


A JOURNEY INTO THE FIRST EVER GLOBAL SOIL BIODIVERSITY ATLAS

ACADÉMIE d'AGRICULTURE de FRANCE
AGRICULTURE ▪ ALIMENTATION ▪ ENVIRONNEMENT

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Commission européenne

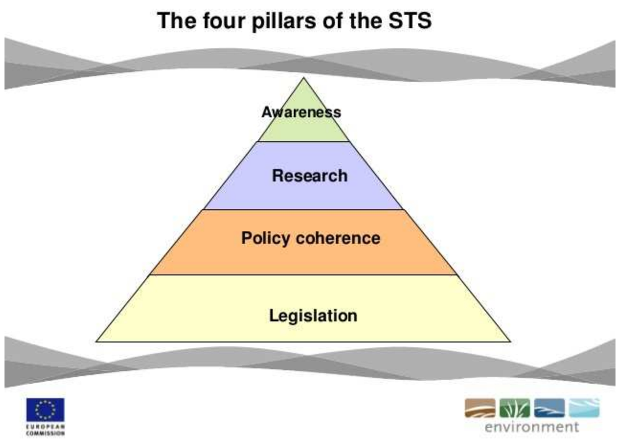


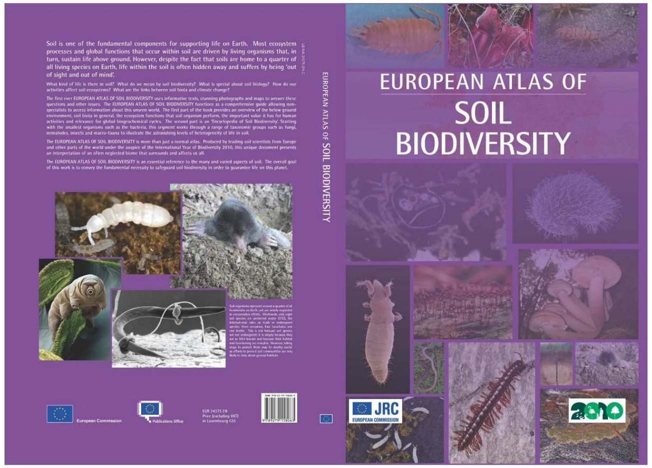

Launch of the Global Soil Biodiversity Atlas in France,
28th November 2016

DRIVERS

European Union perspective

- EU Biodiversity Strategy to 2020
- EU Soil Thematic Strategy (STS)
  - Awareness raising is core concept





GLOBAL
SOIL BIODIVERSITY
INITIATIVE

GLOBAL SOIL PARTNERSHIP

- JRC science service of the European Commission – provide EU policies with scientific base

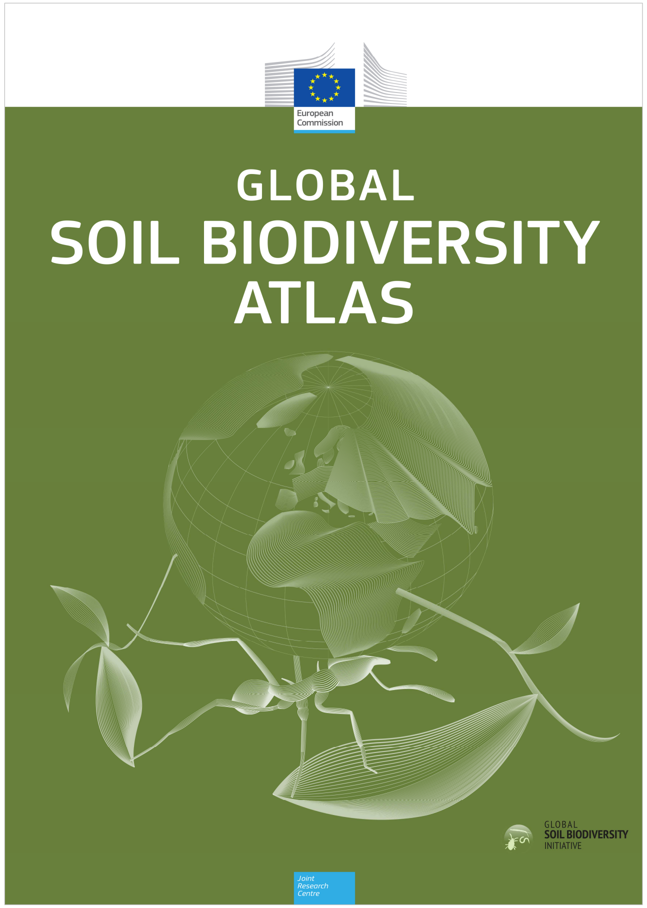
DEPARTURE – February 2013

1st workshop to plan the

GLOBAL SOIL BIODIVERSITY ATLAS

Colorado State University – Fort Collins CO, USA

- Editorial board
- 27 soil biodiversity scientists from 5 continents
- Contributors
- 90 experts from all over the world
- 8 chapters



