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Terrestrial Ecotoxicology Worldwide: a Comparative Analysis

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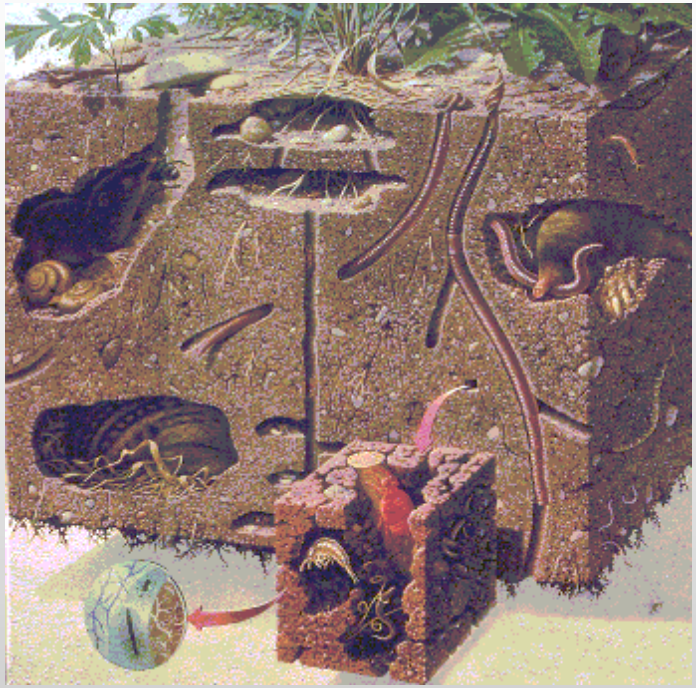
Outline of this Talk

1. **Historical Overview**
   List of main developments
2. **Drivers and players**
   Regulations and methods
3. **Current status**
   Regulations and methods
4. **Regional developments**
   Examples of recent activities



Focal compartment: Soil

Soil is the uppermost layer of the earth crust consisting of 3 media (bulk material, water, air) plus dead/ living organic matter (ISO 11074 (1996)).

Note: What drives Soil Ecotoxcology?

- **Legal regulations requiring ecotoxicological tests:**
  - **Registration of pesticides** and other chemicals since the late 1960s in North America and in the 1970s in Europe
  - Major bust for **soil testing for pesticides** in 1991 in Europe; no such importance in the USA or other regions
- **Development of standard tests methods, mainly by**
  - **OECD** (Chemicals Group): single-chemical testing before market authorization ➔ **prospective protection of soil**
  - **ISO** (Technical Committee 190): soils contaminated by a mixture of chemicals ➔ **retrospective protection of soil**
  - Some national guidelines available (e.g. Canada, Brazil).
- **Laws + methods ➔ Environmental Risk Assessment (ERA)**

Historical Overview I: 1962 - 1984

First papers on effects of pesticides on organisms: Carson (1962):

1967	Ghabbour & Imman	Earthworms and herbicides
1969	Truhaut	Coining the term "Ecotoxicology"
1969	Edwards	Earthworms and pesticides
1978	Butler	Book on principles of ecotoxicology
1983	Domsch	Recovery of microbes
1984	Moriarty	Important textbook
1985	Cairns	Multispecies tests

International consensus on regulation of chemicals ==> OECD developed lab tests

1984 No. 207 Earthworm (*Eisenia fetida*) acute test

Main breakthrough: **artificial soil**

Historical Overview II: 1985 - 2000

Widening scope and activities of soil ecotoxicology:

- from single chemicals in OECD soil to mixtures in field soils
- from short acute tests to longterm chronic tests
- from few standard organisms to species differing in ecology.

