Soil Biology

Chapter 10

The Sounds of Soil

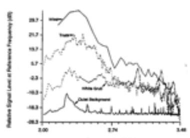


Figure 2. Spectral comparisons of sounds recorded by soil microphone from white grubs, and reference spectra of wind, vehicle noise, and the quiet noise background.

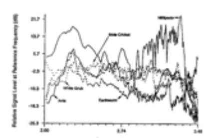
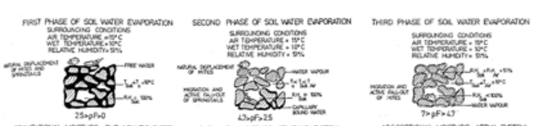
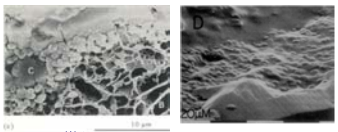


Figure 3. Spectral comparisons of sounds recorded by soil microphone from insects and other soil organisms commonly found in turf.

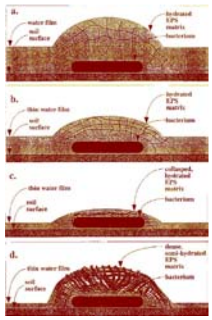
Soil as a Transition Between Aquatic and Aerial System



Bacteria in a Drying Environment



Wet (open structure) Dry (dense)



Holden P.A., J.R. Hunt, and M. K. Firestone, 1997, Toluene Diffusion and Reaction in Unsaturated *Pseudomonas Putida* biofilms. ***Biotech. Bioeng***. 56:656-670.

Classification of Soil Organisms

Classification	Body Width	Examples
Microflora	< 10 µm	Bacteria
		Fungi
Microfauna	< 100 µm	Protozoa
		Nematodes
Mesofauna	100 µm to 2 mm	Acari
		Collembola
Macrofauna	2 mm to 20 mm	Earthworms
		Snails

Organisms and Scale

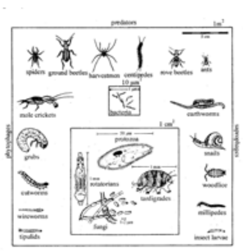
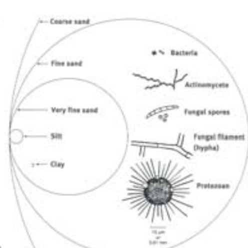


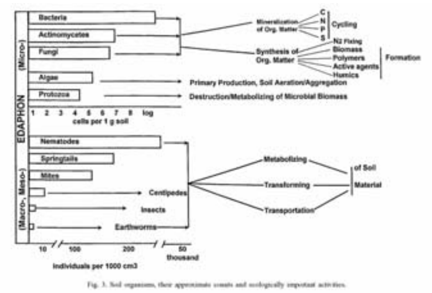
Figure 5. *Composition of a soil fauna selection, arranged according to feeding type (left phytophages, upper predators and right saprophages), size of the animals indicated, and habitat size expressed as various squares (modified after Van der Drift, 1963)*



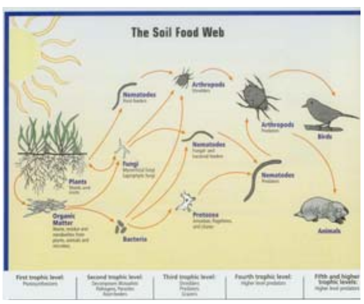
Source: Doelman, P and HJP Eijsackers. 2004. Vital Soil.

Source: Nardi, J.B. 2003. The World Beneath Our Feet.

Size and Function of Soil Organisms



The Soil Food Web



http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_biology_primer.html

Soil Organism Relationships

- Mutualistic associations
- Competition
  - Food source
  - Water
  - Antagonistic mechanisms
    - antibiotics
- Parasitism/Pathogenesis

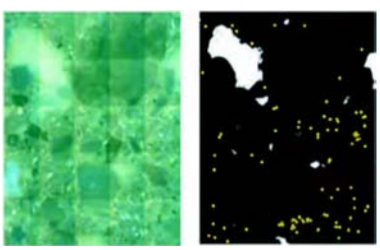
Biological Diversity

- Species diversity
- Functional diversity
- Functional redundancy
  - multiple organisms to perform a function.
  - *stability*: ability to continue to perform. functions under wide variation in conditions or inputs.
  - *resilience*: ability to return to functional health after a disturbance of normal processes.

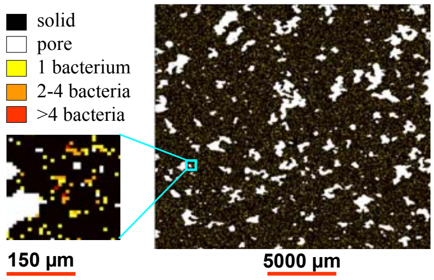
Where Do Organisms Live?

