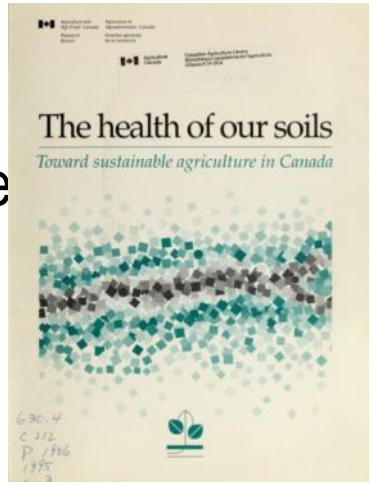
Canadian History

- 1990s: Decade of healing –
  - finding ways to measure and improve soil quality.

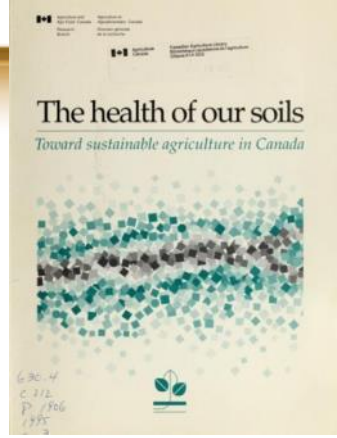
- AAFC: Centre for Land & Biological Resources (Ottawa) formed.

  - The Soil Quality Evaluation Program (SQEP) formed.
  - Goal: Develop a national capability to assess soil and associated environmental quality, and the effects of land use and management practices.

- 1995: Book “The Health of our Soils: Toward sustainable agriculture in Canada”.



Canadian History



- 1995 Book: “The health of our soils – Toward sustainable agriculture in Canada” :-
  - Soil health, or quality, is the soil’s fitness to support crop growth without resulting in soil degradation or otherwise harming the environment”.

- “The terms soil health and soil quality can be used interchangeably”.
- Emphasized crop production, but had concerns about the environment.
- No chapter on soil microbiology (although listed in the first chapter as an indicator of soil quality).

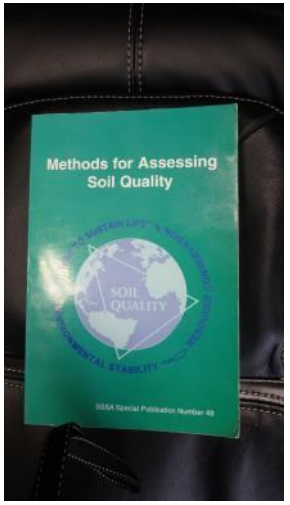
Soil Fertility

- Soil fertility: The natural, sustainable ability of a soil to produce plants (Anonymous, 2016: “The Basics of Soil Fertility: Shaping our Relationship to the Soil” – Organic Research Centre, UK).
  - Nutrient content: Fertility indicator.
  - Crop yield: Fertility measurement.
- The capacity of the soil to supply nutrients to a crop (Chatterjee, 2017: “Soil Fertility Management in Agroecosystems” – ASA, CSSA, SSSA).
- Soil fertility – one aspect of soil quality/health.

USA

- Similar discussions in US, after the National Academy of Sciences published the book: “Soil and Water Quality: An Agenda for Agriculture” (National Research Council, 1993).

- 1996 Book: “Methods for Assessing Soil Quality – SSSA Special Pub. # 49” :-
  - Soil quality simple definition: The capacity of a soil to function.
  - how well the soil does what we want it to do.

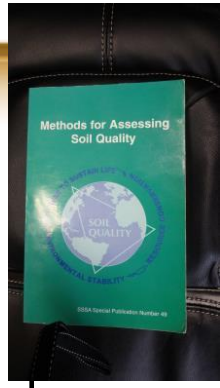


- Recognized multiple functions of soil, including ecological functions.
  - Soil functions: water flow and retention, solute transport and retention, physical stability and support; retention and cycling of nutrients; buffering and filtering of potentially toxic materials; and maintenance of biodiversity and habitat.

USA

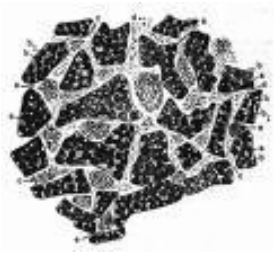
- Ecological definition of soil quality (recognizes multiple soil functions (Doran & Parkin, 1994: “Defining and Assessing Soil Quality” SSSA Special Pub. #35):-
  - The capacity of soil to function, within land use and ecosystem boundaries, to sustain biological (plant and animal) productivity, maintain (or enhance) environmental (water and air) quality, and promote plant, animal and human health”.

