Ecological Function and Biodiversity Indicators in European Soils

EcoFINDERS

http://www.ecofinders.eu/
Soils deliver many ecosystem services

- **Food & biomass production**
  - A. Richer de Forges (CA 45)
  - Infosol (INRA Orléans)

- **Habitat, gene pool**
  - Infosol (INRA Orléans)
  - J. Moulin (CA 36)

- **Storing, filtering & transformation**
  - A. Richer de Forges (CA 45)

- **Source of raw materials**
  - J. Moulin (CA 36)

- **Physical & cultural environment for mankind**

*Courtesy of Antonio Bispo, ADEME*
- Living soils

- Huge quantity of organisms
  - Fauna: 1-5 T/ha
  - Fungi: 3.5 T/ha
  - Bacteria: 1.5 T/ha

- Fantastic diversity …but so little explored…
  - Until recently: only access to culturable microorganisms
  - Methodological progresses
    - Possibility to extract DNA from soils
    - $10^4$ – $10^6$ bacterial genotypes / g sol
Soils and biodiversity are submitted to major threats

- **Erosion**: 115 million hectares subject to water erosion, 42 million hectares to wind erosion.
- **Contamination**: 3.5 million sites could be contaminated
- **Decrease of organic matter**: About 45% of European soils have low organic matter content
- **Soil sealing**: 1990-2000: 1,000 km² of soil/year, 2000-2006, the average loss increased by 3%

Source: D. Arrouays (INRA Orléans)

http://ec.europa.eu/environment/soil/

Meeting of Coordinators, Brussels, 22-23 October 2012
In 2010, EC considered that for establishing Soil Thematic strategy, further knowledge was required on:

- soil biodiversity
- functions and resulting ecosystem services supported by this diversity

This requires:

- the development of standardised methods for the characterisation of soil biodiversity
- the establishment of policy-relevant and cost-effective indicators for biological diversity

Finally, convincing policy makers of the relevance of such Strategy also requires:

- the assessment of the economic value of the ecosystem services provided.

**ENV.2010.2.1.4.4 Increasing the understanding of the role of soil biodiversity in ecosystem functioning**
Decipher relations between soil biodiversity, activities, functions and ecosystem services

Assess the impact of environmental conditions (soil types, climatic zones, land use) on soil biodiversity and relations biodiversity-activities

Integrate information on microbial, faunal and plant communities

Analyse their interactions in food web models and consequences for community and ecosystem stability
- 23 partners
- 10 European countries: D, DK, F, I, IRL, NL, P, S, SK, SLO, UK
- Non-European country: China
- Bringing expertise in various:
  - disciplines: biodiversity, ecological functions, trophic nets, risk assessment, biological indicators, environmental economics
  - soil organisms: archaea, bacteria, fungi, protozoa, microarthropods, oligochatea
Standardization of sampling procedures

- Where, when and how take samples, number of replicates, sampling depth, use of composite samples, ...

_ Plassart et al., in preparation_

Optimisation of DNA extraction

- Assessment of possible biases according to the soil type
- Optimisation to allow extraction of DNA of the major types of organisms targeted
  - Microorganisms (archaea, bacteria, fungi)
  - Fauna (protozoa, nematodes,...)

Identification of bioindicators

- Sensitive
- Consistent – reliable
- Cost-effective
- _Table Annual Reports.docx_

Standardization of methods for biodiversity characterization

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Aims at assessing:

- Range of variations according to soil types, to climatic zones and to land uses
- Range of variations of the identified bioindicators according to soil types, climatic zones and land uses
- Definition of the ‘Normal Operating Range’

Strategy:

- Using data derived from the Joint Research Council, 255 points sampled across Europe to derive indicative values for: Organic Carbon, Texture, pH
- Overlaid onto the LUCAS – landcover survey and sites identified as either forest, grass or tillage.
- Identification of 80 sites per land-use type across Europe to give a range of the above soil properties
EcoFINDERS - LTOs

Connecting soil biodiversity, functions and ecosystem services

- Countries
- ALPINE
- ATLANTIC
- BLACK SEA
- BOREAL
- CONTINENTAL
- MACARONESIAN
- MEDITERRANEAN
- PANNONIAN
- STEPPIC

- Tonnersjoheden:
  - Nutrient cycling (N)
  - Carbon storage

- Veluwe:
  - Nutrient cycling, Carbon storage, Soil structure regulation, Aboveground diversity

- Berchidda:
  - Nutrient cycling (N), Carbon storage, Aboveground diversity

- Lancaster:
  - Nutrient cycle, Carbon storage, Soil structure regulation, Aboveground diversity

- Lusignan:
  - Nutrient cycling (N), Carbon storage, Soil structure regulation & water regulation

- Different land uses: grasslands, tillage, forests
- For each LTO: three levels of intensification

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Microbial diversity varies according to the LTOs.

