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Significance of soil microorganisms with special reference to climate change

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Abstract

There are a large number of agronomic-ecological interactions that occur in a world with increasing levels of CO_2, higher temperatures and a more variable climate. Climate change and the associated severe problems will alter soil microbial populations and diversity. Soils supply many atmospheric green house gases by performing as sources or sinks. The most important of these gases include CH_4, CO_2 and N_2O. Most of the green house gases production and consumption processes in soil are probably due to microorganisms. There is strong inquisitiveness to store carbon (C) in soils to balance global climate change. Microorganisms are vital to C sequestration by mediating putrefaction and controlling the paneling of plant residue-C between CO_2 respiration losses or storage in semi-permanent soil-C pools**.** Microbial population groups and utility can be manipulated or distorted in the course of disturbance and C inputs to either support or edge the retention of C. Fungi play a significant role in decomposition and appear to produce organic matter that is more recalcitrant and favor long-term C storage and thus are key functional group to focus on in developing C sequestration systems. Plant residue chemistry can influence microbial communities and C loss or flow into soil C pools. Therefore, as research takings to maximize C sequestration for agricultural and forest ecosystems - moreover plant biomass production, similar studies should be conducted on microbial communities that considers the environmental situations.

Keywords: Climate change; Carbon; Soil; Microorganisms.

Introduction

Soil is the naturally occurring, unconsolidated mineral and organic material at the earth's surface that provides an environment for living organisms. Recently, it has been referred to as the earth's "critical zone" and as deserving special status, because of its role in controlling the earth's environment and thus affecting the sustainability of life on the planet. Scientists study soil because of the fundamental need to understand the dynamics of geochemical–biochemical–biophysical interactions at the earth's surface, especially in light of recent and ongoing changes in global climate. The soil habitat is defined as the totality of living organisms inhabiting soil including plants, animals, microorganisms and abiotic factors.

The exact nature of the habitat in which the community of organisms is living is controlled by a complex interaction of geology, climate, and vegetation type. This interaction of rock and parent material with temperature, rainfall, elevation, latitude, exposure to sun and wind, and many more factors, over wide geographical regions with analogous ecological conditions and characteristic plant populations, has developed into the current terrestrial biomes through their linked soils. Because soils provide such a tremendous range of habitats, they support an enormous biomass; a single gram of soil contains kilometers of fungal hyphae and more than 10^9 bacterial cells. Areas near the soil surface may be enriched with decaying organic matter and other nutrients, while the subsoil may be nutrient deprived; the soil solution in several pores perhaps greatly acidic,

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others more basic, depending on soil mineralogy and biological activity. Temperature and water contents of surface soil can vary widely from that of subsoil's; and the microenvironment of the surfaces of soil particles, where nutrients are concentrated and water films vary in thickness, is very different from that of soil pores.

In soil, a wide range of factors affect microbial life. The main factors controlling soil microbial community structure and diversity in soil are a) Plant type is a major determinant of the structure of microbial communities in soil, as plants are the main providers of specific carbon and energy sources b) Soil type is a major determinant of the structure of microbial communities, as the combination of soil texture and structure, organic matter, micro aggregate stability, pH and the presence of key nutrients, i.e., N, P, and Fe, determines the habitable niches in soil; and c) Agricultural management regime, such as crop rotation, tillage, herbicide and fertilizer application, and irrigation, is the key determinant of microbial community structure in soil. Humankind has only comparatively freshly started to change the composition of the soil and the energy equilibrium of the planet, micro-organisms have been dictating global climate for billions of years. Microbes has significant task as both users and emitters of greenhouse gases. Both natural and anthropogenic fluxes of carbon dioxide, methane and nitrous oxide are under the control of microorganisms.

Soil Microorganisms and green house gases

Find out the composition and dynamics of microorganisms is necessary if we want to increase our information of the control mechanisms involved in green house gas variations (Allison *et al*., 2010). Nearly all of the green house gas production and consumption processes in soil are mainly due to microbial process. These gases can play diverse functions in the metabolism of microorganisms. Soil microbes has a main role in nutrient cycling and global fluxes of CO_2, CH_4 and N. World soils are projected to hold twofold amount of carbon as compared to atmosphere, making them one of the principal sinks for atmospheric CO_2 and organic carbon (Willey *et al*., 2009). Most of this carbon is stored in wetlands, peatlands and permafrost, the systems where decomposition of carbon due to microbial actions is limited. The quantity of carbon stored in the soil is directly based on the equilibrium among the carbon inputs from plants and carbon outputs from the processes of decay and heterotrophic respiration (Davidson & Janssens, 2006) and indirectly by microbial function as plant symbionts or pathogens and by modifying nutrient availability in the soil system (Van der Heijden *et al*., 2008). Minute variations in degradation rates could not only influence CO_2 emissions in the atmosphere, but also result larger changes to the quantity of carbon stored in the soil (Davidson & Janssens, 2006). Deep ploughing in carbon wealthy soils is known to increases the rates of decomposition and respiration, since it gives microbes greater contact to both buried organic carbon and oxygen (Smith, 2008).

