Review Article
Open Access CrossMark

Soil biodiversity and climate change

Volume 3 Issue 5 - 2016

Saima Khursheed
Department of Agriculture, USDA-NRCS Central National Technology support centre, USA

Correspondence: Saima Khursheed, Department of Agriculture, USDA-NRCS Central National Technology support centre, USA, Email symakhursheed@gmail.com

Received: May 13, 2016 | **Published:** May 18, 2016

Introduction

Global climate change can have significant impacts on all the soil biodiversity and related services. These impacts can be directly or indirectly linked to the alteration of the climatic parameters (e.g. Temperature, humidity). Soil biodiversity is more extensive than any other environment on the globe when all living forms are considered. The soil biota contains representations of all groups of microorganism like fungi, bacteria, algae and viruses, as well as the micro fauna such as protozoa and nematodes. Today, disturbance regimes are changing drastically under the combined effects of climate change, biological invasions and direct human modifications of the environment. However, it remains very difficult to assess and predict how soil communities will respond to these disturbances. Environmental variability is an integral part of the dynamics of ecosystems, and some disturbances are unavoidable. Climate change may intensify these seasonal disturbances, stretching the limits more towards those of extreme events.

Soil organisms contribute a wide range of essential services to the sustainable function of all ecosystems, by acting as the primary driving agents of nutrient cycles, regulating the dynamics of soil organic matter, soil carbon sequestration and greenhouse gas emission; modifying soil physical properties and water regimes, enhancing the amount and efficiency of nutrient acquisition by the vegetation and enhancing plant health. Soil organisms interact in a soil food web, where each tropic level serves as food for the next tropic level. In general a soil food web is based on the degradation of roots and dead organic material (detritus). The stability of the performance of an ecological function is dependent on the stability of the soil food web. Soil microorganisms perform a wide range of functions: they decompose organic matter, release nutrients into plant-available forms and degrade toxic residues; they also form symbiotic associations with plant roots, act as antagonists to pathogens, influence the weathering and solubilization of minerals and contribute to soil structure and aggregation. The time-table of microbial metabolism is meaningful for human interference with turnover rates in soil typically being 0.2-6 years for the soil microbial biomass compared to >40years for the bulk of organic matter.

Soil biodiversity plays a very important role within the global system, and ongoing research continues to highlight this point. Today, disturbance regimes are changing drastically under the combined effects of climate change and biological invasions. Abiotic regulations by climate are large scale determinants of microbial activities. The overall effect of climate on soil microorganisms can be perceived through the seasonal dynamics of microbial populations. These dynamics are due to the fact that growth, activity and composition of microbial communities are susceptible to the two main factors regulated by climate: temperature and moisture. Growth and activity rates are individual characteristics of microbial communities and may vary independently. In general, a rise in atmospheric temperature corresponds to a rise in microbial activity. Changing soil temperature will likely alter microbial mediated nitrification and denitrication dynamics in soil environment due to shift of nitrifiers and denitrifiers population. Sometimes perturbations in the soil environment could lead to community shifts and altered metabolic activity in microorganisms involved in soil nutrient cycling, and to increasing or decreasing survival and virulence of soil mediated pathogenic microorganisms like Salmonella typhimurium. Thus typically, microbial growth and activity generally decrease in winter time, due to the decreased temperature. Extremely high temperatures, in general, are deleterious for many microorganisms. Indeed, some species of chemical engineers may survive such adverse conditions by entering survival inactive forms, which may resist high temperatures better than active individuals. It is worth highlighting that actually much uncertainty exists about how reactive different microbial groups (and fauna) are to temperature. The seasonal changes observed in soil microbial activity are also often associated to modifications in microbe's community composition. The overall effect of climate on soil microorganisms can be perceived through the seasonal dynamics of microbial populations. These dynamics are due to the fact that growth, activity and composition of microbial communities are sensitive to the two main factors regulated by climate: temperature and moisture. Growth and activity rates are individual characteristics of microbial communities and may vary independently. This means that climatic conditions favoring high level of microbial activity do not always facilitate a high microbial growth and associated increased biomass.