Soil Quality vs Soil Health



- "The terms soil quality and soil health are often used interchangeably" ("Methods for Assessing Soil Quality), but noted preferences:-

  - Producers prefer "soil health", which portrays soil as a living, dynamic organism that functions holistically rather than an inanimate mixture of sand, silt and clay.



    - Characterized on the basis of descriptive and qualitative properties.

  - Soil scientists prefer "soil quality", which describes quantifiable physical, chemical and biological characteristics.

    - To scientists, soil "health" requires value judgements that cannot be quantified..

Soil Quality vs Soil Health

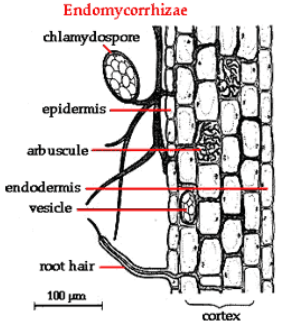
- US conference recommendation: Soil health definition should:-
  - reflect the soil as a living system
  - address all essential functions soil in the landscape
  - compare the condition of a given soil against its own unique potential within climatic, landscape and vegetation patterns
  - enable assessment of trends.

- Same concepts as soil quality, except "living" and "trends".

Soil Quality vs Soil Health

- Soil quality: the capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental (air and water) quality, and promote plant, animal and human health".

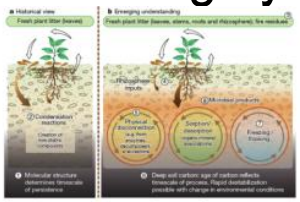
- Soil health: the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health." (Doran et al. 1996: Adv. Agron. 56).



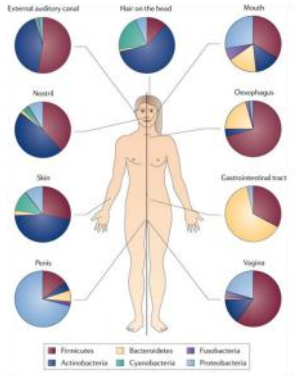
  - Soil health: broader aspects and multiple soil functions, and puts particular emphasis on soil as an integrated, dynamic, living system.

Current Understanding of Soil Health

- Emphasis on soil as a living system - shifting focus to soil biology.



- Soil biology and its importance to soil health - less attention in the past because:-
  - Difficult to measure. New molecular methods have changed that.
  - Significance not fully appreciated. We now know that they affect :-
    - soil structure, erosion, and water availability, decomposition, nutrient cycling, breakdown of toxins, and suppression of pests, and are responsible for a large proportion of the world's genetic diversity.
    - Influence of the Human Microbiome Project.



ARTICLE

doi:10.1038/nature11234

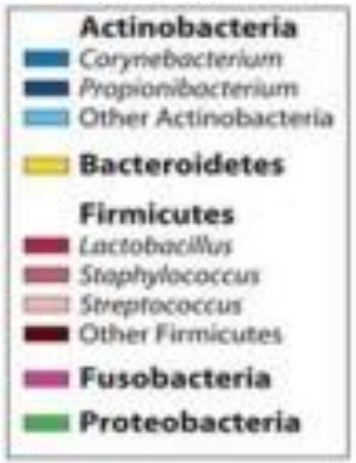
Structure, function and diversity of the healthy human microbiome

The Human Microbiome Project Consortium*

Studies of the human microbiome have revealed that even healthy individuals differ remarkably in the microbes that occupy habitats such as the gut, skin and vagina. Much of this diversity remains unexplained, although diet, environment, host genetics and early microbial exposure have all been implicated. Accordingly, to characterize the ecology of human-associated microbial communities, the Human Microbiome Project has analysed the largest cohort and set of distinct, clinically relevant body habitats so far. We found the diversity and abundance of each habitat's signature microbes to vary widely even among healthy subjects, with strong niche specialization both within and among individuals. The project encountered an estimated 81–99% of the genera, enzyme families and community configurations occupied by the healthy Western microbiome. Metagenomic carriage of metabolic pathways was stable among individuals despite variation in community structure, and ethnic/racial background proved to be one of the strongest associations of both pathways and microbes with clinical metadata. These results thus delineate the range of structural and functional configurations normal in the microbial communities of a healthy population, enabling future characterization of the epidemiology, ecology and translational applications of the human microbiome.

