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REVIEW OF THE INTERNATIONAL INITIATIVE FOR THE CONSERVATION AND SUSTAINABLE USE OF SOIL BIODIVERSITY AND UPDATED PLAN OF ACTION

Note by the Executive Secretary

INTRODUCTION

1. In decision 14/30, paragraph 24 (b), the Conference of the Parties requested the Executive Secretary to review the implementation of the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity, in consultation with the Food and Agriculture Organization of the United Nations (FAO) under the framework of the Global Soil Partnership (GSP) as well as other interested partners, and present an updated draft plan of action for consideration by the Subsidiary Body on Scientific, Technical and Technological Advice at a meeting held prior to the fifteenth meeting of the Conference of the Parties.

2. Pursuant to these requests, the present document contains a review of the implementation of the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity and an updated plan of action.

3. Section I of the present document provides a review of the three objectives of the Initiative as well as an analysis of national reports and national biodiversity strategies and action plans (NBSAPs). Section II highlights the contributions of soil biodiversity to sustainable development and opportunities for the post-2020 global biodiversity framework. The draft plan of action 2020-2030 for the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity appears in annex II below.

4. In decision 14/30, paragraph 23, the Conference of the Parties invited FAO, in collaboration with other organizations and subject to the availability of resources, to consider the preparation of a report on the state of knowledge on soil biodiversity covering current status, challenges and potentialities, and to make it available for consideration by the Subsidiary Body on Scientific, Technical and Technological Advice. A report on the state of knowledge on soil biodiversity prepared by FAO, in collaboration with the Intergovernmental Technical Panel on Soils (ITPS) of the Global Soil Partnership (GSP), the Global Soil Biodiversity Initiative (GSBI), the European Commission and the Secretariat of the Convention on Biological Diversity, is provided in an information document.[1] A summary for policymakers of the report on the state of knowledge on soil biodiversity is also provided in annex I below.

5. Section III contains suggested recommendations.

[*] CBD/SBSTTA/24/1.

[1] CBD/SBSTTA/24/INF/8.

I. REVIEW OF IMPLEMENTATION OF THE INTERNATIONAL INITIATIVE FOR THE CONSERVATION AND SUSTAINABLE USE OF SOIL BIODIVERSITY

A. Background

6. In decision VI/5, the Conference of the Parties established the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity and invited FAO and other relevant organizations to facilitate and coordinate this Initiative. In decision VIII/23, the Conference of the Parties adopted the Framework for Action for the Initiative.

7. At the thirteenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, an in-depth review of the implementation of the programme of work on agricultural biodiversity was undertaken, including a review of the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity. The review led to the request in decision IX/1 for the Executive Secretary to continue to support Parties, Governments, indigenous peoples and local communities, farmers and pastoralists and other stakeholders in implementing the Initiative.

8. In 2012, FAO established the Global Soil Partnership (GSP)[2] as a mechanism for developing a strong interactive partnership and enhanced collaboration and synergy of efforts on soil between all stakeholders, from land users to policymakers. In 2013, the Intergovernmental Technical Panel on Soils (ITPS)[3] was also established by FAO to provide scientific and technical advice and guidance on global soil issues to the GSP. In 2018, an expanded progress report on the implementation of the Initiative was provided by FAO.[4]

9. For the present review, the Secretariat issued a notification[5] in 2019 inviting Parties and other Governments to submit information by completing an online survey. FAO simultaneously invited its member countries to take the survey (available from 2 August to 8 September 2019). The survey received over 70 responses from Parties and other institutions at the national level and academia. The survey consisted of 16 questions divided into five sections: (I) General information; (II) Assessment; (III) Research, capacity-building and awareness-raising; (IV) Mainstreaming (policies, regulations and governmental frameworks); and (V) Gap analysis and opportunities. The present document considers the results of the survey on the status of soil biodiversity in section B.

10. Furthermore, an analysis was undertaken to review the level of integration of measures related to the conservation and sustainable use of soil biodiversity into NBSAPs and relevant policies, plans and programmes. The analysis consisted of a desk review of 170 NBSAPs and a review of sixth national reports. The main themes included in the review were soil conservation, restoration, contamination, erosion, organic matter, ecosystem services, biodiversity, education, sustainable management.

B. Review of the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity

11. The following section organizes the main findings of the survey responses according to the three objectives of the Initiative: (a) sharing of knowledge and information and awareness-raising; (b) capacity-building for the development and transfer of knowledge; and (c) strengthening collaboration among actors and institutions and mainstreaming.

12. Overall, there is recognition from experts in the field that soil biodiversity, and the services it provides, is essential for wider biodiversity goals and to support a growing population. For instance, enhanced use of soil biodiversity, in the case of nitrogen fixing bacteria, has contributed positively to food

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[2] Report of the 23rd Session of the Committee on Agriculture (see http://www.fao.org/3/me654e/me654e.pdf).

[3] Terms of reference of the Global Soil Partnership (see http://www.fao.org/3/a-az891e.pdf).

[4] CBD/COP/14/INF/42.

[5] https://www.cbd.int/doc/notifications/2019/ntf-2019-065-agriculture-en.pdf

production and nutrition. Other examples of important ecosystem services provided by soil biodiversity include nutrient cycling, carbon sequestration, enhancement of agricultural productivity and economic profitability, and human health.

13. Regarding objective one on “sharing of knowledge and information and awareness-raising”, participants’ responses indicate that a wide range of government, research programmes and initiatives that support the development and implementation of sustainable soil management practices exist, but not on soil biodiversity specifically. Likewise, awareness-raising activities have taken place at the national and local levels through initiatives at schools, universities, museums, and local community groups; however, these activities are not specifically directed at the conservation and sustainable use of soil biodiversity and cover other related topics, such as erosion control and reduction of run-off.

14. Most of the developed countries reported a high number of new and emerging research initiatives, on topics such as fungi, DNA barcoding and soil biodiversity in general. Some European countries emphasized the importance for participatory awareness-raising programmes that include the training of farmers and specialists. In Latin America and the Caribbean, financial resources are often the limitation for countries to conduct research on soil and soil biodiversity, while most of the existing research and new knowledge come from academic institutions. Although countries reported on several projects, including restoration of degraded lands and soils, integrated agro-forestry and livestock systems, no-tillage, increasing organic matter and promoting nitrogen fixation, few countries commented on their ability to raise awareness; and, farmers were mentioned as having an important role towards this. Most of the Asian countries that responded to the survey, while citing numerous government and academic initiatives, reiterated that more research is needed. Countries highlighted the importance of raising awareness on conserving or improving soil biodiversity by reducing the amount of chemicals used and increasing organic matter.

15. Regarding objective two on *capacity-building for the development and transfer of knowledge* of soil biodiversity and ecosystem management, few countries provided comments. However, a common view was the importance of the transfer of knowledge to farmers, specialists and field-level stakeholders. In North America, there is concern about the lack of taxonomists and the absence of national institutions in charge of training taxonomists.

16. Regarding objective three on *strengthening collaboration among actors and institutions and mainstreaming* soil biodiversity into national policies and programmes, few countries indicated having legislation or policies that are specific to soil biodiversity and sustainable soil management. Instruments with broader environmental or biodiversity conservation objectives are more commonplace, and in these cases, experts on the issues of soil biodiversity attempt to make use of these instruments and apply them to soil biota.

17. There is recognition among experts of the important role of mainstreaming soil biodiversity in the different sectors. However, this recognition is not shared by policymakers and the general public. Consequently, there are limited sectoral and cross-sectoral policies that integrate soil biodiversity. In cases where sectoral and cross-sectoral policies exist, they are often led by non-governmental organizations, performed at the community level, or indirectly through the adoption of certain agriculture-related policies. Furthermore, in cases where legislation or policies on soil biodiversity and sustainable soil management exist, they still face implementation and resource mobilization challenges.

18. In Latin America and the Caribbean, national instruments on agriculture or biodiversity policy often include the sustainable management of soils in a broad sense, however few consider the regulation, conservation or sustainable use of soil biodiversity. European, African and Asian regions follow the same pattern, where despite existing national frameworks, soil biodiversity is not given due attention. Some African countries stated that lack of mainstreaming soil biodiversity on their part might be due to other priorities, such as land policy.

19. A high number of countries reported on adopting and integrating the FAO World Soil Charter and the Voluntary Guidelines for Sustainable Soil Management into their national policies and programmes, which can allow for a more consistent level of mainstreaming across different regions.

20. Few national assessments specific to soil biodiversity and some assessments with indirect links to soil biota were reported. Although, some countries have soil information systems, either standalone or as part of a larger biodiversity information system, in most cases, these systems do not include soil biodiversity information due to the lack of technical expertise and resources. Some countries reported having carried out assessments on innovations and practices of farmers in relation to soil biodiversity, and some countries have carried out assessments on scientific knowledge and indigenous and traditional knowledge.

21. There are several examples of monitoring activities for soil biodiversity taking place at the local level. However, there are very few examples of systematic monitoring schemes at the national level. Overall, perhaps due to lack of resources, there are no nationally implemented indicators for evaluating soil biodiversity. In cases where indicators do exist, they are applied at local or other levels and cover issues such as soil fertility management, soil carbon sequestration, soil erosion, and biological control of pests and diseases.

22. Overall, lack of information, policy and institutional constraints, and capacity and resource limitations are recognized as the main barriers to implementing better soil biodiversity management strategies, with interlinkages between them. Lack of information and knowledge on soil biodiversity has a variety of causes, including lack of resources that often leads to lack of integration of soil biodiversity issues into policy. Other barriers include lack of political interest in promoting the importance of soil biodiversity and lack of sectoral coordination at the national level.

23. There are rarely arrangements in place to ensure that the conservation and sustainable use of soil biodiversity are considered and included in national planning and sectoral policy development. NBSAPs can be used as a mechanism to ensure the inclusion of conservation and sustainable use of soil biodiversity in national planning.