In general, a rise in atmospheric temperature corresponds to a rise in microbial activity. Thus typically, microbial growth and activity generally decrease in winter time, due to the decreased temperature. However, such expected seasonal dynamics may change in specific soil ecosystems, in tundra soils, microbial biomass is at its maximum in late winter time when temperature is low.[1] Thus, even if there is in general a positive correlation between temperature and microbial growth and activity, responses to temperature can also depend on the species of chemical engineers present in the microbial community and on the considered temperature range. Extremely high temperatures, in general, are deleterious for many microorganisms. A long term increase in temperature, observed under climate change has been shown to influence soil microbial respiration. The respiration of soil microbes is an important factor modulating the overall organic matter decomposition and thus the carbon storage process. The more respiration is efficient, the more organic matter is decomposed with in parallel, a release of CO. In any case, the optimal climatic conditions for enzymatic activity of microbes always vary locally, depending on the specific species assemblage in the considered geographical area.[2]

In addition to temperature, the soil moisture and the frequency of wet/ dry and freeze/ thaw cycles can modify the soil aggregation and have potential important impacts on the availability of organic matter and, as a consequence, on the microbial community structure and activity.

Temperature and moisture are also important determinant of biological regulators community structure and functioning. The main effects have been observed on nematodes and micro arthropods, and are extremely important to estimate the impact of average temperature increase, due to climate change or other more local impacts, such as fires. The sensitivity of nematodes to temperature and soil moisture[3] depends on their metabolic state. This class of organisms has a different strategy of survival in extreme environmental conditions and can form cysts or enter dormant stages allowing them to survive to the most extreme soil temperature and moisture changes.[4]

Mitigation Strategies

Soil management practices have important and sometimes immediate effects on soil biodiversity and the resulting ecosystem services. The main mechanism explaining the changes in soil biodiversity with increased intensification of management practices is linked to organic matter input. Organic matter drives the soil food web, and depending on the type, it will drive bacteria- (low C: N) or fungi- (high C: N) dominated food webs. Greater litter inputs in grasslands encourage fungal- dominated microbial communities,[5] and a greater diversity of nematodes[5,6] and micro arthropods.[7] The enhanced microbial activity may also enhance the biological regulators, and thus reduce nematode and soil pathogen incidence.[8,9] In contrast, in intensively managed (fertilized) grasslands or croplands, microbial communities are depressed[10] and shift to opportunistic bacteria- dominated communities.[11,12] In turn, this tends to favour opportunistic bacteria- feeding fauna.

Soil tillage practices disturb fungal hyphae and the larger earthworm species that visit the soil surface to obtain plant material for food, such as anecic earthworms.[13] Biomass and abundance of anecic earthworms are reduced by a factor of 1.3-3 in conventionally managed soils when compared to organic management types.[14–17] Conventional management also results in poorer soil aeration and soil drainage.

Methods to protect soil biodiversity

Mulching/light soil sealing

Mulching consists of covering the soil surface to protect against erosion and to enhance its fertility. Mulch is usually applied towards the beginning of the crop growing season, and may be reapplied as necessary. It serves initially to warm the soil by helping it retain heat and moisture. A variety of materials can be used as mulch, including organic residues (e.g. crop residue, hay, bark), but also manure, sewage sludge, compost, rubber or plastic films.

Application of organic residues (compost/manure/ sludge)

Application of animal manure, sludge or other carbon-rich wastes, such as coffee-berry pulp or compost, improves the organic matter content of the soil. For agricultural purpose, it is usually better to allow decomposition of organic residues for a period before applying them to the field. This is because addition of carbon-rich compounds immobilizes available N in the soil temporarily, as micro-organisms need both C and N for their growth and development.

Fertilizers

High levels of some inorganic nitrogenous fertilizers provide microbes with easy to use nitrogen, thereby boosting their activity. This increases the rate of decomposition of low quality organic inputs and soil organic matter, resulting in the continuing decline of soil organic matter content which, ultimately, results in loss of soil structure and water holding capacity.

Crop management

Choice of the crops species

The choice of the cultivated crop is important as it defines the kind of habitat available to soil fauna. For example legumes can act as natural fertilizers, improving the nitrogen concentration in soil, thanks to the symbiotic relationship they establish with Rhizobia.

Crop rotations

Crop rotations can also help avoid the build- up of pathogens and pests, as the alternation of crops modifies the associated communities of biological regulators.

Landscape management

Hedgerows and grassy field margins Establishing hedge rows or grassy strips at the edge of arable fields offer a stable habitat, food, and a protective environment for soil fauna next to the intensively managed. Hedge rows are even. More favorable to soil organisms, in particular biological regulators, than grassy field margins, however, due to their low mobility; the soil organisms will have only limited dispersal into the fields. That also counts for field margins, in which 10% of the soil dwelling species present in farm land were found to occur exclusively.

