Hereby I affirm that the essay at hand is my own written work and that I have used no other sources and aids other than those indicated. All passages, which are quoted from publications or paraphrased from these sources, are indicated as such. Moreover, I have not supported other students in writing a graded essay in this module

On soil biodiversity

Logan Lehmann, HAFL, April 2020

Introduction

Soil is the basis of our global livelihood. Soil regulates the water cycle (and thus climate), and soil biodiversity and plant diversity and growth are interlinked. Urbanization and economic activity leave behind soils that are altered beyond self-repair, and cannot be repurposed right away. These alterations include structure modification, exclusion from eco-systems (drying or waterlogging), biogeochemical alterations and pollution (especially by metals), among other things. In the long run, many agricultural practices - focused that they may be on soil functions and services - also lead to soil health degradation (eg: tillage). In many regions on the world, we have asked too much of soil in order to meet production quotas. This general degradation leads to using even more coercive means to meet the quotas, creating a vicious circle. Global food requirements are ever growing, but with most nations now actively pursuing global sustainability goals, one might very well argue that the time to break the vicious circle is now.

Contrary to macro-species which can exist in very narrow habitats (a precarious situation), soil micro-species exist all over the planet. Although the compositions of their communities vary, their functions are the same (integrated in the same biogeochemical cycles), and their richness and diversity can be “rebuilt”. Here we will try and understand soil biodiversity’s challenges and explore possible answers.

Assessing soil biodiversity

Although the concept of biodiversity and its intricacies has already been presented, applying it to soil raises further issues. What does ‘biodiversity’ mean in this context ?

One challenge of soil biodiversity is its assessment. Because soil organisms vary greatly in size and habitat extent, general biodiversity theories may not work very well. A literature review conducted in 2019 listed the challenges of applying conventional biodiversity theories to soil [1]. For instance, the species-energy relationship may significantly deviate for soil micro-organisms since their success is so dependent on soil chemical and biochemical conditions. Their movement may be entirely determined by water flow within the soil, and not nutrient 'search'. The study counted papers in support or against each main biodiversity theory. In particular, niche theory - which is important in sustainable agricultural practices - was found to have debatable validity when it comes to studying soil micro-organism communities. One possible reason is that soil micro-organisms perform their own eco-system engineering, altering their environment, therefore creating a feedback loop. Another challenge is that niche theory makes sense at a given scale, but soil shows many cross-scale interactions. In general, spatial extent is a problem when it comes to applying these theories to soil. However, this doesn't mean that they are invalid. The review found reasonable support that interaction-based and movement-based mechanisms did apply. The researchers go on to propose a framework that takes spatial scale into account.

Another team presented a model for a soil biodiversity function [2]. The model brings numerous soil criteria, from properties and structure to biotic communities, into a decision tree. The SB function would be "the multitude of soil organisms and processes, interacting in an ecosystem, providing society with a rich biodiversity source and contributing to a habitat for aboveground organisms." The study meant to see whether the proposed model would be coherent with independent expert judgement, which it was - with limitations.

[1] *Madhav Thakur; Helen Phillips; Ulrich Brose; Franciska de Vries; Patrick Lavelle; Michel Loreau et al. (2020): Towards an integrative understanding of soil biodiversity. In Biol. Rev 95, pp. 350–364. DOI: 10.1111/brv.12567.*

[2] *Jeroen van Leeuwen; Rachel Creamer; Daniel Cluzeau; Marko Debeljak; Fabio Gatti; Christian Henriksen et al. (2019): Modeling of Soil Functions for Assessing Soil Quality: Soil Biodiversity and Habitat Provisioning. In Frontiers in Environmental Science 7, p. 113. DOI: 10.3389/fenvs.2019.00113.*

Measures for soil biodiversity

In spite of certain grey areas, we know that soil biodiversity is essential to eco-systems and, thankfully, can be encouraged. How can we achieve better soil biodiversity ?