Another significant greenhouse gas is methane and is many times more challenging than CO_2 (Schlesinger & Andrews, 2000). Natural and human-induced CH_4 emissions are due to microbial methanogenesis because methanogens reduce carbon into methane in anaerobic, carbon-rich natural ecosystems, for example wetlands, oceans etc. On the other hand these natural sources are exceeded by emissions from human activities such as rice cultivation, landfill etc. The entire methane produced by methanogenesis is not entering in to the atmosphere though, by the oxidizing action of methanotrophic bacteria methane is converted into CO_2 in the presence of oxygen. While methanogens in the soil produce methane sooner than can be used by methanotrophs in soil layers, methane escapes into the atmosphere (Willey *et al*., 2009). Methanotrophs are consequently important regulators of methane fluxes in the atmosphere.

Likewise CO_2 and CH_4 emissions, world N_2O emissions have mainly microbial in origin. Natural and manmade sources are conquered by emissions from soils, chiefly as a result of microbial nitrification and denitrification (IPCC, 2007). Soil microorganisms arbitrate the nitrogen cycle, making nitrogen available for living organisms. In the course of nitrification, microbes liberate NO and N_2O, serious greenhouse gases, into the atmosphere as intermediates. Proof suggests that humans are stimulating the release of these greenhouse gases by the application of nitrogen-containing fertilizers (Willey *et al*., 2009). The majority of the N_2O produced by nitrification is due to the activity of autotrophic ammonia (NH3)-oxidizing bacteria (Teske *et al*., 1994). In the other hand, denitrification is a long process in which every action is mediated by a definite group of microorganisms and the production of N_2O is characteristically the result of partial denitrification.

Response of soil microorganisms to increased green house gases and temperature

Activity of the microorganisms in soil are frequently dependent on environmental factors such as temperature, moisture, vegetation structure and nutrient availability, all of which are probably to be affected by climate change (IPCC, 2007). Changes in microbial activity have larger impacts in vital ecological processes such as nutrient cycling, which rely on microbial activity. Due to its importance in the global carbon cycle, changes in soil microbes may have significant response effects on climate change and harshly modify aboveground communities. Major uncertainty in climate change predictions is the reaction of soil microbes (mainly soil respiration) to warming temperatures (Briones *et al*., 2004). Numerous works showed that increased temperatures accelerate rates of microbial decomposition, thus increasing CO_2 emitted by soil respiration. Thereby large soil carbon losses and an amplification of global warming will occur (Allison *et al*., 2010). However, further studies suggest that this increase in respiration may not persist as temperatures continue to rise. Other peoples have noted that the respiration of soil microorganisms returns to normal after a number of years under warming conditions. The exact microbial processes that cause this decreased long-term response to heated conditions have not been proven, but several explanations have been proposed. Many researchers argued that the microbes take so much of the available food under heated conditions and future levels of decomposition were reduced because of food scarcity. Others argued that soil microbes adapted to the changed environment and reduced their respiration accordingly. Increased CO_2 concentrations in the atmosphere are thought to be mitigated in part by the ability of terrestrial forests to sequester large amounts of CO_2 (Schlesinger & Lichter, 2000). This sequestration was coupled with an increase in soil respiration due to the increase in nutrients available for decomposition by releasing more CO_2 into the atmosphere (Willey *et al*., 2009).

Mitigation options

The capability of different land use to store carbon varies, and it has been suggested that land type can be managed to sequester carbon in soils (Houghton, 2007). The more effective ecosystem to store carbon is Forest because forest soil contains high abundance of fungi relative to bacteria, which favour carbon sequestration (Castro *et al*., 2010). In agriculture practices, large amount of soil organic carbon losses, we can reduce this carbon loses by low- and no-tillage practices, which favour soil communities especially by fungi (Castro et al., 2010). Such agricultural systems inhibit the raise in microbial decomposition and respiration that comes from ploughing and disturbance (Smith, 2008). The transfer of croplands to permanent grassland, which causes a build-up of organic matter at the soil surface (McLauchlan et al., 2006), could also increase carbon sequestration. Furthermore, the plant functional diversity on degraded or agriculturally improved soils (Steinbeiss *et al*., 2008) could be manipulated to manage the levels of carbon released in the soil. Associated application of nitrogen-based fertilizers could enhance soil carbon storage by increasing plant production and by suppressing microbial decomposition of recalcitrant organic matter (Craine *et al*., 2007).

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Most atmospheric CH_4 is emitted by microbial communities; it is theoretically possible to control a substantial proportion of CH_4 emissions from terrestrial ecosystems by managing microbial community structure and processes. There is great potential to make effective use of inhibitors of methanogenesis, such as ammonium sulphate fertilizers, in managed systems to promote the growth of sulphate reducers at the expense of methanogens (Neue, 2007). To reduce methane emissions from ruminant livestock, strategies include improving feed quality and directly inhibiting methanogen communities in the rumen using antibiotics, vaccines and alternative electron acceptors (Smith *et al*., 2008).

