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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Item 5 of the Provisional Agenda

INTERGOVERNMENTAL TECHNICAL WORKING GROUP ON MICROORGANISM AND INVERTEBRATE GENETIC RESOURCES FOR FOOD AND AGRICULTURE

First Session

Rome, 25–27 September 2024

BIOREMEDIATION AND NUTRIENT CYCLING SOIL MICROORGANISMS AND INVERTEBRATES

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I. INTRODUCTION

1. The Commission on Genetic Resources for Food and Agriculture (Commission), at its Seventeenth Regular Session, adopted its Work Plan for the Sustainable Use and Conservation of Microorganism and Invertebrate Genetic Resources for Food and Agriculture (Work Plan).[1] In line with the Work Plan, and based on the findings of a draft study, the Commission, addressed soil microorganisms and invertebrates that contribute to bioremediation of agricultural pollutants and nutrient cycling at its last session.[2]

2. The Commission welcomed the draft study and recommended that it be finalized and published.[3] The study was subsequently published as Background Study Paper No 74.[4]

3. The Commission recommended that the FAO Council request FAO to take the findings of the background study paper into consideration in its work in fields relevant to the management of soil microorganisms and invertebrates, as appropriate. It invited Members to promote the conservation and sustainable use of soil microorganisms and invertebrates and ensure they are given due consideration in local, national, regional and international policies and policy-development processes. It noted, in this regard, the need to give due regard to the roles of Indigenous Peoples and local communities.[5]

4. It invited Members to communicate research findings on the benefits of soil biodiversity and sustainable agricultural practices to relevant stakeholders, farmers in particular, and to raise awareness of how soil biodiversity contributes to climate change mitigation, adaptation and resilience.[6]

5. It also encouraged relevant stakeholders, including scientific institutions, to collaborate on the conservation and sustainable use of soil microorganisms and invertebrates, especially on capacity development in developing countries and countries with economies in transition, including capacity development on the characterization of soil microbial and invertebrate biodiversity and on the establishment of culture collections.[7]

6. It further invited Members and other stakeholders to intensify research on soil microorganisms and invertebrates, in particular on relationships between the properties of healthy soils and their microbial communities, and on the effects that agricultural practices have on soils, including their roles in climate change mitigation, adaptation and resilience, and to strengthen soil biodiversity assessment and monitoring programmes and conservation and cultivation methods for *ex situ* studies of soil microorganisms. It also noted the need for research on links between soil biodiversity and food security and on antimicrobial resistance in soil ecosystems.[8]

7. The Commission also requested the Secretariat to consult relevant experts, and relevant treaties and conventions, in the drafting of specific recommendations on soil microorganisms and invertebrates for consideration by the Commission at its next Session. As part of this consultation, the Secretariat is seeking advice from the Intergovernmental Technical Working Group on Microorganism and Invertebrate Genetic Resources for Food and Agriculture (Working Group).

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[1] CGRFA-17/19/Report, *Appendix E*.
[2] CGRFA-19/23/9.1/Inf.1.
[3] CGRFA-19/23//Report, paragraph 72.
[4] Csorba, C., Hackl, E., Reichenauer, T., van der Putten, W. & Sessitsch, A. 2024. *Sustainable use and conservation of soil microorganisms and invertebrates contributing to bioremediation and nutrient cycling*. Background Study Paper, No. 74. Commission on Genetic Resources for Food and Agriculture. Rome, FAO. https://doi.org/10.4060/cd0147en
[5] CGRFA-17/19/Report, *Appendix E*.
[6] Csorba, C., Hackl, E., Reichenauer, T., van der Putten, W. & Sessitsch, A. 2024. *Sustainable use and conservationof soil microorganisms and invertebrates contributing to bioremediation and nutrient cycling.* Background StudyPaper, No. 74. Commission on Genetic Resources for Food and Agriculture. Rome, FAO. https://doi.org/10.4060/cd0147en.
[7] CGRFA-19/23/Report, paragraph 75.
[8] CGRFA-19/23/Report, paragraph 76.