1991 Publication of Pesticide Registration Guidelines in Europe

1998 Løkke & van Gestel Development of new test systems

1994 Forbes & Forbes Very good textbook

1995 Leeuwen & Hermens Risk assessment

First standard field study (ISO):

1999 No. 11268-3: Effects on earthworms

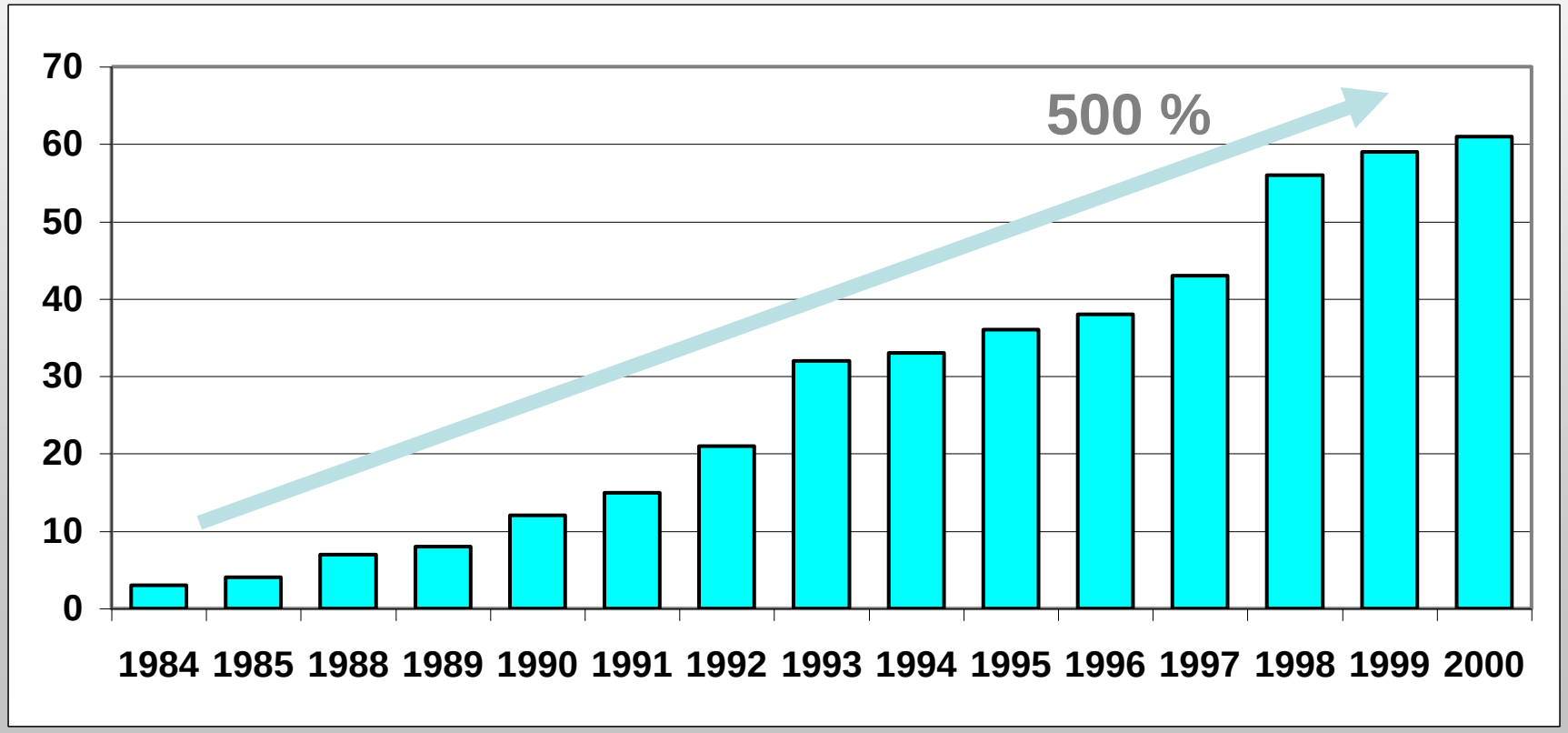
New (incl. functional) tests (OECD):

2000 No. 216: Nitrogen Transformation Test.

Historical Overview III: Number of tests

Number of terrestrial l tests with invertebrates 1984 – 2000

(Microbial tests follow the same tendency)



Historical Overview IV: 2001 - 2014

Further moves towards (ecological) reality:

- Testing of drugs, nanoparticles, and wastes
- Tests with several stressors (e.g. pesticides + climate change)
- Inclusion of bioaccumulation and bioavailabillity
- Use of semi-field tests, e.g. Terrestrial Model Ecosystems (TME)

2003	Van Straalen	Ecotoxicology as „stress ecology“
2010	Laskowski et al.	Meta-analysis of chemicals and envir. stress
2010	Schaeffer et al.	Guidance for semi-field tests

First soil bioaccumulation test (OECD):

2010 No. 317 Earthworms and enchytraeids

First guidance on ecotox test strategies (ISO):

2014 No. 19204 TRIAD: site-specific assessment

Drivers and Players: European Union

The European Union (EU): strongly pushing soil ecotoxicology via legal instruments, published by specific agencies, e.g.:

EFSA: European Food and Safety Authority (Parma, Italy)

ECHA: European Chemical Agency (Helsinki, Finland)

EMA: European Medical Agency (London, UK)

But: In contrast to the water compartment no **Soil Framework Directive** exists!

Why? Soil is usually owned privately – and soil remediation is very expensive.

And: In parallel, all 28 member states can pass own regulations.

Drivers and Players: North America

In the United States, soil ecotoxicology is not an issue, but:

- Remediation of contaminated sites is regulated by the Superfund Act and studied by the Environmental Protection Agency (EPA)
- the Ministry of Defense is performing ecotoxicological testing of soils contaminated by explosives.

The situation is completely different in Canada:

- Legislation is in place to test individual chemicals.
- Focus is on remediation of contaminated sites, mainly used for mining (metals, oil sands).
- The responsible authority, Environment Canada, is developing new or adapting existing (mainly ISO) test guidelines, often for **boreal or arctic regions**.

Drivers and Players: The Tropics?

Already in the Sixties, soil ecotox studies were performed.

Africa: Few soil ecotox studies, mainly in Nigeria and South Africa. (Almost) no activity in political or standardization organizations.

Asia: Traditionally, much soil ecotox in India, Indonesia, Sri Lanka. Legal requirements rare, but active role in ISO (Korea, Japan).

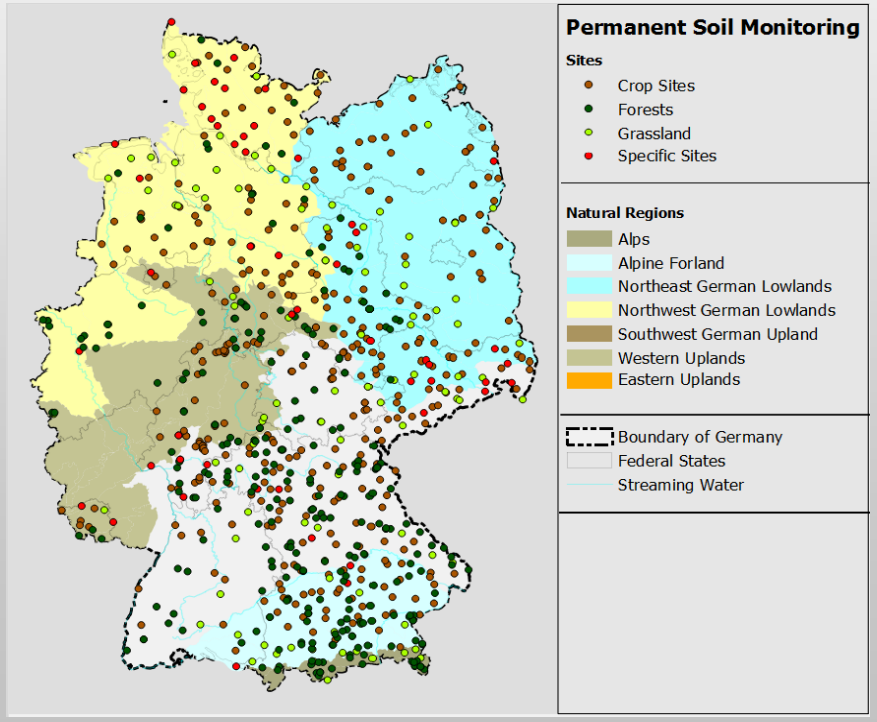
Latin America: In most countries except of Brazil, Argentina and Mexico soil ecotoxicological studies are rare. However, legal requirements often exist, and method adaptation is under way.