It seems intuitive enough that higher plant diversity would lead to higher soil biota diversity. However, this has been intensely debated. A long-term study published in PNAS in 2013 shows that it is indeed the case [3]. Plant diversity was shown to cause a significant improvement for many soil biodiversity indicators. The main mechanism at play is ressource increase : “plant diversity increased soil pH, soil N concentration, soil water content, and plant root biomass”. This in turn was shown to increase microbial biomass, as well as the density of detritivores. Could a feedback loop based on the improvement of the food web be why long-term studies (>5y) like this one show a strong effect of plant diversity, whereas previous short-terms studies have shown no or weak effect ? Overall, plant diversity was found to have greater effect than nitrogen deposition at the experiment site.

Beyond root biomass and properties, phylogenetic plant diversity implies more functionally diverse litter. Dead leaves and branches exhibit different biochemical properties, providing a more varied ‘diet’ for soil micro-organisms. Furthermore, each plant species’ chemical composition can have different effects on the microbial community. One study used the MicroResp method on 92 4x4m plots on a natural species richness gradient near Marseilles, France [4]. Microbial metabolic activity was shown to increase with litter species richness, but only after 2 years of decomposition. Interestingly, species composition seemed to have no effect.

Finally, one characteristic that is essential to biodiversity at all scales is structure. Where soil structure itself has been modified by human activity, the question is whether a fertile soil can be reengineered and through what means. One admittedly trendy product could provide an answer : biochar. Biochar is the result of the pyrolisis of organic matter : thermal decomposition (300-1000°C) without oxygen. This material is very stable and will not decompose (even after centuries). Its properties can vary, notably its pH. It contains almost no nutrients. Biochar amendment has been shown to increase soil fertility, especially when used together with an organic fertilizer like compost. This is due to modifications of total organic carbon availability, nitrogen loss and ammonium adsorbtion [5]. With respect to the topic at hand, biochar also provides soil aeration which supports biotic activity. It exhibits very high porosity and retains wood vessel structure, providing durable habitat for micro-organisms as well as water- and nutrient-retention capabilities, which are crucial.

[3] *Nico Eisenhauer; Tomasz Dobies; Simone Cesarz; Sarah E. Hobbie; Ross J. Meyer; Kally Worm; Peter B. Reich (2013): Plant diversity effects on soil food webs are stronger than those of elevated CO2 and N deposition in a long-term grassland experiment. In PNAS. DOI: 10.1073/pnas.1217382110.*

[4] *Ammar Shihan; Stephan Hättenschwiler; Alexandru Milcu; François-Xavier Joly; Mathieu Santonja; Nathalie Fromin (2017): Changes in soil microbial substrate utilization in response to altered litter diversity and precipitation in a Mediterranean shrubland. In Biology and Fertility of Soils 53 (2), pp. 171–185. DOI: 10.1007/s00374-016-1166-9.*

[5] *Hardy Schulz; Gerald Dunst; Bruno Glaser (2013): Positive effects of composted biochar on plant growth and soil fertility. In Agron. Sustain. Dev. 33 (4), pp. 817–827. DOI: 10.1007/s13593-013-0150-0.*

Conclusion

We have seen that soil is an incredibly complex environment, if only by its richness and abundance in organisms of different sizes and trophic levels. Interaction patterns within it are difficult to study. Soil interacts with climate, restricting the validity of experiment results. As for remediation, we have seen that some solutions already exist, the first of which is fostering plant species richness. Not all solutions provide direct leverage on biodiversity, but rather could be part of mitigation strategies or measures to support the transition towards sustainable land management.

However, coming up with treatments and pairing them with sites are two additional - and delicate - matters. Polluted sites are a natural choice for the time being, since their situation cannot be worsened. Phytomining (nb: my personal topic of interest) seems like a promising endeavour [6].

[6] *Morse, Ian (2020): Down on the Farm That Harvests Metal From Plants. In The New York Times, 2/26/2020. Available online at [https://www.nytimes.com/2020/02/26/science/metal-plants-farm.html (https://www.nytimes.com/2020/02/26/science/metal-plants-farm.html)](https://www.nytimes.com/2020/02/26/science/metal-plants-farm.html), checked on 4/25/2020.*