CHAPTER 1

THE SOIL HABITAT

- What is soil?
- Where does soil come from?
- Soil-forming factors
- Soil-forming processes
- Map of global distribution of soils

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CHAPTER 1

THE SOIL HABITAT

Map of global

distribution of soils

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CHAPTER 2

DIVERSITY OF SOIL ORGANISMS

- Prokaryota
- Protists
- Fungi
- Photosynthesisers
- Microfauna
- Mesofauna
- Macrofauna
- Megafauna
- Methods to study soil biodiversity

CHAPTER 2

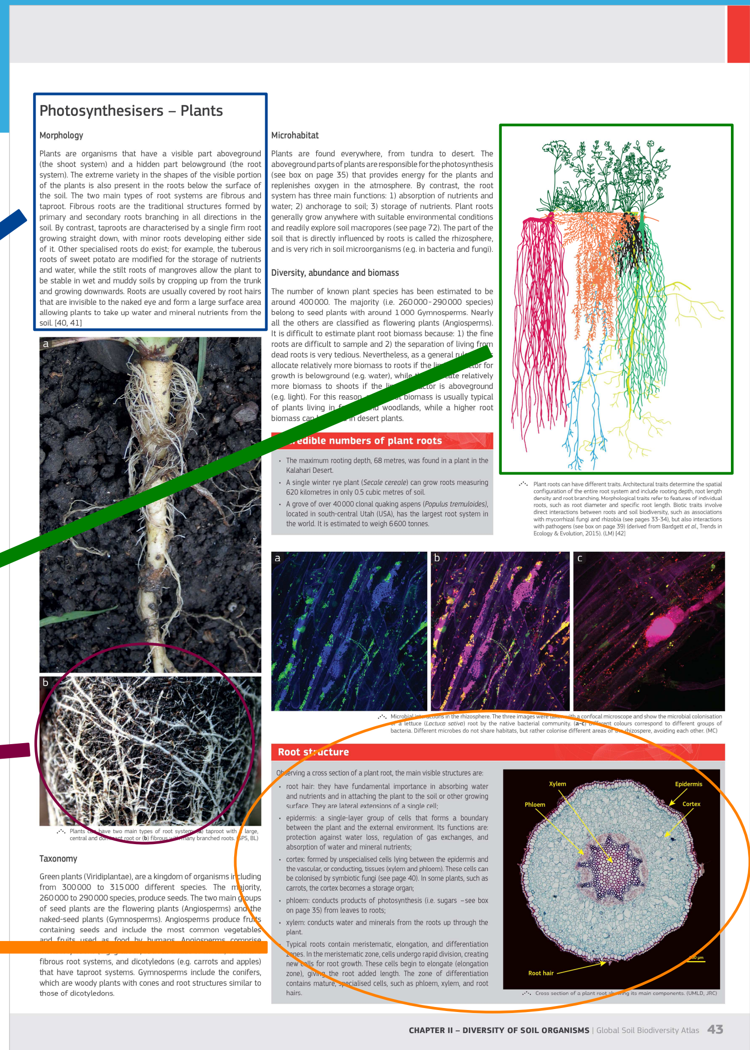
DIVERSITY OF SOIL ORGANISMS

Clear texts

Comprehensive illustrations

Effective images

Informative boxes



Photosynthesisers – Plants

Morphology

Plants are organisms that have a visible part aboveground (the shoot system) and a hidden part belowground (the root system). The extreme variety in the shapes of the visible portion of the plants is also present in the roots below the surface of the soil. The two main types of root systems are fibrous and taproot. Fibrous roots are the traditional structures formed by primary and secondary roots branching in all directions in the soil. By contrast, taproots are characterised by a single firm root growing straight down, with minor roots developing either side of it. Other specialised roots do exist; for example, the tuberous roots of sweet potato are modified for the storage of nutrients and water, while the stilt roots of mangroves allow the plant to be stable in wet and muddy soils by cropping up from the trunk and growing downwards. Roots are usually covered by root hairs that are invisible to the naked eye and form a large surface area allowing plants to take up water and mineral nutrients from the soil. [40, 41]

Plants can have two main types of root systems: (a) taproot with a large, central and dominant root or (b) fibrous with many branched roots. (SPS, BL)

Taxonomy

Green plants (Viridiplantae), are a kingdom of organisms including from 300 000 to 315 000 different species. The majority, 260 000 to 290 000 species, produce seeds. The two main groups of seed plants are the flowering plants (Angiosperms) and the naked-seed plants (Gymnosperms). Angiosperms produce fruits containing seeds and include the most common vegetables and fruits used as food by humans. Angiosperms comprise [illegible] fibrous root systems, and dicotyledons (e.g. carrots and apples) that have taproot systems. Gymnosperms include the conifers, which are woody plants with cones and root structures similar to those of dicotyledons.