- *Around roots*: rhizosphere is the narrow region of soil directly around roots.
- In *litter*, particularly fungi.
- On *humus*, only fungi can degrade humus.
- On the *surface of soil aggregates* biological activity is greater than within aggregates.
- In spaces *between soil aggregates*.

Visualizing Bacteria on Thin Sections



Simulated Bacterial Distribution

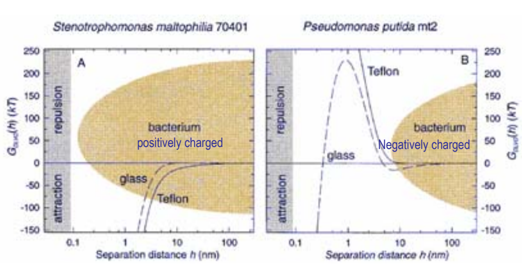


- Measured bacterial cell count - 34370 (cm^2)
- Simulated bacterial cell count - 34236 to 35250 (cm^2)

Surface Area And Microorganisms

- It is estimated that microorganisms cover less than 1% of the soils total surface area.
- Despite the small coverage, microorganisms are directly related to a variety of ecosystem services whose global value is estimated to be more than $20T.

Bacteria and the Double Layer



Source: Jucker, BA., H Harms, and AJB Zehnder. 1996. Adhesion of the Positively Charged Bacterium *Stenotrophomonas (Xanthomonas) maltophilia* 70401 to Glass and Teflon, *J. Bacter*. 178:5472-5479.

Metabolic Grouping

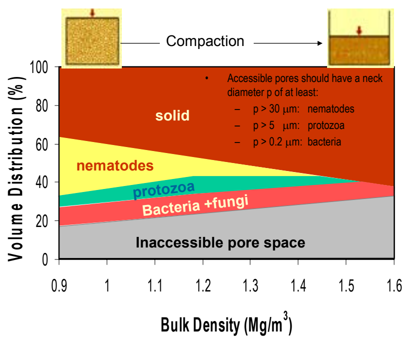
Energy Source	Carbon Source	
	Autotrophs (fix CO_2)	Heterotrophs (use organic C)
Light (Photo-)	Photoautotrophs	Photoheterotrophs
Chemical (Chemo-)	Chemoautotrophs	Chemoheterotrophs

- Photo-autotrophs: algae, cyanobacteria, and higher plants:
  - $CO_2 + H_2O \Rightarrow$ Organic C + O_2
- Chemo-heterotrophs: most bacteria, fungi, protozoa, etc:
  - Organic C + $O_2 \Rightarrow$ microbial biomass + CO_2 + waste

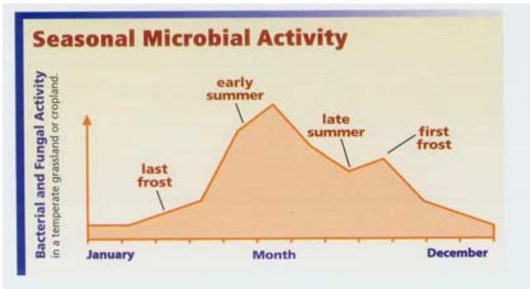
Soil Ecology

- Soil conditions limit the habitat of microorganisms
  - Temperature (optimal 15-25 °C)
  - Soil water content and potential (optimal: -10 to -70 kPa).
  - Soil porosity (mainly pore size: habitable *vs*. non-habitable pore space).

Change in Habitable Pore Space

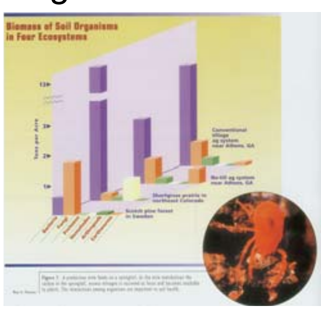


Source: Adapted from van der Linden, AMA, LJJ Jeurissen, JA van Veen, and B Schippers. 1989. Turnover of the Soil Microbial Biomass as Influenced by Compaction. In: JA Hansen and K Henriksen (eds.) Nitrogen in Organic Wastes Applied to Soils.



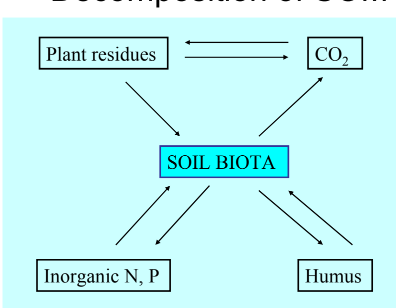
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_biology_primer.html

Microorganisms Distributions



http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_biology_primer.html

The Role of Soil Biota in the Decomposition of SOM



Concentration of CO_2 in the Soil Atmosphere

- Related to respiration by bacteria, fungi, protozoa and other chemo-heterotrophs.
- Several experiments found that temperature is between 2-5 times more important than water content in determining concentrations of CO_2 in soils.
- An empirical equation relates log (PCO_2) and Actual Evapotranspiration (AET):