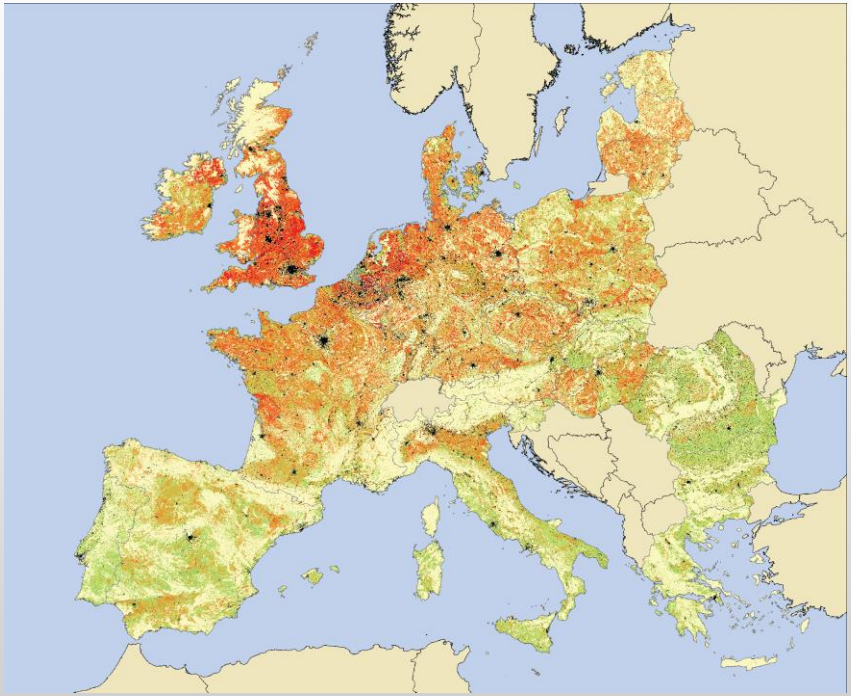
==> **So far, tropical soil ecotoxicology is weak but activities and interest are growing, especially in Brazil.**

Current Trends in Europe I.

Monitoring of soil properties:

Overview on German permanent soil monitoring sites





Mapping of soil properties:

First EU-wide map of contaminated soil

Source: European Atlas of Soil Biodiversity

Europe: Current Trends IIa:

Soil biodiversity is now recognized as an important protection goal. However, many of these species are not yet described.

Microflora and -fauna, e.g.:

Bacteria, fungi, springtails, mites, ants, termites

Macrofauna, e.g.:

Earthworms, wood-lice, ants, termites, snails etc.

Europe: Current Trends IIb:

Project EcoFINDERS:

Sampling at 90 sites.

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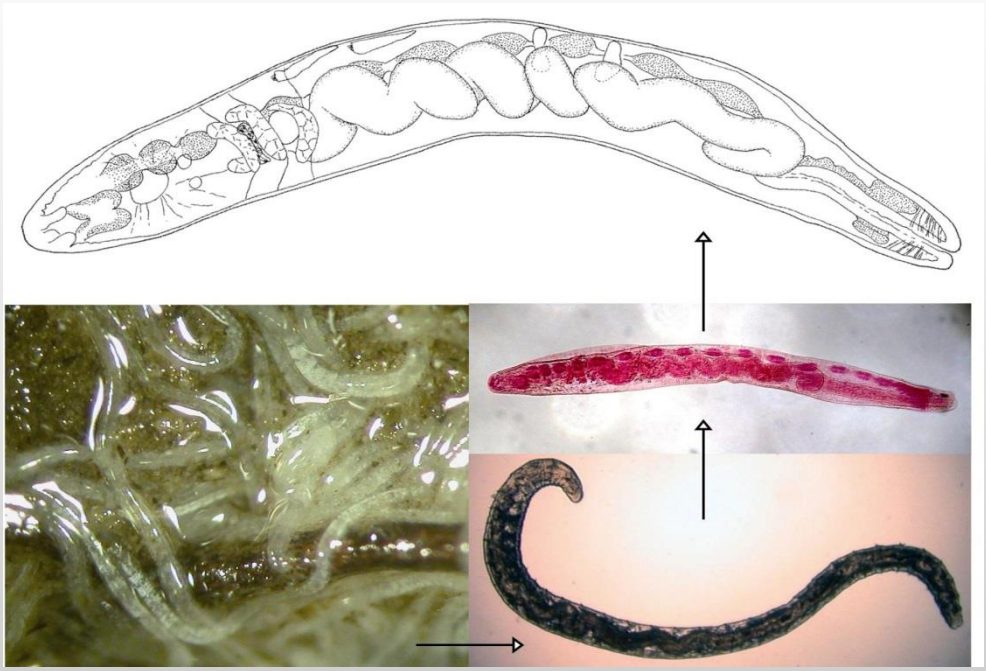