Microhabitat

Plants are found everywhere, from tundra to desert. The aboveground parts of plants are responsible for the photosynthesis (see box on page 35) that provides energy for the plants and replenishes oxygen in the atmosphere. By contrast, the root system has three main functions: 1) absorption of nutrients and water; 2) anchorage to soil; 3) storage of nutrients. Plant roots generally grow anywhere with suitable environmental conditions and readily explore soil macropores (see page 72). The part of the soil that is directly influenced by roots is called the rhizosphere, and is very rich in soil microorganisms (e.g. in bacteria and fungi).

Diversity, abundance and biomass

The number of known plant species has been estimated to be around 400 000. The majority (i.e. 260 000 - 290 000 species) belong to seed plants with around 1 000 Gymnosperms. Nearly all the others are classified as flowering plants (Angiosperms). It is difficult to estimate plant root biomass because: 1) the fine roots are difficult to sample and 2) the separation of living from dead roots is very tedious. Nevertheless, as a general [illegible] allocate relatively more biomass to roots if the [illegible] for growth is belowground (e.g. water), while [illegible] relatively more biomass to shoots if the [illegible] is aboveground (e.g. light). For this reason [illegible] biomass is usually typical of plants living in [illegible] woodlands, while a higher root biomass can [illegible] in desert plants.

[illegible]edible numbers of plant roots

- The maximum rooting depth, 68 metres, was found in a plant in the Kalahari Desert.
- A single winter rye plant (*Secale cereale*) can grow roots measuring 620 kilometres in only 0.5 cubic metres of soil.
- A grove of over 40 000 clonal quaking aspens (*Populus tremuloides*), located in south-central Utah (USA), has the largest root system in the world. It is estimated to weigh 6 600 tonnes.

Plant roots can have different traits. Architectural traits determine the spatial configuration of the entire root system and include rooting depth, root length density and root branching. Morphological traits refer to features of individual roots, such as root diameter and specific root length. Biotic traits involve direct interactions between roots and soil biodiversity, such as associations with mycorrhizal fungi and rhizobia (see pages 33-34), but also interactions with pathogens (see box on page 39) (derived from Bardgett *et al.*, Trends in Ecology & Evolution, 2015). (LM) [42]

Root structure

Observing a cross section of a plant root, the main visible structures are:

- root hair: they have fundamental importance in absorbing water and nutrients and in attaching the plant to the soil or other growing surface. They are lateral extensions of a single cell;
- epidermis: a single-layer group of cells that forms a boundary between the plant and the external environment. Its functions are: protection against water loss, regulation of gas exchanges, and absorption of water and mineral nutrients;
- cortex: formed by unspecialised cells lying between the epidermis and the vascular, or conducting, tissues (xylem and phloem). These cells can be colonised by symbiotic fungi (see page 40). In some plants, such as carrots, the cortex becomes a storage organ;
- phloem: conducts products of photosynthesis (i.e. sugars –see box on page 35) from leaves to roots;
- xylem: conducts water and minerals from the roots up through the plant.
- Typical roots contain meristematic, elongation, and differentiation zones. In the meristematic zone, cells undergo rapid division, creating new cells for root growth. These cells begin to elongate (elongation zone), giving the root added length. The zone of differentiation contains mature, specialised cells, such as phloem, xylem, and root hairs.

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CHAPTER 3

GEOGRAPHICAL AND TEMPORAL DISTRIBUTION

- Distribution patterns
- Soil biodiversity and time
- Soil biodiversity and ecoregions
- Anthropogenic ecosystems
- Map of global distribution of soil biodiversity