24. The following were identified by respondents of the survey as actions that present opportunities for soil biodiversity knowledge and conservation:

(a) Description of soil biota in conditions of natural and agricultural ecosystems to assess degrees of vulnerability and initiating a new round of research on soil microorganisms using molecular genetic methods;

(b) Development of methods and technologies for ensuring the recovery of soil biota;

(c) Development of soil biodiversity information systems to establish a national standard for soil quality;

(d) Modernization of soil biology educational institutions, including modern equipment and technical facilities;

(e) Organization of training programmes for soil microbiology and zoology professionals;

(f) Creation and publication of training and information materials on soil biodiversity;

(g) Increasing the social significance of soil biodiversity and ecosystem services through workshops and round tables with farmers and local communities.

25. In addition to the survey, an analysis was undertaken to review the level of integration of measures related to the conservation and sustainable use of soil biodiversity into NBSAPs and relevant policies, plans and programmes.

26. Out of the 170 NBSAPs that were reviewed, 120 Parties implemented actions or initiatives related to improving soil quality in general; of which, 23 Parties recognized the importance of conserving soil

biodiversity and implemented actions targeted specifically to soil biodiversity. A similar number, 28 Parties, included soil conservation as a priority in their action plans and 20 Parties, implemented plans for soil restoration.

27. Only 10 Parties considered the conservation of soil biodiversity by promoting sustainable agricultural management practices (including crop rotations, crop diversification, use of organic fertilizers) and an even smaller number, 6 Parties, prioritized the conservation of soil biodiversity in order to maintain soil health and fertility. However, 34 Parties implemented plans or targets to reduce soil erosion, particularly by increasing vegetative cover or adopting agroforestry practices, both of which can also benefit soil biodiversity. Reducing soil pollution was also reported in the NBSAPs, with 21 Parties prioritizing the reduction of synthetic fertilizer and pesticide use in order to improve soil quality.

28. A number of Parties targeted the collection of data on soil quality and contamination in order to gain a better understanding of the status of their soils and 10 Parties aimed to monitor soil pollution levels and sources in order to create a national soil pollution database; a similar number planned to establish systems for monitoring important soil indicators, such as fertility.

29. Promoting sustainable soil management was highly reported on by Parties in the NBSAPs. In total, 43 Parties aimed to promote sustainable soil management practices, especially in agricultural systems. From the total analysed, 7 Parties aimed to implement financing schemes or economic incentives in order to encourage the adoption of sustainable soil management practices and 3 Parties specifically planned to use payments for soil ecosystem services. Furthermore, 5 Parties set specific targets to increase the number of farmers using integrated soil fertility management and 2 Parties developed specific guidelines for soil conservation.

30. Increasing education and awareness about the importance of sustainable soil management was also reported on in NBSAPs. In this regard, 15 Parties planned to educate farmers and other stakeholders on best soil management practices and 23 Parties aimed to support research and create multidisciplinary networks related to several soil themes, including: soil biodiversity conservation, understanding functions of soil organisms, soil preservation and the benefits of agroforestry for soil.

31. Furthermore, of the sixth national reports received, 83 reports were also analysed with 76 Parties reporting implementation of at least one action related to improving soil quality or biodiversity. Increasing soil fertility and quality was a priority for 24 Parties and 33 Parties prioritized soil conservation. Overall, improving and protecting soils was also seen as a means to increase income and alleviate poverty, since many populations rely on soils for their livelihoods.

32. Promoting the sustainable use and management of soils, mainly in agricultural systems, was reported highly, with 58 Parties indicating so. This consisted in promoting practices such as conservation agriculture, crop diversification, no-till farming, integrated fertilizer and pest management, erosion-minimizing irrigation technologies, crop rotations and agroforestry. In this context, many Parties introduced incentives or compensation programmes to offset the extra costs associated with these sustainable practices. Some parties also reformed subsidies that encouraged the use of harmful agricultural chemicals.

33. Parties also noted difficulties in identifying soil micro and macrofauna, due to lack of expertise and tools. Difficulties with training and capacity-building due to lack of funds were also raised as challenges to overcome. Lack of funds and technical resources (e.g. laboratories and equipment to test soil samples) also prevented Parties from monitoring the effectiveness of their measures (e.g. if pesticide levels in soil had gone down, for example); thus, some Parties were unable to confirm whether their measures were actually effective. Some parties also noted challenges in promoting the adoption of sustainable agricultural practices because of associated decreases in profit while 16 Parties reported work on improving knowledge and 11 recognized the importance of traditional knowledge regarding soil management and highlighted its benefits.

II. CONTRIBUTIONS OF SOIL BIODIVERSITY TO SUSTAINABLE DEVELOPMENT AND OPPORTUNITIES FOR THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK

34. Soil biodiversity is key for sustainability, for the achievement of the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs).[6] Evidence supports important links between the conservation and sustainable use of soil biodiversity and the achievement of the Goals, as well as the need for an integrated approach to implementation. Soil biodiversity will be instrumental to ensuring nature's contributions to people and will contribute to the success of the implementation of the post-2020 global biodiversity framework. The following section describes some of these links.

35. *Links between soil biodiversity, food security and sustainable agriculture, and SDG 2. Soil biodiversity underpins a multitude of ecosystem functions that are essential to sustain food production and manage the impacts of agro-ecosystems beyond farming*. Healthy soils are essential for sustainable agriculture. The quantity and nutritional quality of crops is very much a product of the soils in which they grow. The link between crop production and soil quality is well established. Subsistence farmers, who often lack access to industrial inputs, rely heavily on soil biota and the ecosystem services they provide to support production. Similarly, soil biota plays an important role in high input agricultural systems. For example, soil organisms play a key role in nutrient cycling, including the transformation of nutrients into forms that are more or less available to plants (e.g. ammonium versus nitrate), more readily leached into waterways (e.g. nitrate), or converted into greenhouse gasses (e.g. nitrous oxide). Soil biota also plays a key role in the cycling of carbon in soils including increasing soil carbon which can help mitigate climate change, while improving soil structure, water retention and reduce risk of soil erosion. Further, soil biota that can symbiotically fix nitrogen can form beneficial associations with plants and take up and deliver nutrients, including phosphorus, zinc and nitrogen to plants. Soil biota plays an important role in regulating pests and pathogens that cause significant crop losses. Likewise, soil biota (especially arbuscular mycorrhizal fungi and plant growth promoting bacteria) can confer disease resistance on plants; they can also increase plant tolerance to drought, salt and heavy metal toxicity and stimulate photosynthesis and plant hormones important for growth, increasing overall plant productivity.[7] Studies have shown that this increase in plant productivity increases pollination,[8] leading to better fruit set and higher yields. In certain contexts, soil biodiversity increases the resilience of agroecosystems to disturbances, meaning key soil functions are retained.[9] This is especially relevant when considering the threat to crop productivity and food security in the face of climate change.

36. *Links between soil biodiversity and health, and SDG 3. Soils affect human health via the quantity, quality, and safety of available food and water, as a source of essential medicines, and via direct exposure of individuals to soils*. According to the World Health Organization, soil-transmitted helminth infections are among the most common infections worldwide and affect the poorest and most vulnerable communities. Soil biodiversity also affects nutrient cycling and human nutrition. Emerging research suggests that soil biodiversity has a more direct impact on our health by boosting the nutrient content of our food, protecting us from foodborne illness, and modulating our immune response. The phytobiome — a region surrounding the roots of plants comprised of non-living structures, and micro and macro fauna — influences plant yield and nutrition and, by extension, human health and nutrition.[10] The abundance and

[6] General Assembly resolution 70/1 of 25 September 2015, entitled "Transforming our world: the 2030 Agenda for Sustainable Development", annex.

[7] Chen, M., Arato, M., Borghi, L., Nouri, E. and Reinhardt, D., 2018. Beneficial Services of Arbuscular Mycorrhizal Fungi – From Ecology to Application. Frontiers in Plant Science. 9.

[8] Gange, A.C. and Smith, A.K., 2005. Arbuscular mycorrhizal fungi influence visitation rates of pollinating insects. Ecological Entomology. 30, 600-606.

[9] Bryan S. Griffiths, Laurent Philippot, Insights into the resistance and resilience of the soil microbial community, FEMS Microbiology Reviews, Volume 37, Issue 2, March 2013, Pages 112–129, https://doi.org/10.1111/j.1574-6976.2012.00343.x

[10] Leach JE, Triplett LR, Argueso CT, Trivedi P. (2017) Communication in the Phytobiome. Cell. 169(4):587-596. doi:10.1016/j.cell.2017.04.025

profile of microorganisms can vary across plant habitats and plant genotypes, but one consistent finding is that their diversity within the phytobiome accelerates plant growth, increases plant yield, and increases plant nutrient density. Furthermore, soil plays an important role for air quality, as soil microbes have been reported to help purify air.[11] It is also worth noting that soil microbes and soil fauna can help to bind soil particles together and improve soil structure in some situations. In doing so, they can reduce the risk of wind erosion, thereby helping to reduce levels of dust in the air and contribute to air quality.

37. *Links between soil biodiversity and water quality, and SDG 6. Although the influence of soil biodiversity on water dynamics and quality is often complex and varies with the environment, soils are key for storing and transmitting water to plants, the atmosphere, groundwater, lakes and rivers*. The influence of microorganisms is usually indirect and results from their impact on soil organic matter dynamic, which in turn impact soil aggregation and soil porosity dynamics as well as the quality of the soil solution (e.g., the amount of dissolved organic carbon and minerals). Soil biota plays an important role in regulating the movement of water into and through soil as well as cycling of nutrients. Similarly, some soil microbes play an important role in helping plants to access nutrients and water, thereby reducing the risk of nutrient leaching.[12] Soil macrofauna can influence soil hydrological properties at different scales of observation and through antagonistic processes. At a small scale, any changes in clay and soil organic matter contents, as well as in soil porosity, are likely to influence water holding capacity and resistance to water. At a medium scale, the production of a dense network of foraging galleries connected to the soil surface usually improves water infiltration. Soils are not only important for storing and supplying water; they also filter it. Soils are bioreactors. They contain charged surfaces at which exchange reactions can occur, such as bacteria fungi and soil animals that process nutrients and contaminants, and act as a medium to support plant growth that cycles nutrients and water through the ecosystem.

