Common ground: Soil biodiversity and DNA barcoding

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They say that no two are alike

The head of the bacterial-feeding soil nematode

*Acrobeles complexus* (courtesy of D. Bumbarger)
Why Soil Biodiversity?

• Moving ‘forgotten biodiversity’ to the world stage
• Soils are in crisis, time is short, progress is slow
• DNA barcoding and other tools are needed to help conserve biodiversity, for standardized sampling;
  • and a soil biodiversity global assessment
Linking Soil Biodiversity to the World

• What is the Global Soil Biodiversity Initiative (GSBI)?
• What does the GSBI do?
• Advances and Frontiers in Soil Biodiversity Science
• Moving forward to meet Sustainability Challenges
What is the Global Soil Biodiversity Initiative (GSBI)?

- 2011 - A scientific agenda started by scientists
- Recognized by the UN Convention on Biological Diversity, Global Soil Partnership, FAO
- All lands, all aspects of soil biodiversity science
- Secretariat - Colorado State University, Fort Collins, CO, USA

www.globalsoilbiodiversity.org.
What is there? One quarter living diversity on Earth belowground

The Global Soil Biodiversity Initiative (GSBI) is a bottom-up collaboration of international scientists dedicated to advancing the knowledge of soil biodiversity science and ecosystem services for use in policy and management of global terrestrial ecosystems.
 Soil biodiversity is intimately linked to aboveground species

- Wildlife depends on soil organisms as food
- Soil organisms suppress pathogens
- Soil biodiversity regulates rate of carbon stored
- Soil fertility enhances aboveground biodiversity
Scientific Advisory Committee

Diana Wall  
*Scientific Chair*

Elizabeth Bach  
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Fred Ayuke  
Kenya

Richard Bardgett  
UK

Ciro Gardi  
Italy

Nobuhiro  
Kaneko  
Japan

Fatima Maria de Souza Moreira  
Brazil

Luca Montanarella  
EU

Johan Six  
Switzerland

Wim van der Putten  
Netherlands
Global Soil Biodiversity Initiative ~111 countries

>1300 participants
Why a GSBI? Soils are at the center of global policy agendas but life in soils is often ignored
Why a GSBI? Advances in soil biodiversity research inform people and policies for land, air, water and health.
Links with Partners

International Soil Modelling Consortium

UNCCD

Global Urban Soil Ecology and Education Network

www.globalsoilbiodiversity.org
Linking Soil Biodiversity to Sustainability

What is the Global Soil Biodiversity Initiative?

What does the GSBI do?

Advances in Soil Biodiversity Science

Moving forward to meet Sustainability Challenges
What does the GSBI do?

- Policy
- Education/outreach
- Knowledge gaps
GLOBAL LAND OUTLOOK WORKING PAPER

THREATS TO SOILS: GLOBAL TRENDS AND PERSPECTIVES
A Contribution from the Intergovernmental Technical Panel on Soils, Global Soil Partnership
Food and Agriculture Organization of the United Nations

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Gary Pierzynski (United States) and Brajendra (India)
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September 2017
Assessment on Land Degradation & Restoration
Global Assessment on Biodiversity & Ecosystem Services
POLICY: GSBI provides cutting-edge biodiversity science

GLOBAL SOIL BIODIVERSITY INITIATIVE

Side meetings on Soil Biodiversity - United Nations

Rio UNCSD
Nairobi, UNEP
Cancun, UNCBD
22 Keynotes

>1000 attendees
From 47 countries

2nd Global Soil Biodiversity Conference
October 2017 Nanjing, China

Call for:
Global Soil Biodiversity Assessment

>100 oral presentations
Download Full Atlas pdf FREE

>120+ scientists were authors
>45,000 downloads
>4 Million views on-line
>125 Million social media views

€25/$29 + shipping for print copy
Estimated distribution of soil biodiversity

Soil biodiversity index
High
Low
Not available
Water
Ice

P.90-91 Global Soil Biodiversity Atlas
Potential threats to soil biodiversity
Interventions to protect soil biodiversity

- Prevention and restoration of invaded sites
- Agroforestry, afforestation and perennial cultures
- Fire management
- Soil erosion control
- Diversification of cropland
- Bioremediation
- No-tillage
- Land sparing versus land sharing

P.137 Global Soil Biodiversity Atlas
The Global Soil Biodiversity Atlas Launch
United Nations Environmental Program COP
Side meeting, Nairobi, June 2016

Australian Parliament
French Academy of Agriculture
Brazilian Soil Science Society
BENEATH OUR FEET
AN INTERNATIONAL FORUM FOR
DISCUSSION

KNOWLEDGE GAPS

GLOBAL SOIL BIODIVERSITY INITIATIVE

Beneath Our Feet
A Global Soil Biodiversity Blog

GLOBAL SUSTAINABLE LAND MANAGEMENT
HUMAN WELL-BEING
POLICY
KNOWLEDGE GAPS

Advances in Soil Biodiversity Research

Number of items published in each year:
‘Soil Biodiversity’

1988 to 11 May 2017

Web of Science
Knowledge Gaps: Taxonomic Impediment

Antarctic cold desert: McMurdo Dry Valleys
Soil inverts are highest animal taxa

Photo by Hilary Dugan
4 Barcodes, 3 species: Which population represents the new species in Antarctica?