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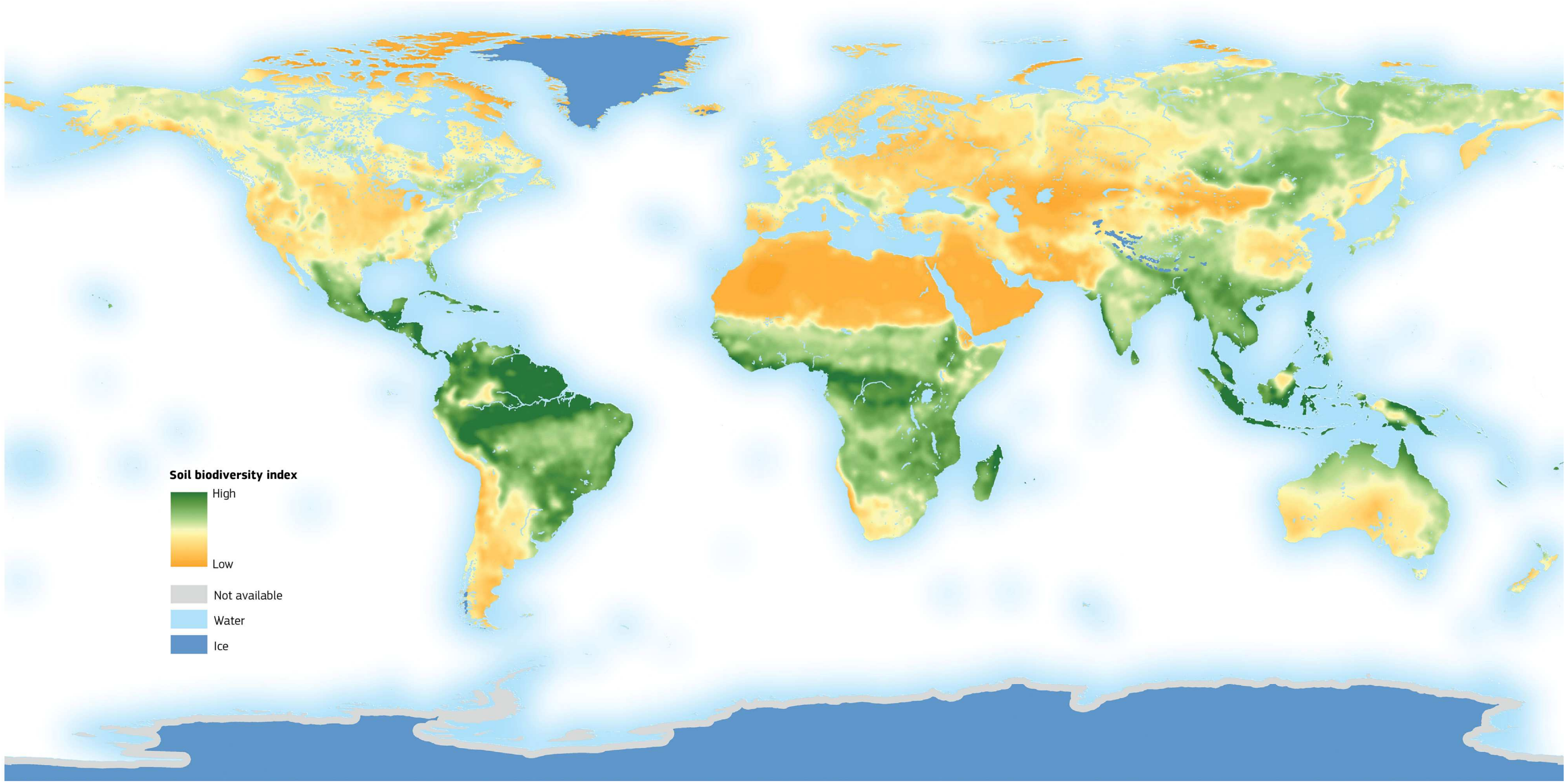
Map of global distribution of soil biodiversity



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CHAPTER 4

ECOSYSTEM FUNCTIONS AND SERVICES

- Provisioning services
- Regulating services
- Supporting services
- Cultural services

CHAPTER 4

ECOSYSTEM FUNCTIONS AND SERVICES

- Production of food and fibre
- Biotechnology

- Atmospheric composition and climate regulation
- Water supply and quality
- Biological population control

- Soil formation and maintenance

- Natural capital

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Supporting services – Soil formation and maintenance

INCIPIENT
Very young or development limited by drought or frost

YOUNG
Limited nutrient loss so far
Intermediate depth

MATURE
Fully developed profile
Deep

OLD
Impoverished horizon
Mostly acidic
Deep

Microorganisms

Micropredators

Litter transformers

Ecosystem engineers

The age of soil

As soils evolve, they get deeper and distinct horizons develop. The first horizon (**INCIPIENT**) forms where organic matter is mixed with minerals detached from the weathering bedrock. Thereafter, another distinct horizon forms (**YOUNG**) where clay, base and, ultimately, organic matter accumulate (**MATURE**). Finally a leached horizon (**OLD**) forms. During this process, soil becomes progressively impoverished in nutrients.

Soil communities comprise four major groups that have different relative importance and functions as soils mature.

Microorganisms are always present, although their composition may vary greatly, with large proportions of nitrogen-fixing algae and cyanobacteria in the earliest stages. Fungi are abundant when leaf litter is continuous and thick, whereas bacteria are more common in humid grasslands and cropped fields where earthworms are numerous.