**Bacteria**

**Archaea**

**Fungi**

Lusignan  Berchidda  Lancaster  Veluwe  *Tonnersjoheden*
Within a given LTO, microbial diversity differ according to the level of intensification
e.g. Berchidda, Sardinia, Italy

- Bacteria
- Archaea
- Fungi

Wooded land (Low intensity)  ▲  Wooded pasture (Medium intensity)  ▼  Intensive grassland (High intensity)
Within a given LTO, microbial diversity differ according to the level of intensification.

**Overall effect of land-use intensity**

- **France**: Bacteria (blue) > Archaea (red) > Fungi (green)
- **Italy**: Bacteria (blue) > Archaea (red) > Fungi (green)
- **UK**: Bacteria (blue) < Archaea (red) < Fungi (green)
- **Netherlands**: Bacteria (blue) < Archaea (red) < Fungi (green)
- **Sweden**: Bacteria (blue) < Archaea (red) < Fungi (green)

Environmental filters influence biodiversity, leading to different effects across LTOs.
How these variations translate in soil functioning?

**SOM mineralization**

Mineralization: D1 > D2 > D3

Mineralization SOM = f (Microbial diversity)
How these variations translate in soil functioning?

**Water regulation**

![Graph showing macropores (mean number/m²) vs. water infiltration rate and earthworm activity.](image)

- Macropores (mean number/m²) under different rotation systems and grass levels.
- Water infiltration rate increases with earthworm activity.

**Biodiversity**
- DNA
- Genome
- Activities
- Functions
- Ecosystem services

**Genome**
- Transcriptome
- Proteome & Metabolome

**Activities**
- Water regulation
- Water infiltration rate
- Earthworm activity

**Level of intensification**
- Rotation with grass
- Permanent grass
- + level of intensification
- - level of intensification

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Mesocosm experiments

Assessing hypotheses raised from LTOs studies

- Minimal diversity for a function to be expressed

- Relations between above and below ground biodiversity
  - How plant communities affect the resistance and resilience of belowground communities to drought?
  - Impact of plant-derived C into the soil and different soil biota, in connections with soil food web and associated processes.
Evaluation of the ISO Standard 11063 DNA Extraction Procedure for Assessing Soil Microbial Abundance and Community Structure

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Conclusions

✓ In contrast with the statement made by Beijerinck in 1913, everything is not everywhere, biodiversity is not randomly distributed
✓ The same organisms are not found everywhere
✓ Progresses in the knowledge of the environmental filters impacting soil biodiversity: soil physico-chemical, especially pH, and land use

❖ Relevance of the ‘Normal Operating Range’ concept
❖ Need of data bases for diagnostic of the soil biodiversity
❖ Need of Standard Operating Procedures

Challenges: Moving from diagnosis to action

✓ Based on diagnosis, define strategies of mitigation and soil restoration
✓ This requires
  ✓ to further progress in our knowledge of the soil functioning as supported by biodiversity
  ✓ to combine expertises in soil physics, chemistry, ecology
Conclusions and challenges

**Challenges: Moving from diagnosis to action**

- ✓ to deal with possible trade-offs

![Diagram showing the cycling of CO₂, plants, residues, root exsudates, diversity of soil decomposers (bacteria/fungi), soil organic matter (SOM), and the release of carbon and nutrients (N, P, K, S,...).](image)

Courtesy of Pierre-Alain Maron
Conclusions and challenges

- Challenges: Moving from diagnosis to action
  - to guarantee the soil multifunctionalities at different spatial and temporal scales
  - to capitalise European and National means and information on a set of Critical Zones Observatories and Long Term Observatories
  - to match with world global initiatives

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