A major source of human made N_2O emission is due to the use of nitrogen fertilizers in agriculture practices. Considerable quantities of added fertilizers are emitted in the form of N_2O gas, enhanced targeted fertilizer usage, which reduce the availability of nitrogen to microbes will significantly cut N_2O emissions. Potential strategies comprise reducing the quantity of fertilizer and applying it at an proper time, using slow-release fertilizers, and avoiding nitrogen forms that are possible to produce great emissions or leaching losses. In the same way, better land drainage and healthier management practices to limit anaerobic circumstances in soils could reduce denitrification rates and this leads to low N_2O emissions. Lastly, for the mitigation of N_2O fluxes from agriculture, the application of nitrification inhibitors in fertilizers to control nitrate production and subsequent leaching or denitrification losses is now a well-established strategy (Smith, 2008). Similar microorganism-mediated strategies have great potential to decrease greenhouse gas emissions from the land use and agricultural sectors.

Future Challenges

Knowledge about soil microbial ecology is essential to our capability to evaluate the relationship between soil carbon and soil microbes with warming temperature and increased CO_2. But, the complexity of the soil microbial population and its various functions joined with the numerous ways that climate and other global changes can affect soil, this uncertainty is a main challenge. Soil microbial populations are enormously diverse, and one of the greatest challenges is to understanding how microbial diversity responds to climate change and the useful consequences of this for soil carbon trade, counting the uptake, stabilization and emission of carbon from soil as greenhouse gas. Next main problem is based on diversity of carbon substrates in soil, and a major challenge is to understand the complexity of this carbon and how climate change and other environmental factors affects its availability to enzymes that catalyze its degradation. Finally, soil microbes and their activities are inextricably linked to aboveground communities, including plants, herbivores, pathogens and parasites. Understanding the effects of climate change on carbon dynamics need open consideration of the feedbacks that happen between aboveground and belowground communities and their response to climate change (Bardgett *et al*., 2008).

Conclusion

The complexity of microbial population living in soil and the different ways they interact with their background create complication to pin down the different responses that soil microorganisms may have to climate change. Soil respiration has a vital role in global warming because large quantity of CO2 and CH4 emissions produced during respiration. Advance studies in long-term feedback effects of soil respiration on climate change are needed to understand the overall microbial impacts to climate change.

References

1. Allison SD, Wallenstein MD and Bradford MA (2010) Soil carbon response to warming dependent on microbial physiology. *Nature Geosci.* 3, 336–340.
2. Bardgett RD, Freeman C and Ostle NJ (2008) Microbial contributions to climate change through carbon cycle feedbacks, *ISME Journal*., 2, 805–814.

Indian J. Edu. Inf. Manage., Vol. 1, No. 3 (Mar 2012) ISSN 2277 - 5374

3. Briones MJI, Poskitt J and Ostle N (2004) Influence of warming and enchytraeid activities on soil CO_2 and CH_4 fluxes. *Soil Biol Biochem*., 36, 1851-1859.
4. Castro HF, Classen AT, Austin EE, Norby RJ and Schadt CW (2010) Soil microbial community responses to multiple experimental climate change rivers. *Appl. Environ. Microbiol.,* 76, 999–1007.
5. Craine JM, Morrow C and Fierer N (2007) Microbial nitrogen limitation increases decomposition. *Ecology*., 88, 2105–2113.
6. Davidson EA and Janssens IA (2006) Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature,* 440, 165-173.
7. Houghton RA (2007) Balancing the global carbon budget. *Annu. Rev. Earth Planet. Sci.,* 35, 313–347.
8. IPCC (2007) Intergovernmental Panel on Climate Change. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (eds Solomon S. et al.) (Cambridge Univ. Press, Cambridge, UK, 2007).
9. McLauchlan KK, Hobbie SE and Post WM (2006) Conversion from agriculture to grassland builds soil organic matter on decadal timescales. *Ecol. Appl.,* 16, 143-153.
10. Neue HU (2007) Fluxes of methane from rice fields and potential for mitigation. *Soil Use Manag.,* 13, 258–267.
11. Schlesinger WH and Andrews JA (2000) Soil respiration and the global carbon cycle. *Biogeochemistry*, 48, 7–20.
12. Schlesinger WH and Lichter J (2001) Limited carbon storage in soil and litter of experimental forest plots under increased CO_2. Nature, 411, 466-469.
13. Smith P (2008) Land use change and soil organic carbon dynamics. *Nutr. Cycl. Agroecosyst,* 81, 169-178.
14. Steinbeiss S (2008) Plant diversity positively affects short-term soil carbon storage in experimental grasslands. *Glob. Chang. Biol.*14, 2937–2949.
15. Teske A (1994) Evolutionary relationships among ammonia-oxidizing and nitrite-oxidizing bacteria. *J. Bacteriol.,* 176, 6623–6630.
16. Van der Heijden MGA, Bardgett RD and van Straalen NM (2008) The unseen majority: soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems. *Ecol. Lett.,* 11, 296–310.
17. Willey JM, Sherwood LM and Woolverton CJ (2009) Prescott's Principles of Microbiology. McGraw-Hill, New York, NY.