8. Drawing on previous work carried out for the Commission,[9] this document briefly summarizes the status and trends of conservation, use and access and benefit-sharing, maps regional and international organizations and other institutions most relevant for bioremediation and nutrient cycling soil microorganisms and invertebrates and provides an analysis of gaps and needs in this area. It seeks the Working Group's advice on further work of the Commission in this field.

II. BACKGROUND

9. Soil microorganisms and invertebrates are highly diverse and exist within complex communities that play vital roles in nutrient cycling and in maintaining soil structure. They are thus vital to food production. They provide a range of options for dealing with the contamination of soils with heavy metals and other pollutants (bioremediation). Their roles in the carbon cycle mean that they are vital to efforts to maintain and increase carbon sequestration in the soil. They contribute in various ways to "One Health", the approach that combines human, animal, plant and environmental health.

10. For healthy growth, plants require a wide range of macro- and micronutrients, specifically the elements carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, copper, zinc, molybdenum, boron and chlorine. Most plants obtain carbon via photosynthesis and other nutrients from the soil in which they grow.

11. The carbon cycle involves the transformation of dead organic material into soil organic matter by microbial and invertebrate decomposers. Carbon is naturally sequestered in the soil through the activity of photosynthesizers, soil-bioturbator invertebrates and oxalate producers.

12. The cycling, bioavailability and biomineralization of all macro- and micronutrients are connected to the biological activities of soil organisms. Key microbial functions include fixing nitrogen from the atmosphere and transforming it into plant-available forms and biomineralizing organic phosphorus into inorganic compounds.

13. Various microorganisms can be actively recruited from the rhizosphere soil by plants to colonize their inner root tissues. This results in a metabolically profound plant–microbe relationship and is often crucial for plant development.

14. The mobility and availability of most metals in the soil depend on microbial processes. Numerous native soil bacteria contribute naturally to the reduction of toxicity levels by excreting exopolysaccharides that absorb heavy metals.

III. STATUS, TRENDS AND THREATS

15. Only a fraction of soil microorganisms have been taxonomically described, and the status and trends of individual species and even genera are mainly unknown. Many soil invertebrates also remain undescribed and data on their spatial distribution and population dynamics are limited. Where trends are concerned, the available evidence suggests that losses of functional and taxonomic diversity have been massive. However, their worldwide extent has not been quantified.

16. Land-use change and unsustainable agricultural practices are important drivers of soil biodiversity loss. However, knowledge of the effects that particular practices have on soil microorganisms and invertebrates remains patchy. Broadly speaking, it appears that tillage, inappropriate irrigation practices, heavy pesticide use and long-term monoculture negatively affect components of soil biodiversity.

17. Various invasive alien invertebrates and microorganisms have been found to have severe effects on soil biodiversity. The spread of antibiotic resistance genes (ARGs), which enter the soil mainly via animal manure and irrigation with human wastewater, is another concern. The use of antibiotics in agriculture poses a major threat to soil microbial biodiversity.

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[9] Csorba, C., Hackl, E., Reichenauer, T., van der Putten, W. & Sessitsch, A., 2024. *Sustainable use and conservation of soil microorganisms and invertebrates contributing to bioremediation and nutrient cycling*. Background Study Paper, No. 74. Commission on Genetic Resources for Food and Agriculture. Rome, FAO. https://doi.org/10.4060/cd0147en

18. Soil biodiversity is affected by changes in temperature and soil moisture content and is therefore vulnerable to the impacts of climate change. Precise effects remain difficult to predict, but studies suggest that impacts on the roles of microorganisms in the carbon cycle and in nitrogen fixation may be substantial.