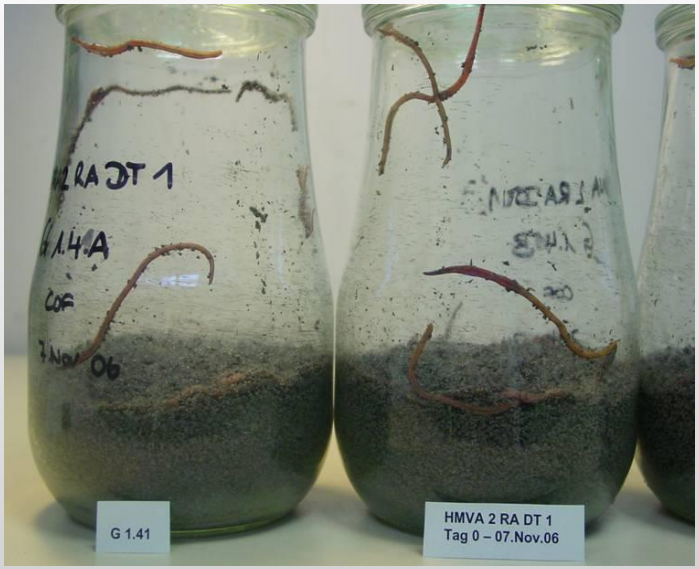
Microflora and -fauna, e.g.: Bacteria, fungi, springtails, mites, **Enchytraeidae**

So far, > 50 new species identified

Current Trends in Europe III.

Hazard assessment of wastes with soil organisms:

Problem: heterogeneity of test material



	Test species	Group	Endpoint	Guideline
Solid waste tests	*Arthrobacter globiformis*	Bacteria	Enzyme activity	ISO 18187
	Brassica rapa	Plants	Growth	ISO 11269-2
	Eisenia fetida	Earthworms	Avoidance	ISO 17512-1

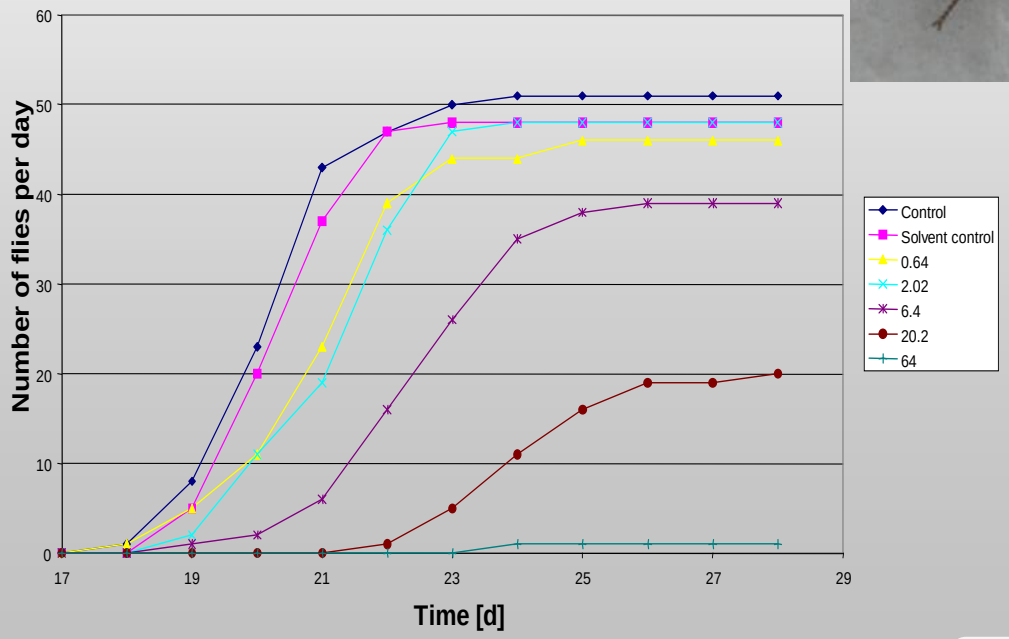
Current Trends in Europe IV.