Micropredators are comprised of a large diversity of small invertebrates of the micro- (< 0.2 mm) and meso- (0.2 to 2 mm) fauna that feed on microbial communities, thus regulating their composition and overall activity. They are the first group to develop in incipient soils, and may also be the only one left in severely degraded soils.

Litter transformers are invertebrates from the meso- and macro- (> 2 mm) fauna that live in and feed on leaf litter. They comprise a large number of micro- and macroarthropods that fragment and digest the partly decomposing litter left by the microorganisms. They are present whenever soil is covered with dead vegetation. They are most numerous and diverse in deciduous forests in temperate regions and in tropical forests.

Ecosystem engineers mainly comprise macroinvertebrates (ants, termites and earthworms), but also some mesofaunal groups (such as enchytraeids), able to cause intense bioturbation through active burrowing. By tunneling, they alter the soil space and create pores, channels and solid aggregate structures that constitute the habitat of other small organisms: microbial communities, and micro- and mesofauna. In the volume of soil that they control, also called their functional domain, they determine the composition and activity of microorganisms and the micro-predator food web.

While ants may be present in every type of ecosystem, with harsh climatic conditions and/or severe degradation, termites and earthworms are more dependent on stable conditions. Enchytraeids dominate wet and cold systems, such as moorlands. Ecosystem engineers are mainly present in well-developed soils at young and mature stages and tend to disappear in soils subjected to intensive agriculture.

The four main stages of soil evolution. Soil organisms play important roles in each stage. (PL, JRC)

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CHAPTER 5

THREATS

- Loss of aboveground biodiversity
- Introduction of invasive species
- Pollution
- Acid rain and nutrient overloading
- Agricultural practices
- Overgrazing
- Fire
- Soil erosion
- Land degradation and desertification
- Climate change

- Map of potential threats to soil biodiversity

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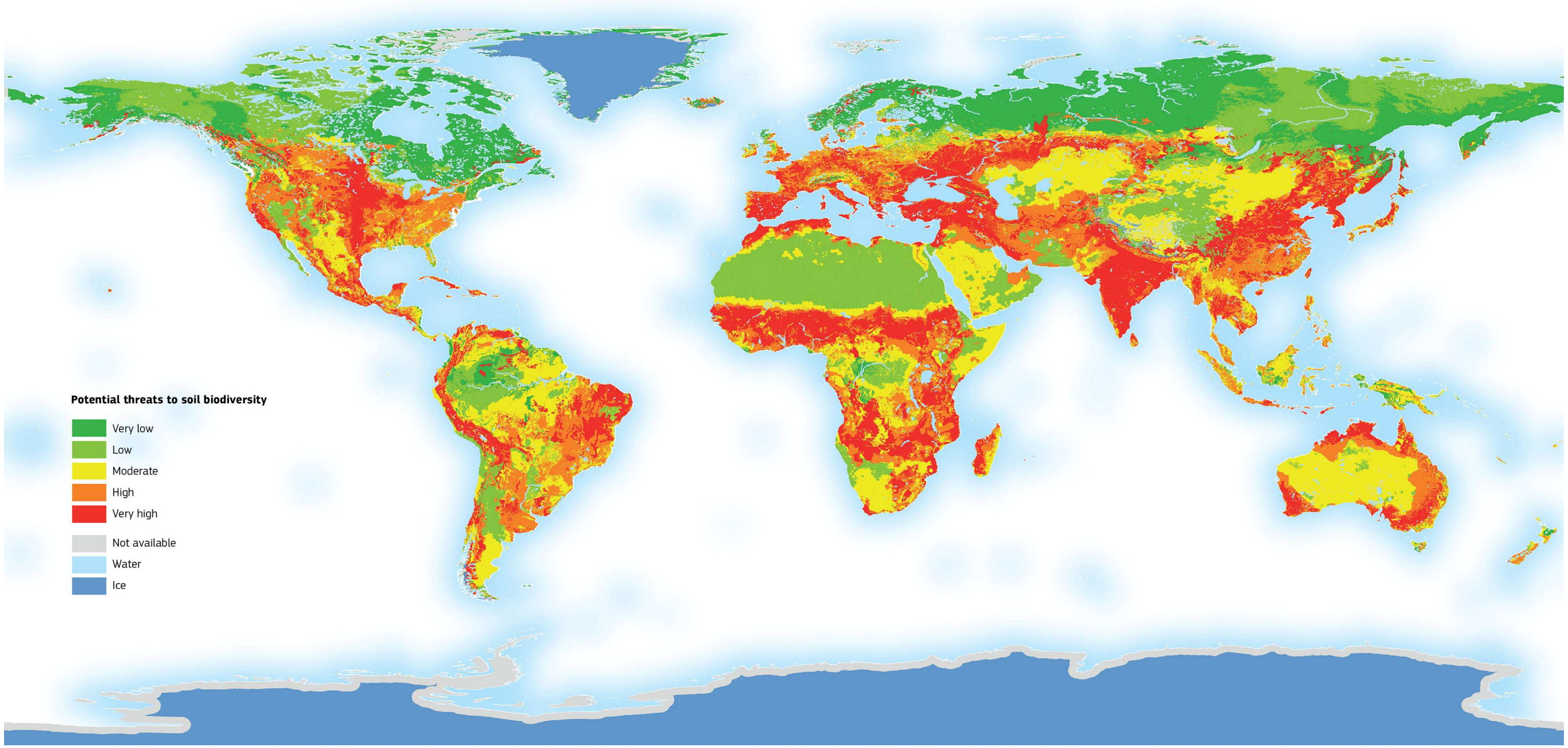
Map of potential threats to soil biodiversity