38. *Links between soil biodiversity and climate action, and SDG 13. Soil organisms are responsible for decomposition and their activity leads to soils either absorbing or contributing greenhouse gasses to the atmosphere.* Respiring soil organisms, including plant roots, and other soil microbial activities are a source of carbon dioxide and nitrous oxide emissions to the atmosphere. At the same time soil organisms are critical for carbon sequestration, by supporting plant growth and photosynthesis, incorporating plant litter and other microbial processes, and storing related soil organic carbon (SOC) in the soil, where it is incorporated in soil organic matter (SOM) in varying states of decomposition and stability. When agricultural soils are tilled, the increased oxygen can spur biological activity and release of carbon dioxide which can contribute to climate change. Moreover, certain soil microbes under anaerobic conditions (e.g. flooded or very wet soils) can transform nitrate into nitrous oxide, which is a potent greenhouse gas. Similarly, other soil microbes can release methane from soil, which also contributes to climate change.

39. Soil also has the potential to sequester large amounts of carbon. It is estimated that the global technical potential of SOC sequestration is 1.45-3.44 Gt C (5.3-12.6 Gt CO2) per year.[13] SOC sequestration represents between 38-91 per cent of global emissions from the energy industry, 67-100 per cent of global emissions from the transport sector,[14] and 9-23 per cent of total global emissions (53 Gt CO_2) from all sectors in 2017.[15] Maintaining existing soil organic carbon (SOC) stocks and enhancing SOC

[11] Gholamreza Khaksar, Chairat Treesubsuntorn, Paitip Thiravetyan. (2016) Endophytic Bacillus cereus ERBP—Clitoria ternatea interactions: Potentials for the enhancement of gaseous formaldehyde removal, Environmental and Experimental Botany, Volume 126. Pages 10-20

[12] Cavagnaro, T., Bender, S., Asghari, H. and Heijden, M. (2015). The role of arbuscular mycorrhizas in reducing soil nutrient loss. Trends in Plant Science, 20(5), 283-290.

[13] Lal, R. 2018. Digging deeper: A holistic perspective of factors affecting soil organic carbon sequestration in agroecosystems. Global Change Biology, 1-17.

[14] Muntean, M., Guizzardi, D., Schaaf, E., Crippa, M., Solazzo, E., Olivier, J.G.J. and Vignati, E. 2018. Fossil CO_2 emissions of all world countries. 2018. Publications Office of the European Union, Luxembourg.

[15] Global Soil Partnership. 2019. Recarbonization of Global Soils. A tool to support the implementation of the Koronivia Joint Work on Agriculture. Food and Agriculture Organization of the United Nations (FAO). http://www.fao.org/3/ca6522en/CA6522EN.pdf

sequestration through practices for maintaining carbon rich soils (peatlands, black soils, permafrost, etc.) and for sequestering more carbon in soils with such potential (croplands and degraded soils) constitute a feasible solution to offset global emissions while providing multiple benefits for the environment, people and the economy.

40. *Links between soil biodiversity and coastal and marine ecosystem, and SDG 14. Soil biodiversity increases nutrient immobilization and plant nutrient uptake, reducing leaching and limiting some of the negative impacts that land-based activities can have on coastal and marine ecosystems*. Debris and nutrient pollution caused by land-based human activities can enter freshwater, coastal and marine ecosystems through chemical and nutrient run-off from agricultural activities that seep into groundwater or drain into tributaries. Nutrient pollution, mainly in the form of nitrogen and phosphorus compounds that come from farmland run-off, excess fertilizers and manure, untreated sewage and detergents in domestic wastewater, causes eutrophication and harmful algal blooms in freshwater, coastal and marine ecosystems. Soil biota, including arbuscular mycorrhizal fungi and mesofauna, can significantly reduce nutrient leaching from soil, immobilize nutrients in their tissues, increase plant nutrient uptake and intercept nutrients from soil. By reducing nutrient leaching, they prevent eutrophication and can reduce pollution in marine systems.[16] Furthermore, soil microorganisms (such as plant growth promoting bacteria and symbiotic nitrogen fixers) can transform a wide variety of toxic metals (e.g. heavy metals) into less toxic forms or can simply remove them from the soil by accumulating them in their tissues. Therefore, soil biodiversity can contribute to the remediation of contaminated soils, preventing leaching of toxic metals into water bodies.[17]

41. *Links between soil biodiversity and terrestrial ecosystem, and SDG 15. It is increasingly well understood that above- and below-ground communities are closely linked, and that a change in one can affect the other.* For example, a reduction in below-ground diversity can reduce above-ground diversity,[18] while changes in above-ground vegetation can alter below-ground communities. Recent data shows that by reducing soil tillage, planting a cover-crop or increasing crop rotations, the formation of beneficial mycorrhizal associations (symbiosis between plant roots and soil fungi) improve plant nutrient acquisition.[19] Soil fauna including nematodes, collembola, and mites have been shown to increase plant diversity.[20] Furthermore, increases in soil faunal and microbial diversity can lead to greater soil fertility, since different species specialize in the mineralization of different nutrients, leading to complementarity.[21]

42. *The conservation and sustainable use of soil biodiversity can play an important role in defining sustainable land-use options for the post-2020 global biodiversity framework.* Soil biodiversity plays a central role in avoiding, reducing, and reversing land degradation by stabilizing soils, regulating nutrient cycling, increasing soil organic matter content, influencing water infiltration and quality, and supporting biodiversity above and below ground. Accumulating evidence suggests that an increase in soil biodiversity is positively linked to an increase in soil function, including an increase in plant growth, resistance to pathogen invasion and higher nutrient use efficiency. This pattern is evident when considering the diversity

[16] S. F. B., and M. G. A. Heijden. 2015. Soil biota enhance agricultural sustainability by improving crop yield, nutrient uptake and reducing nitrogen leaching losses. 52:228-239.

[17] Khan, Mohammad Saghir, Almas Zaidi, Parvaze Ahmad Wani, and Mohammad Oves. "Role of plant growth promoting rhizobacteria in the remediation of metal contaminated soils." Environmental chemistry letters 7, No. 1 (2009): 1-19.

[18] van der Heijden, M. G. A., J. N. Klironomos, M. Ursic, P. Moutoglis, R. Streitwolf-Engel, T. Boller, A. Wiemken, and I. R. Sanders. 1998. Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. Nature 396: 69-72.

[19] Bowles, T., Jackson, L., Loeher, M. and Cavagnaro, T. 2017. Ecological intensification and arbuscular mycorrhizas: a meta-analysis of tillage and cover crop effects. Journal of Applied Ecology, 54(6), 1785-1793.

[20] Deyn, G.B. and Raaijmakers, Ciska and Zoomer, H. and Berg, Matty and Ruiter, Peter and Verhoef, Herman and Bezemer, T.m and Putten, Wim. 2003. Soil invertebrate fauna enhances grassland succession and diversity. Nature. 422. 711-713. 10.1038/nature01548.

[21] Bhatnagar, J.M., Peay, K.G. and Treseder, K.K. (2018). Litter chemistry influences decomposition through activity of specific microbial functional guilds. Ecol Monogr, 88: 429-444. doi:10.1002/ecm.1303.

of specific groups of soil organisms independently, such as bacterial diversity, but also when all groups of soil biodiversity are considered together. This suggests that biodiversity declines in general are likely to have negative consequences for soil functioning and the provisioning of ecosystem services.

43. The achievement of a future target on conservation and enhancement of the sustainable use of biodiversity in agricultural and other managed ecosystems to support their productivity, sustainability and resilience is closely linked to the sustainable management of soil biodiversity and ensuring soil health. Likewise, soil biodiversity may be enhanced by implementing sustainable agricultural and soil management practices thus promoting soil health. Agricultural land-use change almost inevitably results in SOM losses and greenhouse gas emissions. However, as nearly all cropped soils have lost a large percentage of their pre-cultivation SOC, this presents an opportunity for carbon sequestration. The agricultural soil carbon pool is the largest that can be directly managed, representing an important lever for climate-change mitigation.[22] For the post-2020 global biodiversity framework, this can contribute to a potential target on trends in the amount of carbon stored in ecosystems and emissions avoided. Given the vast area of cropland worldwide, even a small increase in SOC per hectare represents a large sink capacity to re-absorb carbon by adoption of agricultural management aimed at increasing soil organic carbon SOC.[23] Many established and emerging SOC management practices exist,[24] which harness the activity of soil biodiversity to sequester and retain carbon in the soil using, for example, agroforestry, increased crop rotational diversity, cover and inter-cropping, retaining crop residues, reduced or minimal tillage, perennial crops and legumes, and selection for diversity and root traits.

44. *A better understanding of soil biodiversity and the role of soil organisms is key for soil remediation and should be included in the plans of ecosystem restoration*. A more comprehensive understanding of the relationship between terrestrial biodiversity and ecosystem functioning is of crucial importance in order to link terrestrial and subterrestrial parameters in ecosystem modelling to better predict the consequences of biodiversity change and loss. Targeted policies and urban planning strategies are needed to integrate sustainable soil management and soil restoration in order to reduce threats to soil biodiversity.