Antiparasiticides affect flies or beetles developing in dung or soil.

Laboratory (OECD 2008, 2010) or field tests (no standard) possible

Effect of ivermectin on the dung

-fly *Scathophaga stercoraria*.



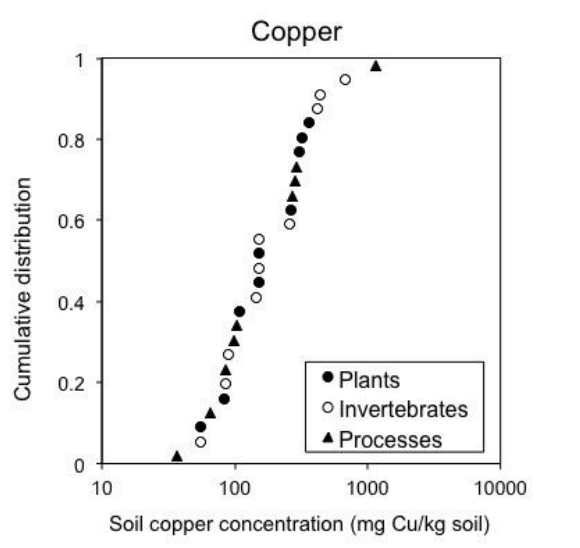
Current Trends in North America: USA

Hazard classification of soils:

Example, Aberdeen Proving Ground

(No. 20 on the list of toxic sites):

Classified as Superfund (1990) ➔ excavation.



Derivation of Soil Clean-up Values (SCVs) for selected metals (e.g. copper) using data from plants, microbes and invertebrates.

Not yet clear how these SCVs will be incorporated in US legislation.

Current Trends in North America: Canada

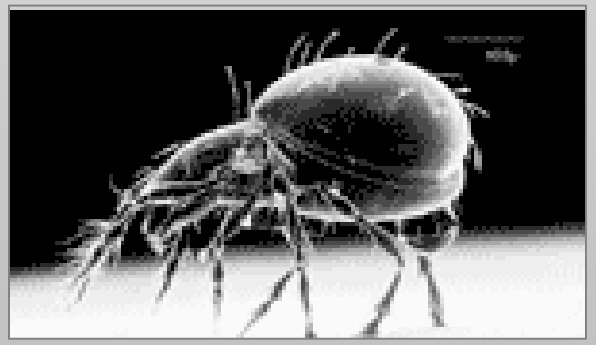
Development of standardized tests with boreal species:

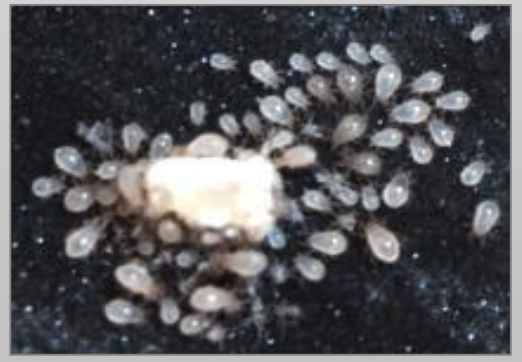
RM47 (2014): **Collembola**: *Proisotoma minuta*