IV. CONSERVATION AND SUSTAINABLE USE

19. There is an urgent need to address the above-described threats and ensure that the contributions of soil microorganisms and invertebrates to food security and the supply of ecosystem services are nurtured. Successful conservation of soil organisms requires a combination of *in situ* and *ex situ* approaches. As noted above, agricultural management practices often pose a threat to soil biodiversity. However, various techniques have proven capable of sustaining diversity and reversing losses. These include maintaining soil cover (e.g. using mulch or cover crops), permaculture, agroforestry, diversified crop rotations, use of indigenous crops, interseeding and reducing pesticide use, although outcomes vary with the particular combination of practices and environmental conditions.

V. POLICY AND LEGAL FRAMEWORKS

20. At global level, the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) decided in 2002 to establish the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity.[10] FAO and other relevant organizations were invited to facilitate and coordinate this initiative.[11] In 2022, the 15th meeting of the COP endorsed a new plan of action for the initiative, covering the period 2020 to 2030.[12] Also at global level, the Framework for Action on Biodiversity for Food and Agriculture[13] makes a number of specific references to soil biodiversity and soil health.

21. At national level, few countries' national biodiversity strategy and action plans (NBSAPs) include measures specifically focused on soil biodiversity. In their national reports to the CBD, countries have referred to difficulties in identifying and understanding soil biodiversity and to a lack of expertise and tools in this field. Data for assessing the impacts of national policies are often lacking.

22. Overall, few countries have put in place effective policy and legal frameworks for the sustainable use and conservation of soil biodiversity, and those that have are largely restricted to the developed regions of the world. However, examples of countries adopting soil biodiversity-related policy measures can be found in all regions of the world.

23. International exchanges of soil microorganisms and invertebrates are affected by legal frameworks related both to access and benefit-sharing and to sanitary and phytosanitary protection.

VI. NETWORKS AND COOPERATION

24. A large number of global and regional networks contribute to the management of soil biodiversity. Prominent among these is the Global Soil Partnership (GSP),[14] a globally recognized mechanism established in 2012 with the mission of positioning soils in the global agenda and promoting sustainable soil management. The GSP, which is hosted by FAO, works to improve soil governance with the aim of guaranteeing productive soils that contribute to food security, climate change adaptation and mitigation, and sustainable development for all.[15] It was under the aegis of the GSP and its advisory Intergovernmental Technical Panel on Soils that the revised World Soil Charter,[16] endorsed by the FAO Conference in 2015,[17] was developed. The *Voluntary Guidelines for*

[10] Decision VI/5.
[11] Decision VI/5.
[12] CBD/COP/DEC/15/28.
[13] CGRFA-18/21/Report, *Appendix C*.
[14] https://www.fao.org/global-soil-partnership/en
[15] See CGRFA-19/23/9.1/Inf.2.
[16] FAO. 2015. *Revised World Soil Charter*. Rome. https://openknowledge.fao.org/server/api/core/bitstreams/65be618a-f5e8-4f67-9cbb-d77f1f5cd31e/content
[17] C 2015/REP, paragraph 57.

Sustainable Soil Management,[18] endorsed by the FAO Council in 2016,[19] which stress the importance of preserving and enhancing soil biodiversity, were also developed within the framework of the GSP.

25. The International Network on Soil Biodiversity (NETSOB)[20] was established in December 2021 to promote the sustainable use and conservation of soil biodiversity and to bring together relevant experts and existing initiatives to contribute to the implementation of the Global Soil Biodiversity Observatory (GLOSOB), a global data platform.

VII. CAPACITY IN RESEARCH AND EDUCATION

26. In recent decades, a shortage of trained specialists has impeded taxonomic work on soil microorganisms. However, there has been a boom in the number of publications, conferences and scientific networks addressing soil-related topics.

27. Citizen-science programmes can make important contributions to the collection of soil-related data, including on species distributions. The number of countries where successful initiatives of this kind have been established is, however, limited.

