Microbiology & Climate Change

By Shyamasri Biswas, PhD

Executive Editor

Role of Microorganisms in Climate Change Biology

Microorganisms and Microbial Biodiversity

Microorganisms are believed to have existed since the origin of life on Earth, which dates back to at least 3.8 billion years ago [1]. They are the sole life forms in all environments and they thrive in all environments including the deep subsurface and extreme environments that are occupied by macroscopic organisms on earth [1]. Microorganisms are usually invisible to the naked eye. But, their abundance and robust presence (~1030 total bacteria and archaea) along with the appreciable diversity make them critically important and significant contributors in maintaining a healthy global ecosystem [1-4].

Thus, it is believed that the microbial world constitutes the life support system of the biosphere. Microorganisms are also believed to be crucial in regulating climate change. They make major contributions in carbon and nutrient cycle. Particularly, they are known for their contribution to carbon sequestration, especially marine phytoplankton that consume as much net CO_2 as terrestrial plants [1]. In addition, they play key roles in animal (including human) and plant health, agriculture and the global food web [1].

However, there is a major concern that the current rapid pace of changes in microbial biodiversity and activities globally could potentially affect the capacity of all other organisms that could eventually diminish their ability to respond to climate change. For example, unfavorable environmental changes that negatively affect marine microbial photosynthesis and subsequent storage of fixed carbon in deep waters could bring catastrophic effects to the global carbon cycle [1]. So, currently there is a significant emphasis on undertaking research to understand human effects on microorganisms that have been less studied and characterized so far [1-4].

There are many research questions that need to be addressed including influencing factors that can balance the microbial greenhouse gas capture versus emission. Especially, it is critical to understand the biome, the local environment, food web interactions and their responses in addition to anthropogenic climate change and other human activities [1]. So the goal is to understand how microorganisms affect climate change (including production and consumption of greenhouse gases), and also how microorganisms will be affected by climate change and other human activities [1].

Microorganisms and Climate Change With Respect To Marine and Terrestrial Biomes

About 70% of Earth's surface is covered by marine biomes. This include coastal estuaries, mangroves and coral reefs to the open oceans (Figure 1) [1]. The sun's energy in the top 200 m of the water column is used by phototrophic microorganisms. On the other hand, it is believed that marine life in deeper zones uses organic and inorganic chemicals for energy [1, 5]. The composition of marine communities is influenced by sunlight and other available forms of energy water temperature (ranging from approximately −2 °C in ice-covered seas to more than 100 °C in hydrothermal vents) [1, 6].