RM56 (2013): **Plants** (several understory and tree species), including guidance on using field-collected forest soils

RM43 (2015): **Earthworms**: *Dendrodrilus rubidus, D. octaedra*

??? **Oribatid mites:** test method development underway

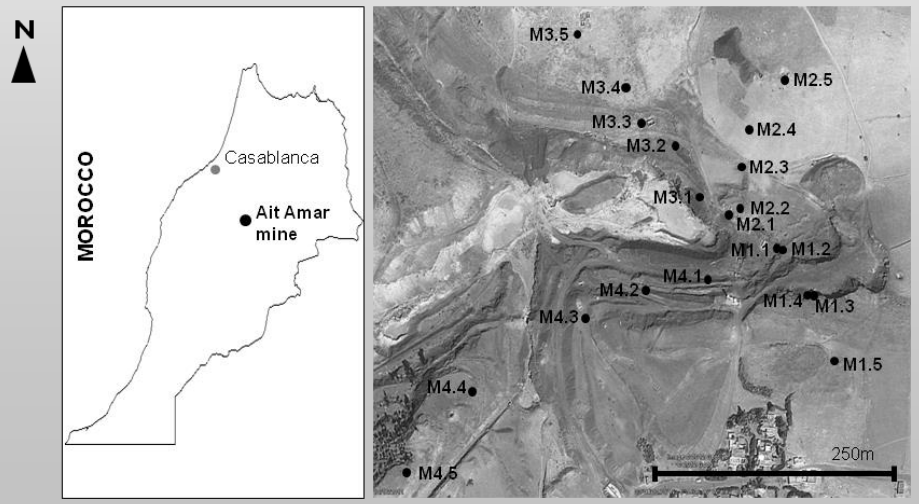




Current Trends in Africa

Effects of pesticides, metals and other stressors (e.g. salts) have been studied since the 1970s, mainly in West and South Africa.

- Cooperation between Morocco, Portugal and Germany
- Aim: study of the effects of mining on soil organisms
- Main achievement: transfer of knowledge and equipment



Current Trends in Asia

Soil is not really acknowledged in Asia, with few exceptions:

India: Since about 1970, about 20 studies known on the effects of pesticides on earthworms, both in the laboratory and the field.

No information regarding legal requirements.

Sri Lanka: Quite recently, several studies on the effects of pesticides in the laboratory.

China: Enormous boom of soil-related work in the last ten years, but relatively few papers on soil ecotox.

Standardization efforts:

China, Japan and South Korea are members of ISO TC 190, but so far did not contribute actively to method development or validation.

Current Trends in South America

Actually, this conference is a good opportunity for an overview!

➔ Just one recent example for the growing interest in retrospective risk assessment: Santo Amaro (Brazil).

Contaminated soil heaps before (left) and after (right) remediation

The importance of soil ecotoxicology is increasing rapidly in research (e.g. pesticide testing, soil value derivation) in Brazil and, partly, Argentina. No robust information available for other countries.

Current Global Trends I:

Soil ecotoxicology is going global, in various ways:

- Anthropogenic stressors are distributed and acting globally:
  - Chemicals emitted in Europe are found in the Arctic.
  - The same pesticides are used all over the world.
  - Climate change is occurring everywhere.
- The principles tackling these problems are also globally used:
  - Environmental risk assessment.
  - Tiered testing approaches.
  - Close interactions between ecology and ecotoxicology.
- Ecotoxicology is becoming globally organized:
  - Scientific organizations co-operate world-wide
  - Method harmonization is performed internationally.