45. *Traditional knowledge of indigenous peoples and local communities can potentially contribute to soil biodiversity conservation and restauration.* In decision XIII/3, paragraph 27, the Conference of the Parties recognized the important contribution of indigenous and local communities, in particular as managers of centres of origin of agricultural diversity, and their role in the management and restoration of critical ecosystems, ecological rotation and agro-forestry. As an example, the *Terra Preta de Índio* or Indian Black Earth is a technic to get a highly fertile soil based on traditional knowledge from indigenous peoples from the Amazonian region.[25]

46. *The conservation and sustainable use of soil biodiversity requires action from all stakeholders and recognition of the role of women and indigenous and local communities in implementing sustainable soil management practices.* According to FAO, women comprise about 43 per cent of the agricultural labour force globally and half or more in many African and Asian countries. Women's knowledge and their contribution to biodiversity and ecosystem management as primary land managers, seed collectors, and many other roles, means they can play an important role as custodians of soil biodiversity. Ensuring equal rights to land, inheritance and natural resources is an important measure in enabling women to promote sustainable agricultural and land management practices, including soil conservation. Security of rights, control and access over land and natural resources creates incentives for long-term investments by

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[22] Kallenbach, C.M., Wallenstein, M.D., Schipanksi, M.E. and Grandy, A.S. (2019). Managing Agroecosystems for Soil Microbial Carbon Use Efficiency: Ecological Unknowns, Potential Outcomes, and a Path Forward. Frontiers in Microbiology, 10.

[23] Zomer, R.J., Bossio, D.A., Sommer, R. *et al.* Global Sequestration Potential of Increased Organic Carbon in Cropland Soils. *Sci Rep* 7, 15554 (2017). https://doi.org/10.1038/s41598-017-15794-8.

[24] Global Soil Partnership. 2019. Recarbonization of Global Soils. A tool to support the implementation of the Koronivia Joint Work on Agriculture. Food and Agriculture Organization (FAO). http://www.fao.org/3/ca6522en/CA6522EN.pdf

[25] More information at https://www.researchgate.net/publication/225244563_Indigenous_knowledge_about_Terra_Preta_formation

subsistence farmers, many of whom are women. Evidence from Rwanda shows that land tenure reforms that reduce gender barriers to ownership have led to a substantial increase in soil conservation investment in structures such as bunds, terraces and check dams, particularly from female-headed households.[26] Measures addressing land tenure reforms may be considered particularly important as women become increasingly responsible in agriculture due to male emigration in many cases.[27]

47. Indigenous peoples and local communities play an important role in ensuring the conservation and sustainable use of soil biodiversity through their traditional agriculture techniques. These techniques that adapt to the changing climate ensure mitigation of climate change, and diversity of crops and seeds. Furthermore, indigenous peoples and local communities often have managed their landscapes and seascapes in ways compatible with, or actively support, biodiversity conservation by "accompanying" natural processes with anthropogenic assets.[28] Indigenous landscape and seascape management protects biological and cultural diversity.

III. SUGGESTED RECOMMENDATIONS

48. The Subsidiary Body on Scientific, Technical and Technological Advice may wish to adopt a recommendation along the following lines:

The Subsidiary Body on Scientific, Technical and Technological Advice,

Having considered the note by the Executive Secretary,[29]

1. *Welcomes* the draft plan of action 2020-2030 for the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity as contained in annex II to the present recommendation;

2. *Also welcomes* the report on the *State of Knowledge on Soil Biodiversity Covering Current Status, Challenges and Potentialities*[30] prepared by the Food and Agriculture Organization of the United Nations in collaboration with the Intergovernmental Technical Panel on Soils of the Global Soil Partnership, the Global Soil Biodiversity Initiative, the European Commission and the Convention on Biological Diversity and its summary for policymakers, provided in annex I to the present recommendation;

3. *Recommends* that the Conference of the Parties at its fifteenth meeting adopt a decision along the following lines:

The Conference of the Parties,

Recalling decisions VI/5, VIII/23 and X/34,

Noting the importance of soil biodiversity in underpinning the functioning of terrestrial ecosystems and therefore most of the services it delivers,

Recognizing that activities to promote the conservation and sustainable use of soil biodiversity services are key in the transition towards the achievement of more sustainable food systems, food security for all and to enhance the achievement of the Sustainable Development Goals,

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[26] Ayalew Ali, D., Deininger, K. and M. Goldstein. 2014. Environmental and gender impacts of land tenure regularization in Africa: Pilot evidence from Rwanda. Journal of Development Economics, 110, 262-275.

[27] Secretariat of the Convention on Biological Diversity. Undated. Biodiversity and the 2030 Agenda for Sustainable Development. Technical note.

[28] IPBES (2019). *Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany.

[29] CBD/SBSTTA/24/7.

[30] CBD/SBSTTA/24/INF/8.

1. *Adopts* the draft plan of action 2020-2030 for the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity, as contained in annex II to the present decision, and considers it a means to support the implementation of the post-2020 global biodiversity framework;

2. *Welcomes* the report on the *State of Knowledge on Soil Biodiversity Covering Current Status, Challenges and Potentialities* prepared by the Food and Agriculture Organization of the United Nations in collaboration with the Intergovernmental Technical Panel on Soils of the Global Soil Partnership, the Global Soil Biodiversity Initiative, the European Commission and the Convention on Biological Diversity;

3. *Encourages* Parties, other Governments and relevant organizations to support the implementation of the plan of action 2020–2030 for the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity through, among other things, the integration of appropriate measures into national biodiversity strategies and action plans, sustainable soil management and relevant agricultural policies, plans, programmes and practices;

4. *Urges* Parties to address the drivers of soil biodiversity loss and land degradation;

5. *Invites* Parties to integrate the conservation and sustainable use of soil biodiversity into agricultural systems and into land and soil management policies;

6. *Encourages* academic and research bodies, and relevant international organizations and networks, to promote further research in order to address gaps identified in the plan of action;

7. *Invites* the Food and Agriculture Organization of the United Nations to facilitate the implementation of the plan of action, following the successful approach of the previous plan;

8. *Invites* the Global Environment Facility and other donors and funding agencies to provide financial assistance for national and regional projects that address the implementation of the plan of action for the conservation and sustainable use of soil biodiversity;

9. *Invites* Parties to provide, on a voluntary basis, information on their activities and results from the implementation of the plan of action, in alignment with the post-2020 global biodiversity framework monitoring framework, and *requests* the Executive Secretary to compile the submissions and to make them available for consideration by the Subsidiary Body on Scientific, Technical and Technological Advice at a meeting held prior to the sixteenth meeting of the Conference of the Parties;

10. *Requests* the Executive Secretary to bring the present recommendation to the attention of the Food and Agriculture Organization of the United Nations and to the United Nations Convention to Combat Desertification.

Annex I

STATE OF KNOWLEDGE OF SOIL BIODIVERSITY: STATUS, CHALLENGES AND POTENTIALITIES

SUMMARY FOR POLICYMAKERS

INTRODUCTION

1. A wealth of new scientific, technical and other types of knowledge relevant to soil biodiversity has been released since the establishment of the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity in 2002 and the Global Soil Partnership in 2012, and the publication of the *Status of the World's Soil Resources* and the *Global Soil Biodiversity Atlas* in 2016.

2. This new wave of research is a consequence of tremendous growth in the methods available for the study of soil organisms by the scientific community. This research has placed soil biodiversity at the heart of international policy frameworks, including the Sustainable Development Goals. Furthermore, soil biodiversity and ecosystem services will be pivotal for the success of the recently declared United Nations Decade on Ecosystem Restoration (2021-2030).

3. This Summary for Policymakers brings the key messages from the report on the *State of knowledge of soil biodiversity: status, challenges and potentialities*[31] prepared by the Food and Agriculture Organization of the United Nations (FAO), the Global Soil Partnership and its Intergovernmental Technical Panel on Soils. The report is a result of the work of soil scientists and experts on soil biodiversity from all regions of the world, and it presents the best available knowledge on soil biota and their ecosystem functions and services.

KEY MESSAGES

Soil organisms drive processes that produce food, purify soil and water, and preserve both human well-being and the health of the biosphere.

What is soil biodiversity?

4. Soil biodiversity can be defined as the variation in soil life, from genes to communities, and the ecological complexes of which they are part. Soil biodiversity encompasses the variety of life below ground. Soils are one of the main global reservoirs of biodiversity, and up to 90 per cent of living organisms in terrestrial ecosystems are associated during their life cycle with below-ground habitats. The two main groups of soil organisms are soil microorganisms and larger soil fauna; the latter range from invertebrates such as insect larvae and earthworms through to the mammals, reptiles, and amphibians that spend considerable parts of their lives below ground.

5. For the purpose of this summary, the terms *soil biodiversity*, *soil biology*, *soil biological diversity*, *soil biota*, *below-ground biodiversity* and *soil organisms* have been used as synonyms, and they include soil microbes and soil fauna. Likewise, the terms *microbial diversity*, *soil microbes*, *soil microbiome* and *soil microorganisms* are used as synonyms specifically to describe soil microbial diversity.

Contributions of soil biodiversity

6. The contributions of soil organisms can be grouped into three broad categories. First, some soil organisms (principally the soil microorganisms) transform the chemical nature of organic and inorganic compounds through an extraordinarily complex suite of biochemical processes. These transformations are critical for ecosystem services such as nutrient availability for plant growth, soil organic matter cycling, and degradation of pollutants in air, water and soil.

[31] CBD/SBSTTA/24/INF/8.

7. Second, soil organisms are part of a vast food web that cycles energy and nutrients from microscopic forms through the larger soil fauna and ultimately to organisms that live on top of the soil. An important part of the food web is carried out by intermediate-sized organisms, such as nematodes, springtails, and mites, which degrade organic residues in the soil and predate on smaller soil organisms.