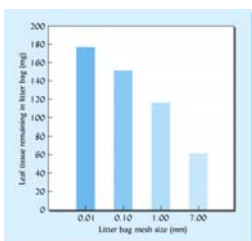


Figure 10.4 Influence of various sizes of soil organisms on the decomposition of corn leaf tissue buried in soil. Small bags made of nylon material with four different-size openings (mesh size) were filled with 558 mg (dry weight) of corn leaf tissue and buried in the soil for 10 weeks. The amount of corn leaf tissue remaining in the bags was considerably greater (less decomposition had taken place) where the meso- and macrofauna were excluded by the smaller mesh sizes. [Data from Weil and Kroontje (1979)]

ELEMENTS OF THE NATURE AND PROPERTIES OF SOILS, 2/e
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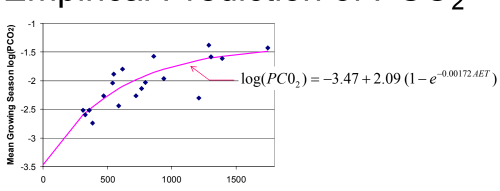
Empirical Prediction of PCO_2



- The model predicts that at AET~0 the $PC0_2$ is atmospheric.
- At high values of AET of about 2000 mm the model predicts a log $PC0_2$ of about -1.50.

Source: Brook, GA, ME Folkoff, and EO Box. 1983. A world model of soil carbon dioxide. Earth Surf. Proc. Landforms, 8: 79-88.

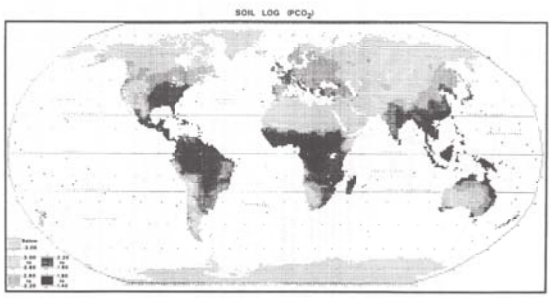


Figure 4.12. Map of soil CO_2 pressure produced with the relationship shown in Figure 4.11 (Brook et al., 1983. Reprinted by permission of John Wiley & Sons, Ltd).

Fungi

- Mushrooms, mildews, molds, yeast
- Some form *hyphae* and *mycelia*
- 10^5 - 10^6/g soil
- Tolerant of acid conditions, aerobic
- Decomposers
  - able to decompose resistant compounds:lignin, cellulose,
- Symbiotic associations
- Pathogens - opportunistic
- Antibiotic production (e.g. penicillin)

Fungal Symbiosis

- *Mycorrhizae* ("fungus-root") associate with plant roots
  - Ecto-mycorrhizae: hyphae grow between root cells and mantle the roots of many trees
  - Endo-mycorrhizae: hyphae grow into root cells
    - Vesicular-arbuscular (VAM)
    - trees, agronomic crops, vegetable & fruit crops
- Mycelium growing into soil increases surface area of absorbing tissue
- Improve P and water uptake

Actinomycetes

- Heterotrophic, aerobic
- Branched hyphae
- 10^7/g soil
- Tolerates low soil moisture, high temperature
- Intolerant of low pH
- Slow growing
- Decompose cellulose and other resistant compounds
- Symbiotic with many plants
- Antibiotics (e.g. streptomycin)

Bacteria

- Very diverse metabolism
  - Autotrophs and heterotrophs
  - Aerobes, anaerobes, and facultative
- Unicellular ~1μm
- Most numerous in soil
  10^8 - 10^9/g soil
- Rapid growth
- *Rhizobium*/legume symbioses

Metabolic Classes of Bacteria

- Source of Energy: autotrophic or heterotrophic
- Terminal Electron Acceptor
  - Oxygen: Aerobic
  - Other: Anaerobic
    NO_3^-, $SO_4^=$, Mn^{+4}, Fe^{3+}
    - decomposition products: methane, ethanol, H_2S
  - Either: Facultative Anaerobe

Rhizobial Symbiosis

- *Rhizobia* or *Bradyrhizobia* associate with legumes
- Specificity of infection
- Root nodules contain bacteria
- N_2 is "fixed", 10 - 20 g $N/m^2/y$
- Nitrogenase enzyme

  $N \equiv N \rightarrow \rightarrow 2NH_3 \rightarrow \rightarrow$ amino acids
- N-compounds available to plant
- Rhizobia receive nutrients and organic compounds from plant

Bacterial-Mediated Transformations

- Nitrifiers
  - oxidation of ammonium: $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$
- Denitrifiers
  - anaerobic reduction of nitrate $NO_3^- \rightarrow N_2O, N$
- N_2 Fixers
  - nitrogen gas reduced into organic forms of nitrogen