CHAPTER 6

INTERVENTIONS

- Agroforestry, afforestation and reforestation
- Prevention and restoration of invaded sites
- Bioremediation
- Diversification of cropland
- Land sparing versus land sharing
- No-till farming
- Fire management
- Soil erosion control
- Soil amendments

CHAPTER 6

INTERVENTIONS

- Suitable actions to protect soil biota are still missing
- Actions to conserve soil organisms are possible
- Sustainable managment of soils
- Need to identify priorities
- Not only farmers and stakeholders, also common people should be involved

Introduction

A significant and increasing proportion of the Earth's land area is covered by crop- and rangelands. Agricultural landscapes hold a large proportion of the world's biodiversity, but knowledge of the relative contribution of each land management type to the conservation of soil biodiversity, the maintenance of ecosystem functions, and the provision of ecosystem services is limited. [167]

Soil is the critical and dynamic regulatory centre of the majority of ecosystem processes. Soil organisms contribute to a wide range of ecosystem services that are essential to the sustainable functioning of natural and managed ecosystems. As mentioned in earlier sections of this atlas, highly diverse soil biological communities are largely linked to the high diversity of niches found in the soil environment, which are fostered by the extremely high physical and chemical heterogeneity at small scales, as well as the different microclimatic characteristics and functions of organisms that promote the development and maintenance of niche diversity.

Conservation of soil biodiversity in agricultural landscapes is thus intrinsically linked to land use and management systems that conserve and promote soil niche diversity. Recent evidence has shown that there are strong links between aboveground biodiversity (vegetation/crops) and belowground biodiversity (soil organisms). This finding supports the concept that modifications in plant communities as a result of changes in land use and agricultural systems can have profound impacts on the niche diversity underpinning soil biodiversity. Furthermore, it highlights the great potential to strategically utilise land management systems to influence the provision of soil-mediated ecosystem services. Limited predictive understanding of plant-soil feedbacks, however, still constrains the ecological management of soil biodiversity.

In this section, we will explore different ways in which soil can be managed to conserve soil biodiversity and sustain soil-mediated ecosystem functions and services. We start with a broad discussion about 'land sparing' versus 'land sharing' as biodiversity conservation strategies. This is followed by efforts to address ecosystem restoration challenges associated with invasive species and pollution, as well as large impact systemic changes imposed by the diversification and perennialisation of agricultural landscapes. Next follows management practices that have been adopted with significant impacts on soil biodiversity, including no-tillage systems and fire management. We conclude with more specific management practices, such as erosion control measures, the application of biochar and other soil reconstruction methods.

What can we do to protect soil biodiversity?

- Support soil-friendly cultivation that minimises the use of chemical fertilisers or pesticides. Look for organic products in the supermarket.
- Try to provide opportunities to encourage soil biodiversity where you live. Leave parts of your garden unmanaged, allow branches and garden waste to rot naturally.
- Reduce your rubbish! Recycle where possible so that we minimise the chances of soil pollution.
- Think about your 'carbon footprint'. How are you contributing to global warming and climate change? Look at your energy consumption, try to use a bicycle or public transport instead of a car.
- Support woodland regeneration schemes.
- Encourage your local authorities to target new developments on brownfield sites so as to minimise their environmental impact. Limit, where possible, the sealing of surfaces by concrete or asphalt.
- Limit soil erosion, organic matter decline, compaction, salinisation and landslides, by identifying and communicating risk areas to land owners and local authorities.
- Carefully dispose of old medicines. Several pharmaceuticals can have significant impacts on organisms. Take old drugs to the pharmacy. Never flush them down the toilet.