8. Finally, many of the larger soil fauna, such as earthworms, ants, termites and some mammals, act as ecosystem engineers that create the pore space in soil that acts as conduits for water and gas transport, and also bind together soil particles into stable aggregates that hold the soil in place and hence resist soil erosion.

Soil biodiversity and agriculture

9. Soil organisms both serve as a source of nutrients for plant growth and drive the transformations of nutrients that make them available to plants. The collective carbon content of all soil bacterial cells is comparable to that of all plants on the earth, and their total nitrogen and phosphorous contents are far greater than that of all vegetation, making these microorganisms the primary source of indispensable nutrients for life.

10. Plants fix carbon from the atmosphere, but they require certain proportions of many chemicals such as nitrogen, phosphorus and potassium to create biomass and transfer nutrients and energy. At the biochemical level, soil microorganisms drive these transformation processes.

11. Larger soil organisms play a key role in the physical breakdown of plant residues, allowing the soil microorganisms to liberate the nutrients and energy bound up in the plant material.

12. The role of soil organisms in agriculture has many beneficial effects beyond plant production. For example, soil microbiota, such as arbuscular mycorrhizal fungi and nitrogen fixing bacteria can minimize cost and dependence on chemical nitrogen fertilizer in agriculture, and enhance soil fertility and environmental sustainability (air, soil, water), including reducing greenhouse gas emissions from the energy-intensive manufacture of nitrogen fertilizer.

Soil biodiversity and climate change

13. The role of soil biodiversity in addressing global climate change cannot be understated: the soil community's activities can contribute either to the emission of greenhouse gases or to absorbing carbon into soils from the atmosphere. Soils comprise the largest carbon stocks on earth, with an estimated total of at least 1,500 Gt carbon (C).

14. Carbon is either fixed or released from soils, depending the activity of the soil organisms and driven by soil conditions. Carbon is fixed into soils through the transformation of plant and animal detritus, and also some bacteria and *archaea* can fix carbon by using atmospheric CO_2 as their energy source. Beyond their direct role in the carbon cycle, soil organisms are also critical for efforts to reduce overall greenhouse gas (GHG) emissions from agriculture. Globally, agricultural ecosystems contribute 10 to 12 per cent of all direct anthropogenic GHG emissions each year, with an estimated 38 per cent resulting from soil nitrous oxide emissions and 11 per cent from methane in rice cultivation. Soil microorganisms are involved in every step of nitrogen and carbon transformations that yield these greenhouse gases and managing the soil environment to minimize emissions is a key objective in sustainable soil management.

Soil biodiversity and human health

15. Soil biodiversity supports human health directly through disease regulation and food production.

16. In the early 1900s, scientists began identifying antibiotic substances in soil that could fight specific microbial infections or more generally modulate human immune response. Since then, many drugs and vaccines have come from soil organisms, from well-known antibiotics, such as penicillin, to bleomycin, which is used for treating cancer, and amphotericin, which is used for fungal infections.

17. Soil biodiversity and healthy soils help to mitigate the risk of foodborne illness by boosting plant defences against opportunistic infections. For example, the very harmful bacterium *Listeria*

monocytogenes is found in low concentration in many agricultural soils, but its pathogenicity depends on the richness and diversity of soil microbial communities.

18. The relationship between plant roots and soil biodiversity enables plants to manufacture chemicals such as antioxidants that protect them from pests and other stressors. When we consume these plants, these antioxidants benefit us by stimulating our immune system and assist in hormone regulation.

Soil biodiversity and environmental protection

19. It is well established that preservation of soil biodiversity is critical for the maintenance and enhancement of above-ground biodiversity. The complex food webs that transfer nutrients and energy from the organic materials in the soil, through soil-dwelling organisms, to birds, mammals, reptiles and amphibians, are central to life on earth.

20. Soil biodiversity can attenuate threats to ecosystem services, for instance by helping to clean the water that percolates through the soil profile, preventing leaching of nutrients into groundwater and drinking water, and preventing eutrophication by helping plants to capture nutrients.

21. Larger soil organisms, such as earthworms, termites and ants, play important roles in controlling soil structure. Well-aggregated soils are inherently resistant to soil erosion by wind and water, and hence a healthy soil is an erosion-resistant soil.

Our current understanding of the role of soil organisms in plant growth and the transformation of pollutants has been harnessed to improve agricultural production and reclaim degraded soils.

Agricultural sector

22. The commonly used organisms for stimulation of nutrient cycling include mycorrhizal fungi and symbiotic nitrogen-fixing bacteria. In Brazil and other countries in Latin America, the inoculation of selected *Bradyrhizobium* bacterial strains in soybean is an example of a major success. In 2018, soybean was cultivated in an area of about 35 million ha in Brazil. Inoculation of selected *Bradyrhizobium* strains in Brazilian soybean production totally replaced mineral nitrogen (N) fertilizers, saving billions of dollars a year. Besides its huge economic advantage, biological nitrogen fixation from the air by *Bradyrhizobium* is a clean biotechnology that avoids the gaseous loss of N-compounds.

23. Soil organisms are also currently used in biocontrol measures in agriculture. The basic concept of biological control is to facilitate the natural ecosystem to counteract the potential of pests and generally to increase biodiversity and ecosystem functioning.

24. Worldwide, the largest commercial success of a biological control agent is without doubt *Bacillus thuringiensis* (Bt), a common bacterium isolated from soil. *Bacillus thuringiensis* is a biological control agent with insecticidal activity against a range of different insects, and different strains and marketed products increases the specificity against the target organisms.

25. Negative feedback between the use of soil organisms and agricultural production also occurs. A significant proportion of antibiotics used in crops and livestock ends up in the soil, affecting soil biodiversity and creating antimicrobial resistance in soil-dwelling organisms.

Environmental remediation

26. Bioremediation technologies can lead to the degradation of a target contaminant to an innocuous state or to levels below concentration limits established by regulatory authorities. Soil organisms are also used directly to transform toxic compounds into benign forms through bioremediation. Many soil bacteria can transform different contaminants, such as saturated and aromatic hydrocarbons (for example, oil, synthetic chemicals and pesticides). Soil bacteria and fungi can reduce petroleum hydrocarbons after a spill by up to 85 per cent.

Challenges to use of soil organisms

27. Many microbial biofertilizers, biopesticides and other related products show great effects when tested under laboratory and greenhouse conditions but fail to provide reproducible results under field conditions. One reason is the difficulty for certain organisms to survive in a highly competitive environment.

28. In addition to their transient and environmentally dependent effect, the high cost of biological products also restrains their adoption by farmers, and especially by smallholders with little purchasing power and poor access to credit.

29. In response to these limitations, some farmers with proper training attempt to reproduce native consortia of soil microorganisms to assemble biofertilizer, biocontrol and biostimulant farm inputs. To this end, farmers rely on relatively simple, rapid and affordable techniques.

Laboratory and analytical advances in the past decade allow us to move beyond research on individual species to study whole communities of organisms, and hence develop new approaches to address food security and environmental protection.

30. With the advent of novel methods, researchers are now able to move beyond a focus on individual species. Scientists have started to discover how the hugely diverse soil microbiome is tied to pathogen control, plant health, increased yield, and an increased ability to overcome abiotic stress.

31. Especially in the last decade, method advances including molecular sequencing techniques and "big data" analytical tools have helped to identify species living in soils and their communities. Artificial intelligence has great potential in the assembly of data and the aggregation of information from multiple databases. Novel metagenomics represents a promising approach for the simultaneous study of all DNA-based information in soils, including all groups of soil organisms and functional gene information.

Agricultural industry

32. New molecular techniques using next generation molecular sequencing allow for improved knowledge of what organisms are in the soil, and what effects those organisms are likely to have on associated cropping systems. This knowledge provides predictive power to our understanding of how the soil systems will respond to changes in climatic factors, new cropping systems, and soil management. Other applications for these tools are the determination of which mycorrhizal fungi and nitrogen-fixing bacteria are present in the soil, and assistance to the field practitioner in assessing the efficacy of these organisms.

33. Soil microbiota have been found to influence the quality and longevity of harvested crops either positively (through beneficial microbial interactions) or negatively (through plant pathogens). Thus, the application of screening methods for associated biota – such as by next generation sequencing – and the subsequent necessary interventions would prove valuable in the post-harvest process. This may enhance sustainability of the full agricultural value-chain.

Food industry

34. Several soil bacteria and fungi are being used traditionally in the production of soy sauce, cheese, wine and other fermented food and beverages. Lactic acid bacteria that could potentially be used to produce heavy metal (cadmium and lead)-absorbing probiotic products have been discovered from mud and sludge samples. Soils provide habitats for a variety of lactic acid bacteria belonging to Lactobacillus, Lactococcus and other genera, opening the possibility for probiotic bacteria useful in food fermentation or other processes to be isolated from soils.

Ecosystem restoration

35. Field studies conducted at relevant scales for ecosystem restoration (i.e. hectares) have demonstrated that a whole-soil inoculation method representing the entire soil biodiversity is a powerful tool in the restoration of terrestrial ecosystems.

Pharmaceutical industry

36. Loss of soil biodiversity could limit our capacity to develop new antibiotics and tackle infectious diseases. While most biopharmaceutical research is focused on identifying unique microbes that can be developed into biotherapeutics, new technologies that make it possible to study the metagenome (or collective genome) in an environmental sample have sparked an interest in exploring how complex microbial communities in soil and other indoor and outdoor environments influences human immune and nervous response via the skin, gut and lungs.

The essential contributions of soil organisms are threatened by soil-degrading practises. Policies that minimize soil degradation and protect soil biodiversity should be a component of biodiversity protection at all levels.