28. Promoting the uptake of management practices that benefit soil biodiversity requires training and education for farmers. Various actions have been taken in this regard, including the development of educational websites and the inclusion of training on soil-related topics in the work of farmer field schools. However, only a limited number of NBSAPs include specific plans to educate farmers and other stakeholders on soil management practices or to support multidisciplinary research networks targeting soil biodiversity conservation.

VIII. GAPS, NEEDS AND POTENTIAL ACTIONS

29. Based on the analysis provided by Background Study Paper No. 74, the following gaps and needs related to the sustainable use and conservation of microorganisms and invertebrates that contribute to nutrient cycling and bioremediation can be identified.

- *Research on nutrient-cycling*. There are major gaps in knowledge on the roles of soil microorganisms and invertebrates in nutrient cycling and how they are affected by agricultural management practices, their roles in potential alternatives to conventional phosphorus fertilization, their roles in carbon sequestration, the links between their roles in nitrogen fixation and their roles in methane production, and how they are affected by ARGs. There is a need for improved microbial gene databases and novel methods for predicting and quantifying microbial functions.
- *Research on microbial products*. Attention needs to be paid to improving the effectiveness of microbial products such as biofertilizers under field conditions, to avoiding non-target effects on native biodiversity and soil functions, and to investigating the potential benefits of using microbial consortia rather than single strains.
- *Research on healthy soils*. There is a need to determine what constitutes a "healthy" soil and how this can be measured in different environments.
- *Research on bioremediation*. Improving bioremediation requires a better understanding of the interactions between bacteria, fungi and invertebrates. Particular attention needs to be given to the roles of invertebrates in the bioremediation of heavy metals and pesticides, to improving *in situ* bioremediation methods, to bioremediation of multiple contaminants and to the identification of bioindicator organisms.
- *Mapping and data management*. Maps and databases containing information on the status and trends of soil biodiversity and of threats such as invasive organisms and soil

[18] FAO. 2017. *Voluntary Guidelines for Sustainable Soil Management*. Rome. https://openknowledge.fao.org/server/api/core/bitstreams/5d66c466-4040-4493-a85f-58470f0bb771/content
[19] CL 155/REP, paragraph 11.
[20] https://www.fao.org/global-soil-partnership/netsob/en

contamination need to be updated and expanded, potentially through the use of new technologies such as remote sensing, drones and robots.

- *Communication*. There is also a need to better communicate research results, such as those related to the benefits of soil biodiversity and sustainable agricultural practices, to farmers and the wider public and to better involve stakeholders in research, dissemination and development activities.
- *Conservation*. Improving the conservation of soil microorganisms and invertebrates will require better knowledge of their status (baseline surveys and frequent monitoring over the long term), better information sharing, efforts to overcome the neglect of these organisms in conservation planning, and identification of ways of incentivizing agricultural practices that benefit them. Conservation programmes for indigenous crops and trees and their associated indigenous microbiota and invertebrates are needed.
- Ex situ *collections*. To strengthen *ex situ* conservation, but also to improve understanding of microbial functions, there is a need to develop protocols and high-throughput technologies that can bring "uncultivable" groups and whole microbiomes into cultivation. There is also a need to centralize the deposition of microbial strains. Shortages of funding and trained personnel are currently big constraints to *ex situ* conservation. Establishing collections that specialize in the cultivation of overlooked soil organisms or organisms that are hard to breed or cultivate under laboratory conditions is crucial.
- *Restoration*. There is a need to develop better methods for restoring soils in heavily disturbed areas such as those degraded by unsustainable agricultural practices. This will require holistic understanding of the interrelationships between plants, invertebrates, protozoa, bacteria, fungi, viruses and connected soil functions. Microbiomes rather than single organisms or limited groups of organisms need to be targeted. Lost soil organisms could potentially be obtained from *ex situ* collections and reintroduced.
- *Policy and regulatory frameworks*. There is a need to improve some regulations relevant to the management of soil biodiversity. For instance the requirement for strain-level registration potentially hinders the introduction of products containing multiple microbes into agricultural use. Rules for the import of invertebrates may also need to be reviewed. Other requirements include improving quality control of the viability of microbial products. There is a need to closely involve scientists and curators of culture collections in policymaking.