We can contribute to soil biodiversity preservation through many simple actions, such as (**a**) supporting soil-friendly initiatives, (**b**) composting our organic rubbish and (**c**) preserving aboveground biodiversity and (**d**) natural predators to reduce the use of pesticides. (KTH, JGI, USMG/EBR, SFA)

There are several actions that can facilitate conservation of soil-living communities, which can be identified when looking at the environment around us. Most of the measures would be possible through a better management of human activities: from diversification of cropland to no tillage and soil erosion control. (ARO, JRC)

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CHAPTER 7

POLICY, EDUCATION AND OUTREACH

- Policies for soil biodiversity
- Historical knowledge
- Research into soil biodiversity
- Knowledge sharing
- Education and awareness
- Resources

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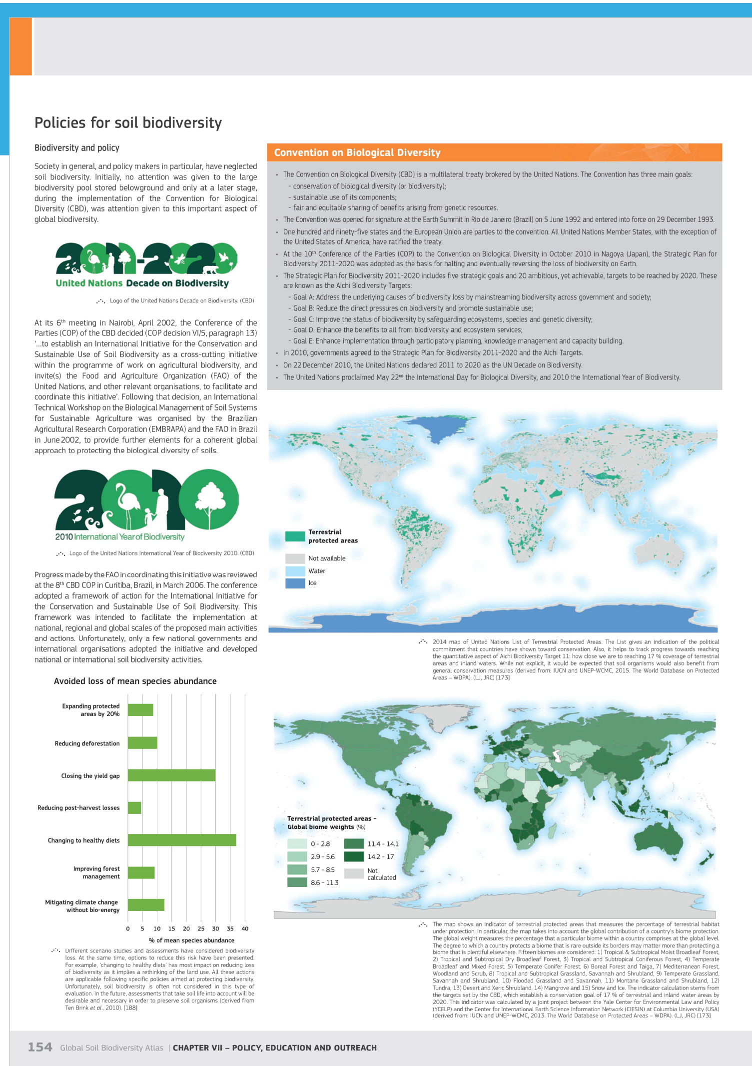
CHAPTER 7

POLICY, EDUCATION AND OUTREACH

- Specific policies for soil biodiversity are needed
- Present services provided by soil biodiversity
- Talk about soil biodiversity
- Scientific research and participatory research
- Awareness events – play with soil biodiversity



Policies for soil biodiversity

Biodiversity and policy

Society in general, and policy makers in particular, have neglected soil biodiversity. Initially, no attention was given to the large biodiversity pool stored belowground and only at a later stage, during the implementation of the Convention for Biological Diversity (CBD), was attention given to this important aspect of global biodiversity.

2011-2020 United Nations Decade on Biodiversity

Logo of the United Nations Decade on Biodiversity. (CBD)

At its 6th meeting in Nairobi, April 2002, the Conference of the Parties (COP) of the CBD decided (COP decision VI/5, paragraph 13) '...to establish an International Initiative for the Conservation and Sustainable Use of Soil Biodiversity as a cross-cutting initiative within the programme of work on agricultural biodiversity, and invite(s) the Food and Agriculture Organization (FAO) of the United Nations, and other relevant organisations, to facilitate and coordinate this initiative'. Following that decision, an International Technical Workshop on the Biological Management of Soil Systems for Sustainable Agriculture was organised by the Brazilian Agricultural Research Corporation (EMBRAPA) and the FAO in Brazil in June 2002, to provide further elements for a coherent global approach to protecting the biological diversity of soils.