37. The important role of soil biodiversity in ecosystem functioning and ecosystem service delivery can be threatened by human activities as well as by natural disasters, though the latter may also be influenced by human-induced changes. These include deforestation, urbanization, agricultural intensification, loss of soil organic matter/carbon, soil compaction, surface sealing, soil acidification, nutrient imbalance, contamination, salinization, sodification, desertification, fire, erosion and landslides. Deforestation and fires in particular have very negative effects on soil biodiversity, and policies designed to control and ideally reduce their occurrence will have very beneficial impacts on soil biodiversity.

Invasive alien species

38. The majority of our knowledge of invasive soil species concerns agricultural pests, of which many contribute to huge economic losses globally. Invasive alien species threaten the integrity of indigenous soil biodiversity. Non-native soil invertebrates can have dramatic negative impacts on native plants, microbial communities, and other soil animals: terrestrial invasive species can arise from any level of biological organization ranging from viruses and microbes (bacteria and fungi) to plants, invertebrates, and mammals.

Agricultural intensification

39. Negative impacts due to agricultural intensification have consequences for the specific functions soil animals perform, including soil structure formation and ecosystem engineering, population regulation by predation, and feeding on fungal hyphae. Human management of agricultural land and other soils is known to significantly alter soil biodiversity:

Tillage: Tillage of the soil causes loss of larger soil fauna and disruption of the soil food chain.

Misuse of fertilizers: Synthetic fertilization may have a negative impact on microbial communities and fauna. Negative impacts of synthetic N fertilization on microbial biomass, arbuscular mycorrhizal fungal (AMF) and faunal diversity have been observed. Nitrogen fertilizers can also greatly increase the populations of predation by soil mite, thereby disrupting microbial communities.

Lime application for pH correction: Most tropical rainforest soils are naturally acidic, and often receive large quantities of lime following deforestation to neutralize pH, especially with the establishment of more intensive cropping systems. Large shifts in pH impose stress on native microorganisms, affecting their growth and reducing ecosystem resilience to disturbance.

Misuse of pesticides: Pesticides may cause resistance and bioaccumulation through the food chains. The use of pesticides can have unintended effects on soil organisms, as different organism groups react differently to various chemical substances.

Monocultures: Monocultures limit the presence of beneficial bacteria, fungi and insects, and contribute to ecosystem degradation. Large-scale monocultures also reduce soil biodiversity due to host specificity of many of the soil bacteria and fungi and larger soil fauna they attract, facilitating the spread and expression of soil-borne diseases.

Assessment of soil biodiversity

40. The current state of soil biodiversity and the distribution of soil organisms remain largely unknown in many regions of the world. Countries have assessed the status and trends of soil biodiversity in different ways, including scientific knowledge, innovations and practices of farmers, indigenous and traditional knowledge, and mapping. Overall, there is an urgent need to coordinate and invest in global soil biodiversity assessments.

Policy development

41. While above-ground biodiversity is familiar to most people, and its protection is managed under national and global laws and regulations, there are few comparable activities that focus on the protection of soil biodiversity. Protecting aboveground biodiversity is not always sufficient to soil biodiversity. Above-ground biodiversity and below-ground biodiversity are shaped by different environmental drivers and are not necessarily linked to one another. They require tailored protection, conservation and restoration considerations because they are connected but, at the same time, they are very distinct.

42. To further promote the conservation and sustainable use of soil biodiversity, long-term monitoring and standardized sampling and analysis protocols need to be developed. With worldwide collaboration, this should enable collation of large data sets, which are critical to amassing scientific evidence for the quantitative and functional significance of soil biodiversity.

43. While some countries have established indicators and monitoring tools for soil biodiversity, for the majority of countries there is a lack of knowledge, capacity and resources to implement soil health principles and adoption of best practices for soil biodiversity enhancement.

44. Some of the major recommendations from the report are as follows:

(a) Soil biodiversity needs to be reflected in national reports and national biodiversity strategies and action plans;

(b) Sustainable soil management practices should be adopted by farmers and land users to prevent and minimize soil biodiversity loss;

(c) Soil remediation and ecosystem restoration plans need to include soil health and soil biodiversity considerations;

(d) There is a need to promote the necessary shift from the use of conventional physical and chemical indicators of soil health to include biological indicators;

(e) There is a need to standardize sampling and analysis protocols worldwide to enable collation of large data sets;

(f) Increase of intersectoral and inter-institutional collaboration to explore synergies and avoid duplication or fragmentation, since soil polices can be under the responsibility of different ministries;

(g) Policies and urban planning need to integrate soil biodiversity into sustainable soil management and ecosystems restoration plans to guarantee healthy soils to people by reducing urban threats to/from soil biodiversity. This can be done by enhancing different species habitat and allowing biomass to decompose naturally.

Annex II

DRAFT PLAN OF ACTION 2020-2030 FOR THE INTERNATIONAL INITIATIVE FOR THE CONSERVATION AND SUSTAINABLE USE OF SOIL BIODIVERSITY

I. INTRODUCTION

45. Since the launch of the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity, a significant amount of new scientific, technical and other types of knowledge relevant to soils and their biodiversity has been released.

46. The plan of action 2020-2030 for the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity is based on the review of the Initiative, the *Status of the World's Soil Resources* report[32] and on the preliminary findings of the report on the *State of Knowledge on Soil Biodiversity: Status, Challenges and Potentialities*[33] prepared by the Food and Agriculture Organization of the United Nations (FAO) and the Intergovernmental Technical Panel on Soils.

47. Improved management of soil and its biodiversity offers solutions for all sectors that rely on soils, including forestry and farming, while it can simultaneously increase carbon storage, improve water and nutrient cycling, and mitigate pollution. Soil biodiversity depends on the type of climate, mineral soil and type of vegetation and, in turn, this biodiversity has an effect on soil. In order to maintain the biodiversity of soils, it is necessary to maintain or restore their physical or chemical properties. Soil biodiversity is an important lever to improve soil quality and function, highlighting the importance of research, monitoring and management that is geared directly at soil biodiversity, and not just soil quality. Soil biodiversity is also crucial to improve not only soil health,[34] but also plant, animal and human health.

48. However, soil is one of the world's most vulnerable resources in the face of climate change, land degradation, biodiversity loss, increased demand for water and food production, urbanization and industrial development. Therefore, in order to safeguard soils and landscapes, it is necessary to prevent soil biodiversity loss from anthropogenic drivers related to land-use change, such as fires, crop monoculture,[35] improper and overuse of agrochemicals, soil pollution, soil sealing, soil compaction, intensive tillage, deforestation and introduction of invasive species.

49. The present plan of action presents global priorities to support the integration of soil biodiversity considerations into the context of the post-2020 global biodiversity framework, as well as within and across productive sectors.

50. The elements of this plan of action recognize the importance of mainstreaming soil biodiversity across sectors and the need for integrated approaches to better address the complex interactions that come into play as the conservation and sustainable use of soil biodiversity usually involve economic, environmental, cultural and social factors. The importance of implementation at the field level with due consideration of local context and specificities is another element reflected in the plan, while awareness-raising, sharing of knowledge, capacity-building and research remain key to ensure a better understanding of the role of soil biodiversity for sustainability.

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[32] Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils (2015). *Status of the World's Soil Resources* – Main Report, Rome.

[33] CBD/SBSTTA/24/INF/8.

[34] Soil health defined as: "The capacity of soil to function as a living system. Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots, recycle essential plant nutrients, improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production". FAO. 2011. Save and Grow A policymaker's guide to the sustainable intensification of smallholder crop production. ISBN 978-92-5-106871-7112.

[35] McDaniel, M.D., Tiemann, L.K. and Grandy, A.S. (2014) Does agricultural crop diversity enhance soil microbial biomass and organic matter dynamics? A meta□analysis. *Ecological Applications*, **24**, 560-570.

51. The present plan of action has been prepared jointly by FAO, the Secretariat of the Global Soil Partnership (GSP) and the Secretariat of the Convention on Biological Diversity, in consultation with other partners and relevant experts, pursuant to decision 14/30.

II. PURPOSE AND OBJECTIVES

52. The *Status of the World's Soil Resources* report identified 10 threats critical to soil functions. The loss of soil biodiversity was identified as one of these threats, and a respective call for action was strongly recommended. The Voluntary Guidelines for Sustainable Soil Management[36] provide a framework for reverting it through a number of policies, research and field actions.

53. The *purpose* of this plan of action is to support Parties, other Governments, indigenous peoples and local communities, relevant organizations and initiatives, to accelerate and upscale efforts towards the conservation and sustainable use of soil biodiversity, towards the assessment and monitoring of soil organisms to promote the conservation, sustainable use and/or their restoration, and to respond to challenges that threaten soil biodiversity and consequently, all terrestrial ecosystems.

54. The *overall objective* of this plan of action is to mainstream soil biodiversity science, knowledge, and understanding into policies, at all levels, and to foster coordinated action to safeguard and promote the conservation and sustainable use of soil biodiversity and its ecosystem functions and services, which are essential for sustaining life on Earth. Achieving this objective will ensure that soil biodiversity recovers and continues to provide a full range of functions. It will also formally promote sustainable soil management practices that can enhance soil biodiversity while increasing the productivity of managed ecosystems.

55. The *specific objectives* of this plan of action are to help Parties, relevant organizations and initiatives with the following:

(a) Implementing coherent and comprehensive policies for the conservation and sustainable use of soil biodiversity at the local, subnational, national, regional and global levels, and mainstreaming their integration into sectoral and cross-sectoral plans, programmes and strategies, including agriculture and food security; environment; climate change; pollution; land degradation; ecosystem restoration; plant, animal and human health; and urban planning;

(b) Encouraging the use of sustainable soil management practices and existing tools, guidance and frameworks to maintain soil biodiversity and to encourage the transfer of knowledge and enable women, indigenous peoples and local communities and all stakeholders, including farmers, foresters, land managers and urban communities to harness the benefits of soil biodiversity for their livelihoods, taking into account national circumstances, land-use type, geographic region and the vulnerability of marginalized communities;

(c) Promoting education, awareness raising and developing capacities in the public and private sectors on the multiple benefits and application of soil biodiversity, sharing knowledge and improving the tools for decision-making, fostering engagement through collaboration, intergenerational transmission of traditional knowledge of indigenous peoples and local communities and partnerships, and providing practical and feasible actions to avoid, reduce or reverse soil biodiversity loss;

(d) Developing standard protocols to assess the status and trends of soil biodiversity, as well as monitor activities in all regions to address gaps in knowledge and foster relevant research.