Human Microbiome Project

Our body organs contain 10x as many microbial cells as our body cells



Oral Microbiome

Caries
Periodontal Diseases
Gingivitis

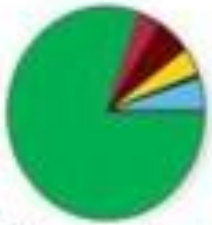
Mouth: tonsils

Gut Microbiome

Obesity
Metabolic Syndrome
Diabetes
C. difficile Infection
Colorectal Cancer
Inflammatory Bowel Diseases
Psychiatric Disorders

Gut: stool

Placenta Microbiome



Pre-term Birth
Chorioamnionitis
Villitis
TORCH Infections

Placenta: term birth

Skin Microbiome

Allergies
Acne
Psoriasis
Atopic Dermatitis
Ectodermal Dysplasia
Skin Cancer

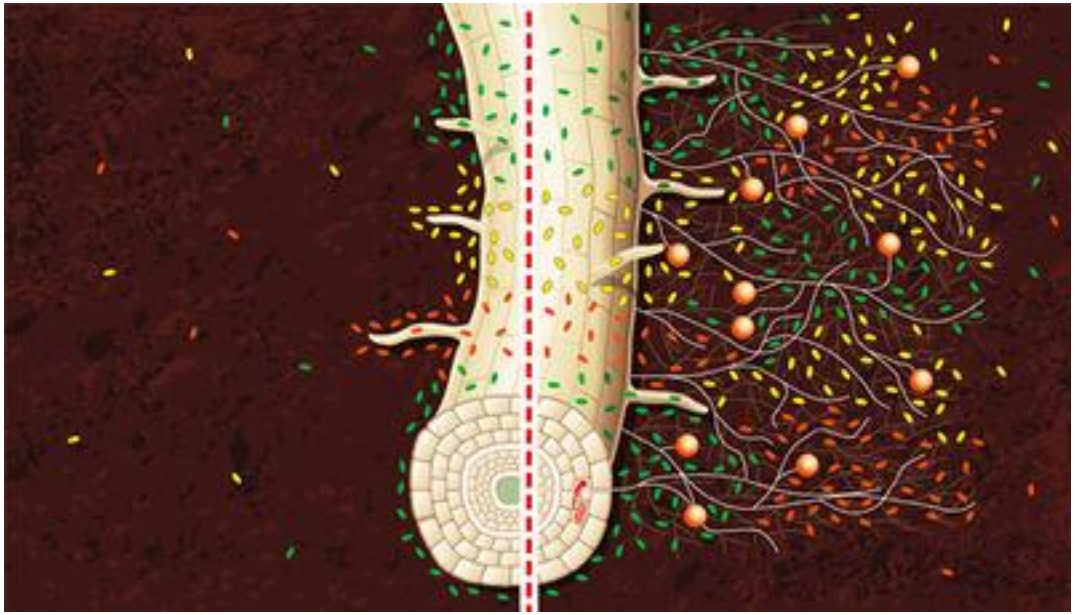
Skin: antecubital fossa

Vagina Microbiome

Vaginosis
Sexually Transmitted Diseases
Yeast Infection

Vagina

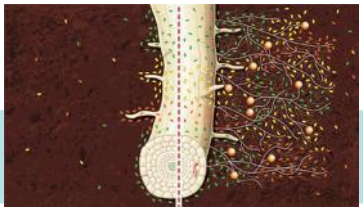
Soil (Rhizosphere)



Soil – more biodiversity than aboveground communities .

The plant root = “inside-out” gut .

Emphasis on Soil Biology: Gut vs Soil Microbiome

Issue	Gut 	Soil 
Normal state	Diverse microbiome	Diverse microbiome
Changes to normal state	The food we eat - processed vs fresh food, antibiotics	Crop/soil management – tillage, fertilizers vs manures, pesticides, antibiotics
Results of “abnormal/impaired” microbiome	Poor health, e.g., obesity, diabetes	Soil degradation (OM loss, soil structure), environmental pollution
Corrective measures	Probiotics (targeted microbes) and prebiotics (microbial food)	Add/boot soil microbial consortia (probiotics) and organic C amendments (prebiotics)

Lessons from the Human Microbiome Project

- Nutrient management: Should combine biology with chemistry (integrated nutrient management), not chemistry alone.
- All major agro-chemical companies now - doing research on biological products:-
  - http://www.monsanto.com/products/pages/microbials.aspx
  - https://agriculture.basf.com/en.html
  - http://www.dupont.com/corporate-functions/our-approach/strategic-priorities/bio-based-industrials.html

Acknowledgements