2010 International Year of Biodiversity

Logo of the United Nations International Year of Biodiversity 2010. (CBD)

Progress made by the FAO in coordinating this initiative was reviewed at the 8th CBD COP in Curitiba, Brazil, in March 2006. The conference adopted a framework of action for the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity. This framework was intended to facilitate the implementation at national, regional and global scales of the proposed main activities and actions. Unfortunately, only a few national governments and international organisations adopted the initiative and developed national or international soil biodiversity activities.

Different scenario studies and assessments have considered biodiversity loss. At the same time, options to reduce this risk have been presented. For example, 'changing to healthy diets' has most impact on reducing loss of biodiversity as it implies a rethinking of the land use. All these actions are applicable following specific policies aimed at protecting biodiversity. Unfortunately, soil biodiversity is often not considered in this type of evaluation. In the future, assessments that take soil life into account will be desirable and necessary in order to preserve soil organisms (derived from Ten Brink *et al.*, 2010). [188]

Convention on Biological Diversity

- The Convention on Biological Diversity (CBD) is a multilateral treaty brokered by the United Nations. The Convention has three main goals:
  - conservation of biological diversity (or biodiversity);
  - sustainable use of its components;
  - fair and equitable sharing of benefits arising from genetic resources.
- The Convention was opened for signature at the Earth Summit in Rio de Janeiro (Brazil) on 5 June 1992 and entered into force on 29 December 1993.
- One hundred and ninety-five states and the European Union are parties to the convention. All United Nations Member States, with the exception of the United States of America, have ratified the treaty.
- At the 10th Conference of the Parties (COP) to the Convention on Biological Diversity in October 2010 in Nagoya (Japan), the Strategic Plan for Biodiversity 2011-2020 was adopted as the basis for halting and eventually reversing the loss of biodiversity on Earth.
- The Strategic Plan for Biodiversity 2011-2020 includes five strategic goals and 20 ambitious, yet achievable, targets to be reached by 2020. These are known as the Aichi Biodiversity Targets:
  - Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society;
  - Goal B: Reduce the direct pressures on biodiversity and promote sustainable use;
  - Goal C: Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity;
  - Goal D: Enhance the benefits to all from biodiversity and ecosystem services;
  - Goal E: Enhance implementation through participatory planning, knowledge management and capacity building.
- In 2010, governments agreed to the Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets.
- On 22 December 2010, the United Nations declared 2011 to 2020 as the UN Decade on Biodiversity.
- The United Nations proclaimed May 22nd the International Day for Biological Diversity, and 2010 the International Year of Biodiversity.

2014 map of United Nations List of Terrestrial Protected Areas. The List gives an indication of the political commitment that countries have shown toward conservation. Also, it helps to track progress towards reaching the quantitative aspect of Aichi Biodiversity Target 11: how close we are to reaching 17 % coverage of terrestrial areas and inland waters. While not explicit, it would be expected that soil organisms would also benefit from general conservation measures (derived from: IUCN and UNEP-WCMC, 2015. The World Database on Protected Areas – WDPA). (LJ, JRC) [173]

The map shows an indicator of terrestrial protected areas that measures the percentage of terrestrial habitat under protection. In particular, the map takes into account the global contribution of a country's biome protection. The global weight measures the percentage that a particular biome within a country comprises at the global level. The degree to which a country protects a biome that is rare outside its borders may matter more than protecting a biome that is plentiful elsewhere. Fifteen biomes are considered: 1) Tropical & Subtropical Moist Broadleaf Forest, 2) Tropical and Subtropical Dry Broadleaf Forest, 3) Tropical and Subtropical Coniferous Forest, 4) Temperate Broadleaf and Mixed Forest, 5) Temperate Conifer Forest, 6) Boreal Forest and Taiga, 7) Mediterranean Forest, Woodland and Scrub, 8) Tropical and Subtropical Grassland, Savannah and Shrubland, 9) Temperate Grassland, Savannah and Shrubland, 10) Flooded Grassland and Savannah, 11) Montane Grassland and Shrubland, 12) Tundra, 13) Desert and Xeric Shrubland, 14) Mangrove and 15) Snow and Ice. The indicator calculation stems from the targets set by the CBD, which establish a conservation goal of 17 % of terrestrial and inland water areas by 2020. This indicator was calculated by a joint project between the Yale Center for Environmental Law and Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) at Columbia University (USA) (derived from: IUCN and UNEP-WCMC, 2013. The World Database on Protected Areas – WDPA). (LJ, JRC) [173]

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CHAPTER 8

CONCLUSIONS

- 1st ever Global Soil Biodiversity Atlas
- Reference pubblication
- 176 pages
- More than 900 images
- More than 50 maps
- Full of interesting stuff!