56. The plan of action contributes to the achievement of the Sustainable Development Goals, in particular Goals 2, 3, 6, 13, 14 and 15, the post-2020 global biodiversity framework, the 2050 Vision for Biodiversity, the FAO Strategy on Mainstreaming Biodiversity across Agricultural Sectors[37] and the

[36] http://www.fao.org/documents/card/en/c/5544358d-f11f-4e9f-90ef-a37c3bf52db7/

[37] http://www.fao.org/3/ca7175en/ca7175en.pdf

objectives, commitments and initiatives under other conventions and multilateral environmental agreements, including, the three Rio conventions, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Stockholm Convention on Persistent Organic Pollutants.

III. SCOPE AND PRINCIPLES

57. The *scope* of this updated plan of action focusses on soils across agricultural landscapes and other managed ecosystems including forests, grasslands, croplands, wetlands, savannas, coastal areas and urban and peri-urban environments. It is wide and far-reaching and context-dependent to ensure that it responds to specific situations and farmer typologies and that it prioritizes actions on the basis of country goals and the needs of direct beneficiaries.

58. The Initiative continues to be implemented as a cross-cutting initiative of the Convention by the Secretariat, FAO and its Global Soil Partnership in partnership with the work of the Intergovernmental Technical Panel on Soils, the Global Soil Biodiversity Initiative, the Science-Policy Interface of the United Nations Convention to Combat Desertification, academic and research institutes, donor agencies, and the private sector, as well as relevant organizations, land owners and land managers, farmers, indigenous peoples and local communities, and civil society.

59. When linked to the post-2020 global biodiversity framework, the United Nations Decade on Ecosystem Restoration, the 2030 Agenda for Sustainable Development and its Sustainable Development Goals, the Paris Agreement[38] and Land Degradation Neutrality targets, the scope of this plan of action can achieve multiple co-benefits of soil biodiversity processes for improved and more sustainable land-use systems and practices.

60. The plan of action adheres to the *principles* of the ecosystem approach,[39] which aim to provide better biological, physical, economic and human interactions associated with sustainable and productive ecosystems.

61. The plan of action focuses on the improvement of livelihoods, on the implementation of integrated and holistic solutions adapted to local contexts and in developing synergies for better soil biodiversity research, monitoring and assessment while ensuring multi-stakeholder participation.

62. FAO will facilitate the implementation of the plan of action and it is intended to align activities on soil biodiversity more closely with other FAO related activities, as well as with regional and country offices in order to create synergies and provide broader support. The full implementation of the plan of action at the national and regional levels will depend on the availability of resources.

IV. PRIORITY GLOBAL ACTIONS

63. To support the implementation of coherent and comprehensive policies for the conservation and sustainable use of soil biodiversity at all levels, the following priority global actions have been identified:

(a) Developing protocols and following standard approaches, methods and tools to ensure more accurate collection of soil biodiversity data around the world;

(b) Including soil biodiversity as an important component of soil description surveys using a large range of tools, including state of the art methods and technology;

(c) Establishing a monitoring network to assess and keep track of the abundance and diversity of multiple soil taxa or units and of the changes in soil biodiversity and its functioning;

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[38] United Nations, *Treaty Series*, Registration No. I-54113.

[39] Decision V/6

(d) Preparing a global assessment of soil biodiversity based on the compilation of information captured from field assessments in all regions;

(e) Implement feasible indicators of soil biodiversity that are related to the provision of key ecosystem services and under the framework of the one-health concept;[40]

(f) Promoting soil biodiversity as an ecosystem-based approach in response to numerous challenges such as improvement of soil organic carbon sequestration, control, prevention and suppression of soil-borne diseases, enhancement of soil nutrients, food security and safety, and pollution mitigation;

(g) Engaging with the United Nations International Decade of Ecosystem Restoration, to pursue restoration of degraded soils and their multi-functionality, including the utilization of restored sealed areas and degraded agricultural areas for food production and avoiding expansion to natural areas where feasible;

(h) Encouraging awareness raising on the importance of soil biodiversity and its functions and services through regional and global platforms, such as FAO and GSP, which provide existing channels to be leveraged.

V. KEY ELEMENTS AND ACTIVITIES

64. The plan of action comprises four main elements that could be undertaken, as appropriate and on a voluntary basis, by Parties and other Governments, in collaboration with relevant organizations:

(a) Policy coherence and mainstreaming;

(b) Encouraging the use of sustainable soil management practices;

(c) Awareness- raising, sharing of knowledge and capacity- building;

(d) Research, monitoring and assessment.

Element 1: Policy coherence and mainstreaming

Rationale

Soil biodiversity loss is a cross-cutting issue, and policies should be designed to integrate considerations not only into the context of sustainable agriculture, but also across sectors. Appropriate and coherent national policies are needed to provide an effective and enabling environment to support activities by indigenous peoples and local communities and all relevant stakeholders, including land users, farmers, small-holders and family farmers, land managers, foresters, the private sector, civil society and other relevant stakeholders. Inclusive policies that take soil biodiversity into consideration can provide multiple benefits by linking agriculture, food production, forestry, human health, culture, spiritual and environmental policies.

Activities

1.1 Mainstream the conservation, sustainable use and management of soil biodiversity into the agricultural, forestry, and other relevant sectors and support the development and implementation of coherent and comprehensive policies for the conservation, sustainable use and restoration of soil biodiversity at the local, subnational, national, regional and global levels;

1.2 Foster activities to safeguard and promote the importance as well as the practical application of soil biodiversity, and integrate them into broader policy agendas for food security, ecosystem restoration, climate change adaptation and mitigation and sustainable development, including the post-2020 global biodiversity framework and the Sustainable Development Goals;

[40] https://www.who.int/features/qa/one-health/en/

1.3 Promote the implementation of sustainable soil management[41] as one of the vehicles to promote integrated and holistic solutions which recognizes the key role of aboveground-belowground biodiversity interactions and of local communities and their local knowledge and practices, considers local contexts and integrated land-use planning, in a participatory manner;

1.4 Adopt integrated ecosystem approaches for the conservation and sustainable use of soil biodiversity and enhancement of agro-ecosystem functions, considering, as appropriate, traditional agricultural practices;

1.5 Develop policies and actions whereby soil biodiversity is central for sustaining all terrestrial ecosystems, including protected areas, and soils of managed systems and whereby it is also a key asset in restoring soil multi-functionality in degraded ecosystems, including urban soils;

1.6 Adopt policies that provide economic incentives to producers or property owners that implement practices that promote or increase the biodiversity of the soil;

1.7 Address linkages between soil biodiversity and human health, nutritious diets, pollutants exposure, including pesticides and veterinary drugs, and the provision of ecosystem functions and services beyond food production;

1.8 Strengthen synergies between scientific evidence, conservation practices, farmer-researcher community practices, and traditional knowledge of indigenous peoples and local communities to better support policies and actions;

1.9 Promote ways and means to overcome obstacles to the adoption of sustainable soil management associated with land tenure, the rights of users, particularly women, the collective rights of indigenous peoples, water rights, gender equality, access to financial services and educational programmes, while recognizing the important contributions of indigenous peoples and local communities and their knowledge and practices;

1.10 Advocate for the use and implementation of existing tools and guidance at the national, regional and global levels, such as the FAO Voluntary Guidelines for Sustainable Soil Management,[42] the FAO's Revised World Soil Charter,[43] the Code of Conduct on Pesticide Management[44] and the International Code of Conduct for the Sustainable Use and Management of Fertilizers;[45] the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forest in the Context of National Food Security;[46]

1.11 Ensure that soil biodiversity is properly reflected in national reports and national biodiversity strategies and action plans.

Element 2: Encouraging the use of sustainable soil management practices

Rationale

Management practices and land-use decisions undertaken by farmers, foresters, land managers, indigenous peoples, local communities and all relevant stakeholders influence ecological processes including soil-water-plant interactions. There is increasing recognition that the sustainability of agricultural, traditional agriculture and other managed systems depends on the optimal use of the available natural resources, including soil biodiversity. Improvement in sustainability requires the optimal use and

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[41] http://www.fao.org/3/a-bl813e.pdf

[42] http://www.fao.org/3/a-bl813e.pdf

[43] http://www.fao.org/documents/card/en/c/e60df30b-0269-4247-a15f-db564161fee0/

[44] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/code/en/

[45] http://www.fao.org/3/ca5253en/ca5253en.pdf

[46] http://www.fao.org/3/i2801e/i2801e.pdf

management of soil fertility and soil physical properties, which rely, in part, on soil biological processes and soil biodiversity. Direct and indirect drivers of soil biodiversity loss need to be addressed in the field, and special attention is needed at the farm and forestry level and across entire ecosystems.