Dearth of taxonomic expertise relative to high diversity for poorly known taxa hampers progress in alpha taxonomy. (Courtesy BJ Adams)
Knowledge Gaps: Soil biodiversity & carbon cycling

Soil fauna increase litter decomposition ~ 27%

Are there links between responses of soil microbes and ecosystem functioning to elevated CO₂, N deposition and warming? A global perspective

Warming: yes
N deposition: yes
CO₂ enrichment: depends
Knowledge Gaps: Soil biodiversity and agricultural productivity

Soil biota enhance agricultural sustainability by improving crop yield, nutrient uptake and reducing nitrogen leaching losses

S. Franz Bender\textsuperscript{1,2,*} and Marcel G.A. van der Heijden\textsuperscript{1,2,3}

Soil microarthropods support ecosystem productivity and soil C accrual: Evidence from a litter decomposition study in the tallgrass prairie

Jennifer L. Soong\textsuperscript{a, b, *}, Martijn L. Vandegehuchte\textsuperscript{a, c, d}, Andrew J. Horton\textsuperscript{a}, Uffe N. Nielsen\textsuperscript{c}, Karolien Denef\textsuperscript{f}, E. Ashley Shaw\textsuperscript{a, d}, Cecilia Milano de Tomasel\textsuperscript{a, d}, William Parton\textsuperscript{a}, Diana H. Wall\textsuperscript{a, d}, M. Francesca Cotrufo\textsuperscript{a}
Global soil carbon projections are improved by modelling microbial processes

William R. Wieder\textsuperscript{1*}, Gordon B. Bonan\textsuperscript{1} and Steven D. Allison\textsuperscript{2}

Beyond microbes: Are fauna the next frontier in soil biogeochemical models?

A. Stuart Grandy \textsuperscript{a, *}, William R. Wieder \textsuperscript{b, c}, Kyle Wickings \textsuperscript{d}, Emily Kyker-Snowman \textsuperscript{a}
Knowledge Gaps: Emerging Frontiers

Biodiversity at multiple trophic levels is needed for ecosystem multifunctionality

Soliveres et al. 2016

Models with trophic group as a significant predictor (%)
Soil networks become more connected and take up more carbon as nature restoration progresses Morriën et al.
Knowledge Gaps: Emerging Frontiers

Soil fauna responses to natural disturbances, invasive species, and global climate change: Current state of the science and a call to action

David R. Coyle a,*, 1, Uma J. Nagendra b, Melanie K. Taylor c, J. Holly Campbell a, 1, Chelsea E. Cunard b, Aaron H. Joslin a, Abha Mundepi d, Carly A. Phillips e, Mac A. Callaham Jr. c

Soil Biology & Biochemistry (2017)
Knowledge Gaps: Emerging Frontiers

Molecular study of worldwide distribution and diversity of soil animals

Tiehang Wu, Edward Ayresb,1, Richard D. Bardgett,1, Diana H. Wallh,d, and James R. Garey

Global diversity and geography of soil fungi

Leho Tedersoo,‡‡ Mohammad Bahram,‡ Sergei Pölme,‡ Urmas Kõlja,‡
Nourou S. Yorou,‡ Ravi Wijesundera,‡ Luis Villarreal Ruiz,‡ Aída M. Vaseo-Palacios,‡
Pham Quang Thu,‡ Are Sulija,‡ Matthew E. Smith,‡ Cathy Sharp,‡ Erik Sahveer,‡
Alessandro Salitta,‡‡‡ Miguel Rosas,‡ Taavi Ritt,‡ David Ratkowsky,‡ Karin Prötz,‡
Kadri Põldmaa,‡ Melke Piepenbrinck,‡ Cherchel Phoerl,‡ Marko Peterson,‡
Kaarin Parts,‡ Kadri Pärte,‡ Eveli Otsing,‡ Eduarto Nonhra,‡ André L. Njouonkou,‡‡
R. Henrik Nilsson,‡‡ Luis N. Morgado,‡‡ Jordan Mayor,‡‡ Tom W. May,‡‡
Luiza Majnukin,‡‡ D. Jean Lodge,‡‡ Su See Lee,‡‡ Karl-Henrik Larsson,‡‡ Petr Kohout,‡
Kentaro Hosaka,‡‡ Indrek Hlialski,‡ Terry W. Henkel,‡ Helery Haren,‡
Liang-dong Guo,‡‡ Alina Greslebin,‡‡ Gwen Grelet,‡‡ Josep Geml,‡‡ Genevieve Gates,‡‡
William Dunstan,‡‡ Chris Dunk,‡‡ Rein Drenkhahn,‡‡ John Deursley,‡‡ André De Kesel,‡‡
Tan Dang,‡ Xin Chen,‡‡ Franz Buegger,‡‡ Francis Q. Brearley,‡‡ Gregory Bonito,‡‡
Sten Anslat,‡ Sandra Aheii,‡‡ Kesey Abarenkov‡‡
Knowledge Gaps: Emerging Frontiers