30. Again based on the background study paper, the following can be identified as areas in which strategic, multidisciplinary, international collaboration is needed:

- development of strategies for better public and stakeholder outreach and communication, including information materials on soil organisms and their use;
- facilitation of interdisciplinary and international research and partnerships on topics related to soil biodiversity;
- transfer of knowledge among the agricultural, academic, industrial and policymaking sectors to improve products, relevant legislation and funding schemes for research;
- coordination of research, and development of protocols defining the concept of a "healthy" soil microbiome and for commonly used laboratory and analysis techniques; and
- harmonization of soil biodiversity-relevant monitoring programmes, networks, initiatives and databases.

31. Likewise, the following potential actions to improve the conservation and sustainable use of soil microorganisms and invertebrates can be highlighted.

- Guidelines and standard operation procedures for the definition of "healthy soils" need to be elaborated and used in comparative assessments of soil biodiversity. These guidelines and procedures need to include well-defined key soil parameters, which include biological

parameters such as microbial/invertebrate taxa indicating soil health, and carefully chosen quality standards.

- There is a need to develop consensus on: (a) the most important soil functions; (b) parameters for inclusion in assessments of the effects that new agricultural methods have on soils; (c) key soil biodiversity parameters; and (d) unified sampling, laboratory and analysis procedures for soil biodiversity.
- Recommendations on ideal soil conditions and on best practices and interventions in soil management in agriculture should be based on long-term observations made under a range of different environmental conditions and geographical regions.
- The uptake of promising agricultural practices that are beneficial to soil biodiversity conservation needs to be supported by improving evaluation of their applicability and their ease of implementation and should consider potential undesired effects.
- The functionality, standardization and maintenance of databases of soil-health parameters and soil-biodiversity characteristics at regional scales need to be improved.
- Addressing the complex problems facing soil protection in agricultural systems requires scientific approaches that are interdisciplinary and involve a range of specialists, including environmental chemists, biologists, agronomists and taxonomists.
- More and better coordination is needed among the numerous research activities and scientific networks working on the sustainable use and conservation of soil microorganisms and invertebrates.
- Raising awareness and building capacities in soil biodiversity conservation through the education and involvement of producers, as well as better dissemination and public outreach, are essential.
- Already existing *ex situ* and *in situ* conservation initiatives need to be better coordinated and should also address the cultivation and conservation needs of understudied groups of soil organisms.
- Short-term and long-term goals for the conservation and sustainable use of soil organisms need to be identified and a priority list established among them.

IX. GUIDANCE SOUGHT

32. The Working Group may wish to make recommendations to the Commission as to what should be done to:

(i) support and better coordinate research on the roles of soil microorganisms and invertebrates in nutrient cycling and bioremediation and on agricultural practices that may affect soil health and soil biodiversity;
(ii) promote the uptake of agricultural practices identified as beneficial to soil microorganisms and invertebrates that contribute to nutrient cycling and bioremediation;
(iii) support the management of data related to the sustainable use and conservation of soil microorganisms and invertebrates that contribute to nutrient cycling and bioremediation;
(iv) improve the coordination of existing *ex situ* and *in situ* conservation initiatives targeting soil microorganisms and invertebrates that contribute to nutrient cycling and bioremediation and to improve the conservation of understudied groups of such organisms;
(v) improve the identification of goals and the setting of priorities in the conservation and sustainable use of soil microorganisms and invertebrates that contribute to nutrient cycling and bioremediation;

(vi) better reflect the need for adequate management of soil microorganisms and invertebrates that contribute to nutrient cycling and bioremediation in relevant policy, legal and institutional frameworks at national and international levels; and

(vii) strengthen efforts by all relevant stakeholders to implement the *Voluntary Guidelines for Sustainable Soil Management*.