Activities

2.1 Promote the improvement of soil health and the enhancement of soil organism abundance and diversity, while also improving their food, water and habitat conditions through sustainable practices, such as the maintenance of adequate soil organic matter content, adequate soil microbial biomass, provision of sufficient vegetative cover, use of organic fertilizers, minimization of soil disturbance and tillage, minimization of the use of herbicides that cause the accumulation of toxic products and affect the soil microbiota, and restoration of degraded soils to increase landscape connectivity and production areas;

2.2 Develop, enhance and implement science-based risk assessment procedures, on a regular basis, considering field-realistic exposures and longer-term effects, for veterinary drugs (e.g. antibiotics[47]), pesticides and pesticide-coated seeds, pollutants, biocides and other contaminants to inform risk management decisions, to limit or minimize pollution and to promote the judicious application of veterinary drugs, fertilizers and pesticides (e.g. nematicides, fungicides, insecticides and herbicides) to enhance the conservation of soil biodiversity, human health and well-being;

2.3 Ensure that all relevant stakeholders have access to policies, tools and enabling conditions, such as access to technologies, innovation and finance, as well as to traditional practices that promote the conservation and sustainable use of soil biodiversity at the field level, taking into account the full and effective participation of women, youth, indigenous peoples, local communities and stakeholders in the implementation of this Initiative;

2.4 Encourage crop rotation in the field, inter-cropping, cover crops, mixed crops, addition of organic matter through manure, biochar, or biosolids, and preservation of perennial plants in field margins and biodiversity refuges;

2.5 Facilitate site-specific remediation of contaminated soils;[48] preferring those alternatives that show minor risks to biodiversity, while exploring the implementation of bioremediation strategies that use endemic microorganisms;

2.6 Prevent the introduction and spreading, and minimize the impact of invasive alien species that present a direct and indirect risk to soil biodiversity, and monitor the dispersion of those already established;

2.7 Protect and conserve soils that provide significant ecosystem services, particularly those with high amounts of biological diversity or agricultural suitability, including through the use of sustainable soil management practices;

2.8 Promote sustainable soil and associated water and land management practices that maintain and promote the resilience of carbon rich soils (such as peatlands, black soils and permafrost);

2.9 Promote sustainable soil and associated water and land management practices that support the achievement of land degradation neutrality;

2.10 Promote ecosystem-based approaches to avoid land-use changes that cause soil erosion, the removal of surface cover and loss of soil moisture and carbon, and implement mitigation measures to alleviate degradation;

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[47] For example, antibiotics used on livestock that can seep into the soil.

[48] The importance of special soils creating environments for specific soil biota (for example, natural extremely acidic or alkaline soils; natural hypersaline soils; natural soils containing high quantities of rare elements) should be recognized. Although they are not necessarily productive or high biodiverse soils, they host important communities as gene reserves and merit protection as they may contain unknown, adapted organisms that can be useful in the future.

2.11 Promote ecosystem-based approaches that conserve, restore and avoid degradation of soil biodiversity in ecosystems with high soil carbon sequestration potential and in ecosystems that contribute to climate change adaptation and disaster risk reduction, such as riparian buffers, watersheds, drainage basins and floodplains, wetlands and coastal regions;

2.12 Promote ecosystem-based approaches that conserve, restore and avoid degradation of soil biodiversity in ecosystems that restore long-term sink capacity and maximize the carbon sequestration potential of marginal and degraded land.

Element 3: Awareness-raising, sharing of knowledge and capacity-building

Rationale

Increased awareness and understanding are critical for the development and promotion of improved practices for the conservation and sustainable use of soil biodiversity and ecosystem management. This requires collaboration that ensures the full and effective participation of and feedback from a broad range of stakeholders, including women, youth, small-holder farmers, indigenous peoples and local communities, and relevant institutions and organizations to ensure effective actions and collaborative mechanisms. Strengthening capacities to promote integrated and multidisciplinary approaches are needed to ensure the conservation, sustainable use and enhancement of soil biodiversity. This will further improve information flows and cooperation among actors to identify best practices and foster sharing of knowledge and information.

Activities

3.1 Increase understanding of the role of soil biodiversity in agricultural, silvopastoral and other managed systems, and in the effect on land management practices and ecosystem and environmental health;

3.2 Increase understanding of the consequences of soil biodiversity decline in specific agroecosystems and natural environments and engage targeted key stakeholder groups, including farmers, ranchers, extension workers, foresters, non-governmental organizations, schools, the mass media, and consumer organizations on the value of soil biodiversity for health, well-being and livelihoods;

3.3 Strengthen the understanding of the impacts of land-use and soil-management practices, as an integral part of agricultural and sustainable livelihood strategies, including their economic valuation, and develop modalities to incorporate soil biodiversity in the true cost accounting of agriculture and food production;

3.4 Promote awareness raising and sharing of knowledge through tools and digital technology and promote capacity-building and mutual learning, including at the local and field level by developing collaborative activities, such as peer-to-peer learning, for the promotion of best practices for soil biodiversity assessment, management and monitoring for all land management activities;

3.5 Enhance education, and knowledge on soil biodiversity and the ecosystem functions and services they provide, through the update of educational curricula for professionals, including economy, agronomy, veterinary, taxonomy, microbiology and zoology, and through the creation and dissemination of training and information materials on soil biodiversity;

3.6 Support citizen science campaigns and activities to engage relevant stakeholders in the conservation and sustainable use of soil biodiversity, including celebrations on 5 December of World Soil Day, which was established by the United Nations General Assembly in 2014;[49]

3.7 Build and strengthen the capacities of farmers, ranchers, foresters, land-owners, land managers, private sector, scientists, indigenous peoples and local communities and vulnerable communities, as appropriate, in designing and implementing sustainable soil management practices and the sustainable application of soil biodiversity and eventually contributing to data collection;

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[49] See General Assembly resolution 68/232 of 7 February 2014 on World Soil Day and International Year of Soils.

3.8 Protect, maintain and promote traditional knowledge, innovations and sustainable practices of indigenous peoples and local communities related to soil biodiversity maintenance, soil fertility and sustainable soil management and promote work mechanisms between traditional agricultural knowledge and scientific knowledge that contribute to implementing sustainable agricultural practices in accordance with local agro-ecological and socioeconomic contexts and needs;

3.9 Develop partnerships and alliances that support multi-disciplinary approaches, foster synergies and ensure multi-stakeholder participation with respect to sustainable soil management.

Element 4: Research, monitoring and assessment

Rationale

Assessing and monitoring the status and trends of soil biodiversity, of measures for the conservation and sustainable use of soil biodiversity and of the outcomes of such measures, is fundamental to inform adaptive management and to guarantee the functioning of all terrestrial ecosystems, including the long-term productivity of agricultural soils. The assessment and monitoring data need to be coordinated and harmonized at a global scale for efficient reporting to better guide the decision-making process, with particular focus on those regions currently lacking data. Academic and research bodies and relevant international organizations and networks should be encouraged to undertake further research, taking into consideration soil biodiversity functions regional pedodiversity, and relevant traditional knowledge, to address gaps in knowledge, and to expand research and to support coordinated global, regional, national, subnational and local monitoring efforts.

Activities

4.1 Increase taxonomic capacity and address taxonomic assessment needs in different regions, and design targeted strategies to fill the existing gaps;

4.2 Promote further research to identify ways to integrate the application of soil biodiversity into farming systems as part of efforts to improve yield quantity and facilitate the harmonization of protocols for research, data collection, management and analysis, storage and curation of samples;

4.3 Promote further research to identify risks to soil biodiversity under climate change and potential adaption measures and mitigation tools, including the potential loss of key species and their habitats, as well as the role of soil biota in wider ecosystem resilience and restoration that contributes to the formulation of public policy plans in various fields related to, for example, climate change, biodiversity conservation, food security, nature-based solutions, soil and water treatment and public health;

4.4 Promote further research and analysis on pest management as it interacts directly with functions and services provided by soil biodiversity, taking into account the negative impact of pesticides on soil organisms to support the development of more feasible and sustainable alternatives;

4.5 Quantify soil biodiversity deficits in agricultural and in other managed ecosystems, where feasible, and apply consistent and comparable protocols to support decision-making, and identify the most effective intervention measures;

4.6 Promote research, information management and dissemination, data collection and processing, transfer of knowledge and technologies, including modern geospatial technologies, and networking;

4.7 Mobilize targeted participatory research and development, ensuring gender equality, women's empowerment, youth, gender-responsive approaches and the full and effective participation of indigenous peoples and local communities in all stages of research and development;

4.8 Develop and apply tools to assess the status of soil biodiversity in all regions and to address gaps in knowledge in all levels, by using a range of available tools, from traditional macro-organism and soil fauna observation, national statistics, soil surveys, to cutting-edge approaches and new technologies, such as DNA technologies for rapid species identification and satellite imagery, as appropriate;

4.9 Generate data sets on soil biodiversity, pedodiversity and on soil degradation at the national and regional levels through a monitoring process that allows the creation of regional, national, subnational and local visual maps, georeferenced information systems and databases to indicate the status and trends of soil biodiversity and crop-specific vulnerability to support decision-making;

4.10 Promote dissemination and exchange of information and data, in line with Articles 8(j) and 8(h) of the Convention on Biological Diversity, and through interdisciplinary approaches ensuring that all decision makers and stakeholders have access to reliable and up-to-date information;

4.11 Encourage the development of standard baselines, indicators and national-level monitoring activities of soil biodiversity with the inclusion of a vast range of soil organisms, from microorganisms to fauna, as well as monitoring the effectiveness of soil management interventions in the field;

4.12 Encourage and support the development of community-based monitoring and information systems (CBMIS) or simplified assessment methodologies and tools for measuring soil biodiversity that are directly accessible in all regions of the world;

4.13 Compile, synthesize and share lessons resulting from experiences or case studies on the implementation of sustainable soil management practices in the context of agricultural practices with positive impacts on soil sustainability.

VI. SUPPORTING GUIDANCE, TOOLS, ORGANIZATIONS AND INITIATIVES RELATING TO THE CONSERVATION AND SUSTAINABLE USE OF SOIL BIODIVERSITY

65. Relevant guidance and tools developed under the Convention, and those developed by partner and relevant organizations and initiatives, such as the Voluntary Guidelines for Sustainable Soil Management and the World Soil Charter prepared by FAO, among others, will be made available in the clearing-house mechanism.