Microbes do not follow the elevational diversity patterns of plants and animals

Noah Fierer,1,2,8 Christy M. McCain,1 Patrick Meir,3 Michael Zimmermann,3,4 Joshua M. Rapp,5 Miles R. Silman,5 and Rob Knight6,7

Cross-biome metagenomic analyses of soil microbial communities and their functional attributes

Noah Fierer2,1, Jonathan W. Leffb, Byron J. Adams5, Uffe N. Nielsen4, Scott Thomas Batesb, Christian L. Lauberb, Sarah Owense,f, Jack A. Gilberte,g, Diana H. Wallh, and J. Gregory Caporasoe,i
Termite mounds can increase the robustness of dryland ecosystems to climatic change 2015

Juan A. Bonachela,1* Robert M. Pringle,1,2 Efrat Sheffer,1 Tyler C. Coverdale,1 Jennifer A. Guyton,1 Kelly K. Caylor,2,3 Simon A. Levin,1 Corina E. Tarnita1,2†
Knowledge Gaps: Regional Assessments

Soil biota in a megadiverse country: Current knowledge and future research directions in South Africa

Mapped:
Nematoda (round worms)
Oligochaeta (earthworms, enchytraeids)
Diplopoda (millipedes)
Araneae (spiders)
Oribatida (oribatid mites)
Trombidiformes (trombidiform mites)
Collembola (springtails)
Formicidae (ants)
Knowledge Gaps: Regional Assessments of threats


Intensive agriculture reduces soil biodiversity across Europe

MARIA A. TSIAFOULI1, ELISA THÉBAULT2, STEFANOS P. SGARDELIS1, PETER C. DE RUITER3, WIM H. VAN DER PUTTEN4,5, KLAUS BIRKHOFER6, LIA HEMERIK3, FRANCISCA T. DE VRIES7, RICHARD D. BARDGETT7, MARK VINCENT BRADY9, LISA BJÖRNLUND9, HELENE BRACHT JØRGENSEN6, SØREN CHRISTENSEN9, TINA D'HERTEFELDT6, STEFAN HOTES10,11, W.H. GERA HOL4, JAN FROUZ12, MIRA LIIRI13, SIMON R. MORTIMER14, HEIKKI SETÄLÄ13, JOSEPH TZANOPoulos15, KAROLINE UTESKENY16, VÁCLAV PIzl12, JOSEF STARY12, VOLKMAR WOLTERS17 and KATARINA HEDLUND6

Conventional tillage decreases the abundance and biomass of earthworms and alters their community structure in a global meta-analysis

María Jesús I. Briones1,2 | Olaf Schmidt3
A communal catalogue reveals Earth’s multiscale microbial diversity

Luke R. Thompson\textsuperscript{1,2,3}, Jon G. Sanders\textsuperscript{1}, Daniel McDonald\textsuperscript{1}, Amnon Amir\textsuperscript{1}, Joshua Ladau\textsuperscript{4}, Kenneth J. Locey\textsuperscript{5}, Robert J. Prill\textsuperscript{6}, Anupriya Tripathi\textsuperscript{7,8}, Sean M. Gibbons\textsuperscript{9,10}, Gail Ackermann\textsuperscript{1}, Jose A. Navas–Molina\textsuperscript{1,11}, Stefan Janssen\textsuperscript{1}, Evguenia Kopylova\textsuperscript{1}, Yoshiki Vázquez–Baeza\textsuperscript{1,11}, Antonio González\textsuperscript{1}, James T. Morton\textsuperscript{1,11}, Siavash Mirarab\textsuperscript{12}, Zhenjiang Zech Xu\textsuperscript{1}, Lingjing Jiang\textsuperscript{1,13}, Mohamed F. Haroon\textsuperscript{14}, Jad Kanbar\textsuperscript{1}, Qiyun Zhu\textsuperscript{1}, Se Jin Song\textsuperscript{1}, Tomasz Koscielak\textsuperscript{1}, Nicholas A. Bokulich\textsuperscript{15}, Joshua Lefler\textsuperscript{1}, Colin J. Brislawn\textsuperscript{16}, Gregory Humphrey\textsuperscript{1}, Sarah M. Owens\textsuperscript{17}, Jarrad Hampton–Marcell\textsuperscript{17,18}, Donna Berg–Lyons\textsuperscript{19}, Valerie McKenzie\textsuperscript{20}, Noah Fierer\textsuperscript{20,21}, Jed A. Fuhrman\textsuperscript{22}, Aaron Clauset\textsuperscript{19,23}, Rick L. Stevens\textsuperscript{24,25}, Ashley Shade\textsuperscript{26,27,28}, Katherine S. Pollard\textsuperscript{4}, Kelly D. Goodwin\textsuperscript{3}, Janet K. Jansson\textsuperscript{16}, Jack A. Gilbert\textsuperscript{17,29}, Rob Knight\textsuperscript{1,11,30} & The Earth Microbiome Project Consortium*
EU Land-Use/Cover Area Survey (LUCAS) sequencing >27,000 soil samples - 2018