Conclusion

The complexity of microbial communities living belowground and the various ways they associate with their surroundings make it difficult to pinpoint the various feedback responses that soil microbes may have to global warming. Whether a positive feedback response results, in which microbial processes further contribute to climate change, or whether a negative feedback response slows its effects, it is clear that microbes can have a huge impact on future climate scenarios and ecosystem-level responses to climate change. Soil respiration plays a pivotal role in these effects due to the large amount of CO2 and CH4 emissions produced during respiration, the reliance of carbon stocks in soils on rates of respiration, and the initial sensitivity of soil respiration to increased atmospheric temperatures. Further studies in long-term feedback effects of soil respiration on climate change can contribute to our understanding of the overall impacts of climate change; including the ability of terrestrial forests to uptake excess CO2 from the atmosphere. As we attempt to mitigate greenhouse gas emissions and adapt to predicted climate change effects, turning towards microscopic life that lies below the surface can perhaps help us to become better equipped for future changes at the macroscopic and even global scale.

Climate change is likely to have significant impacts on soils that may affect all of the services provided by soil biodiversity; indeed the quantification of these impacts is needed. In any case, all mitigation and attenuation measures taken to limit global climate change are expected to have a beneficial impact on soil biodiversity preservation, soil functioning and associated services.

Acknowledgements

None.

Conflict of interest

The author declares no conflict of interest.

References

1. Schadt CW, Martin AP, Lipson DA, et al. Seasonal dynamics of previously unknown fungal lineages in tundra soils. *Science*. 2003;301(5638):1359–1361.
2. De Santo AV, Berg B, Rutigliano FA, et al. Factors regulating early–stage decomposition of needle litters in five different coniferous forests. *Soil Biology and Biochemistry*. 1993;25(10):1423–1433.
3. Ruess L, Michelsen A, Schmidt IK, et al. Simulated climate change affecting microorganisms, nematode density and biodiversity in subarctic soils. *Plant Soil*. 1999;212(1):63–73.
4. Wall DH, Virginia RA. Controls on soil biodiversity:insights from extreme environments. *Applied Soil Ecology*. 1999;13(2):137–150.
5. Bardgett RD, Leemans DK, Cook R, et al. Seasonality of soil biota of grazed and ungrazed hill grasslands. *Soil Biology and Biochemistry*. 1997;29(8):1285–1294.
6. Wasilewska L. The effect of age of meadows on succession and diversity in soil nematode communities. *Pedobiologia*. 1994;38(1):1–11.
7. Siepel H. Biodiversity of soil micro arthropods:The filtering of species. *Biodiversity & Conservation*. 1996;5(2):251–260.
8. Freckman DW. Bacterivorous nematodes and organic–matter decomposition. *Agriculture, Ecosystems & Environment*. 1988;24(1–3):195–217.
9. Griffiths BS, Ritz K, Wheatley RE. Nematodes as indicators of enhanced microbiological activity in a Scottish organic farming system. *Soil use Manage*. 1994;10(1):20–24.
10. Lovell RD, Jarvis SC, Bardgett RD. Soil microbial biomass and activity in long–term grassland – effects of management changes. *Soil Biology and Biochemistry*. 1995;27(7):969–975.
11. Bardgett RD, Frankland JC, Whittaker JB. The effects of agricultural management on the soil biota of some upland grasslands. *Agriculture, Ecosystems & Environment*. 1993;45(1–2):25–45.
12. Bardgett R, Leemans D. Soil microbial activity on exposed mountain ridges in Snowdonia (Eryri), North Wales. *Soil Biol Biochem*. 1996;28(10):1533–1536.
13. Emmerling C, Schloter M, Hartmann A, et al. Functional diversity of soil organisms – a review of recent research activities in Germany. *Journal of Plant Nutrition and Soil Science*. 2002;165(4):408–420.
14. Pfiffner L, Mader P. Effects of biodynamic, organic and conventional production systems on earthworm Populations. *Biol Agric Hortic*. 1997;111555:3–10.
15. Siegrist S, Schaub D, Pfiffner L, et al. Does organic agriculture reduce soil erodibility? The results of a long–term field study on loess in Switzerland. *Agriculture, Ecosystems & Environment*. 1998;69(3):253–264.
16. Maeder PA, Fliessbach A, Dubois D, et al. Soil fertility and biodiversity in organic farming. *Science*. 2002;296(5573):1694–1697.
17. Hoschitz M, Kaufmann R. Soil nematode communities of Alpine summits–site differentiation and microclimatic influences. *Pedobiologi*. 2004;48:313–320.