Current Global Trends II:

Functions provided by soil organisms are becoming important:

Weathering of rocks and formation of soils:

=> all soil organisms

Mixing and stabilisation of organic and mineral particles =>

earthworms, bacteria and fungi

Decomposition and mineralisation of organic material

=> all saprophagous soil organisms

Binding of atmospheric nitrogen

=> bacteria

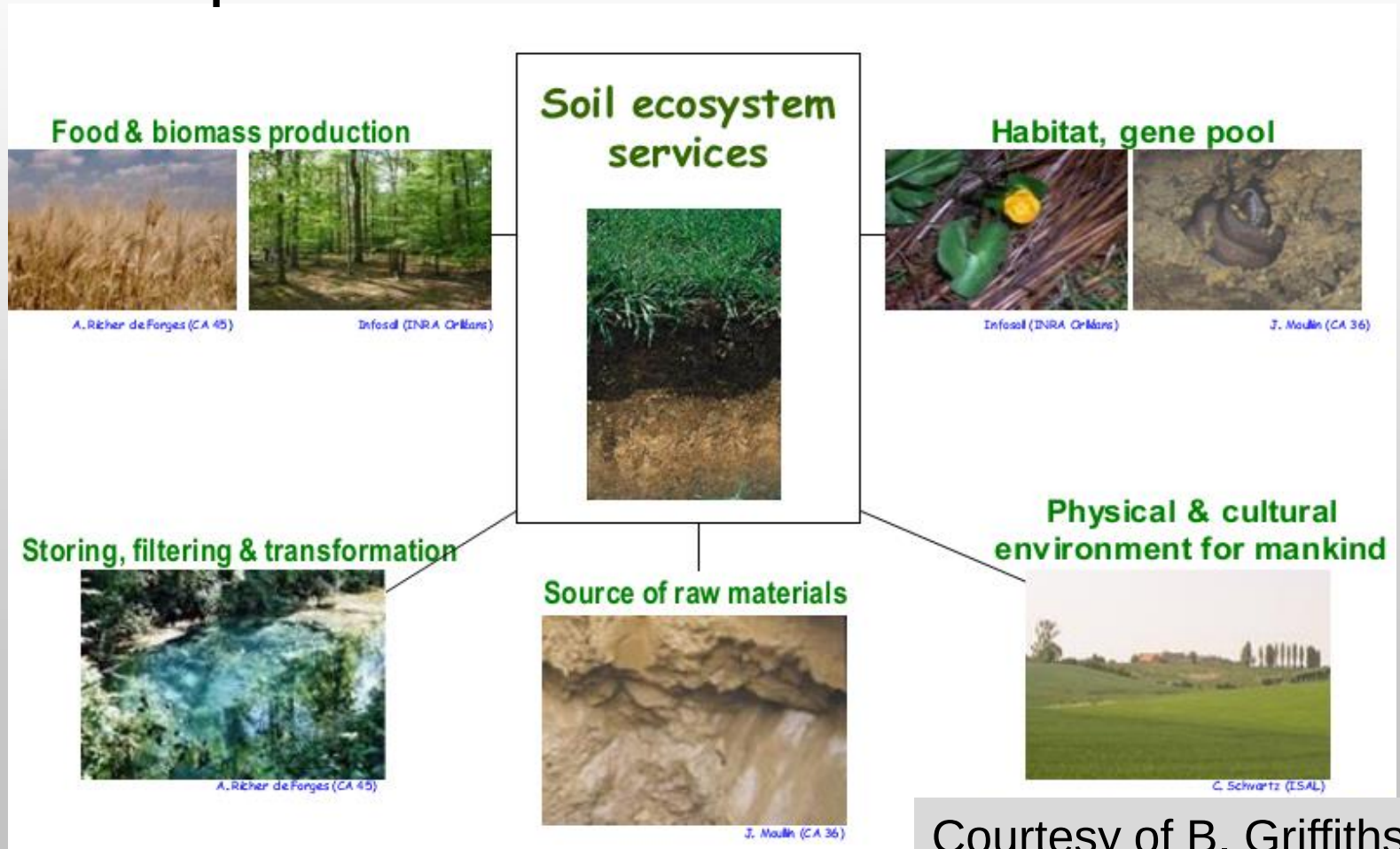
Basis of the terrestrial food web

=> all soil organisms

Basis: Biodiversity, including gene pool

Current Global Trends III.

Soil biota provide the basis for services relevant for mankind.



Courtesy of B. Griffiths

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