China Soil Microbiome Initiative 35M USD

Africa Soil Microbiology Project
USAID funded to U Pretoria, Centre for Microbial Ecology & Genomics

Biome of Australian Soil Environments (BASE) Delgado - Baquerizo et al. 2017
Knowledge Gaps: Regional Assessments

China Soil Microbiome Initiative
PI: Renfang Shen, Nanjing Univ.
- Biogeography
- Microbial mediated biogeochemistry
- Above- below-ground processes
- Technology innovation

USAID funded
PI: Don Cowan
Centre for Microbial Ecology & Genomics, U Pretoria
1000 samples
10 countries
Knowledge Gaps: Regional Assessments

Editorial

Soil biodiversity and ecosystem functions across Europe: A transect covering variations in bio-geographical zones, land use and soil properties  

_Biological indicators_
- Bacteria: Biolog plates
- Respiration: MicroResp
- Exo-enzyme activity
- Phospholipid fatty acids (PLFA)

_Bacteria biodiversity: 16S sequencing_
- Collembola
- Nematodes
- Mites
- Earthworms
Knowledge Gaps: Regional Assessments

Biome of Australia Soil Environments (BASE)

Create reference map of:
- Bacteria (16S)
- Fungi (ITS)

Procedures, protocols, and data available
Toward a global platform for linking soil biodiversity data

Knowledge Gaps: Global Workshops

The Synthesis Centre for Biodiversity Sciences (sDIV)

sWORM WORKING GROUP

Synthesizing & providing access to global earthworm data

Principal investigators:
Erin Cameron & Nico Eisenhauer
Why now? Accelerating Scientific Knowledge - Collaborative, international, interdisciplinary research and tools to address challenges

Regional Assessments

Microbiomes - National and International Microbiomes

Soil Microbiomes – USAID African Soil Microbiome; Earth Microbiome; Plant Microbiome (USA)

Experiments, standardized methods, microbes + animals

GLIDE- Global litter Invertebrate Decomposition experiment; Drought NET

EcoFINDERS – Soil biodiversity and ecosystem functioning cross-Europe network experiment
The Global Soil Biodiversity Initiative: Future Directions

• **Global Soil Biodiversity Assessment (UN CBD – FAO)**
  – GSBI coordination - working groups /reports/ assessments
  – Distributed data (Ramirez et al. 2015)
  – Trait based bank for soil fauna

• **Knowledge Gaps**
  – Who, where, what they do and why we should care
  – Cross-disciplinary approaches for spatial scales
  – Global collaborative experiments on response to CChange: long term observations
Linking life in soil to sustainability
www.globalsoilbiodiversity.org.
We can’t breathe, eat, drink, or be healthy without sustainably managing soils.

Wall & Six, Science, 2015

Global Soil Biodiversity Atlas, 2016
Common ground: Soil biodiversity and DNA barcoding
Actions for Soil Biodiversity Science and SDGs

1. Include soil biodiversity with human, plant and animal health research
2. Develop a global database for soil biodiversity
3. Use soil biodiversity as a criterion for determining wilderness and protected areas, and soil quality
4. Focus research on conservation of soil biodiversity as a management tool to improve human health in the long-term
5. Coordinate, collaborate, highlight efforts among societies and global
Support from our universities and institutes

SCHOOL OF GLOBAL ENVIRONMENTAL SUSTAINABILITY
COLORADO STATE UNIVERSITY

Joint Research Centre

WESTERN SYDNEY UNIVERSITY

MANCHESTER 1824
The University of Manchester

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

NETHERLANDS INSTITUTE OF ECOLOGY (NIOO-KNAW)