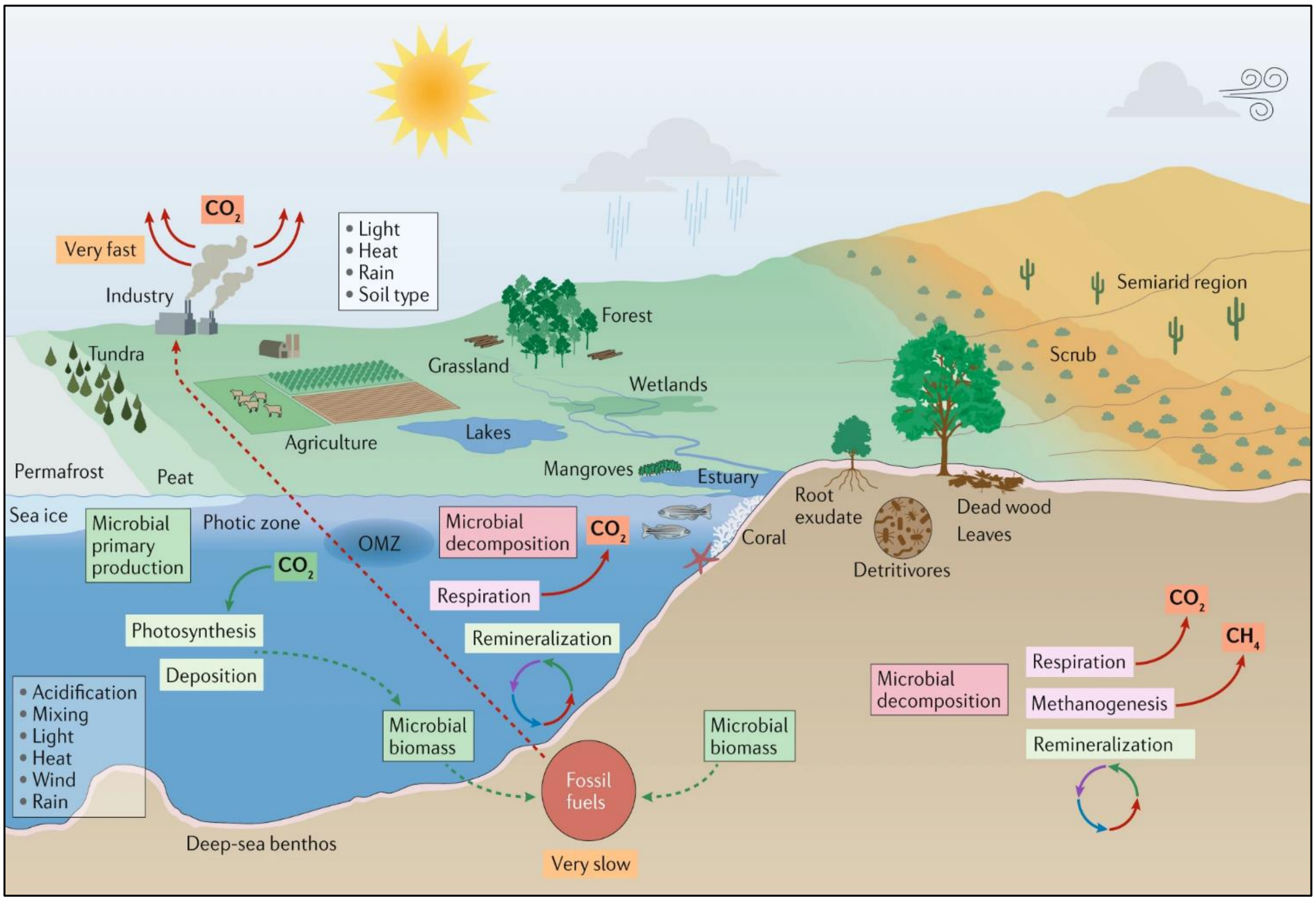

Figure 1: A pictorial depiction showing how microorganisms and climate change occur in marine and terrestrial biomes [Source: Nature Reviews Microbiology (2019)].

Previous studies have shown that rising temperatures not only affect biological processes but also it can reduce water density [1]. This can result in stratification and circulation affecting organismal dispersal and nutrient transport [1]. Stratification, mixing and circulation are also affected by precipitation, salinity and winds. Further, it has been found that microbial community composition and function all are affected by nutrient inputs from air, river and estuarine flows, and climate change affects all these physical factors [1].

Researchers have shown microbial primary production contributes substantially to CO_2 sequestration in marine environments (Figure 1) [1]. During the process of releasing CO_2 to the atmosphere, marine microorganisms also recycle nutrients for use in the marine food web. It has been observed that microorganisms are the key decomposers of organic matter in a broad range of terrestrial environments, where they release nutrients in the soil for plant growth as well as CO_2 and CH_4 into the atmosphere (Figure 1) [1]. Studies have confirmed that over millions of years, conversion of microbial biomass and other organic matter (remnants of plants and animals) to fossil fuels has been happening at a regular pace. By contrast, it has been found that burning of fossil fuels liberates greenhouse gases in a small fraction of that time [1]. This puts the carbon cycle out of balance, and as a result, it is predicted that atmospheric CO_2 levels will continue to rise as long as fossil fuels continue to be burnt (Figure 1) [1]. Additionally, the complex network of microbial interactions that occur with other microorganisms, plants and animals are significantly influenced by the effects of human activities, including agriculture, industry, transport, population growth and human consumption. This can also be combined with local environmental factors, including soil type and light [1]. All these observations on interactions indicate that how such microorganisms respond to variations and it affects climate change including for example, through greenhouse gas emissions [1]. This also strongly suggests how climate change including higher CO_2 levels, warming, and precipitation changes can affect microbial responses [1].

Microorganisms and Climate Change With Respect To Agriculture and Other Human Activities

Microbial communities are influenced by various agricultural practices influence in specific ways [1]. For example, plant type and land usage and sources of pollution including chemical fertilizers can significantly alter microbial community composition and function. This can result in perturbing natural cycles of carbon, nitrogen and phosphorus transformations [1]. Further, it has been observed that methanogens can produce substantial quantities of methane directly from ruminant animals including cattle, sheep and goats. This also includes saturated soils with anaerobic conditions, which are basically rice paddies and constructed wetlands. It can be concluded then from this observation that lesser human activities that cause a reduction in microbial diversity can also simultaneously reduce the capacity for microorganisms that can help support plant growth [1].

In addition to the anthropogenic methane production associated with standard fossil fuels, studies have shown that methanogens can also produce methane in natural and artificial anaerobic environments including sediments, water-saturated soils such as rice paddies, gastrointestinal tracts of animals (particularly ruminants), wastewater facilities and biogas facilities (Figure 2) [1, 7]. It is to be noted that atmospheric oxidation and microbial oxidation in soils, and sediments and water act as the main sinks for CH4 [1, 7]. Recent studies have indicated a sharp rise in the atmospheric CH4 levels in recent years (2014–2017). However, the reasons for this rise are unclear so far. It is generally believed that such rise in CH4 levels might involve increased emissions from methanogens and/or fossil fuel industries and/or reduced atmospheric CH4 oxidation, which indicate a potential major threat to efforts in combatting climate warming (Figure 2) [1, 8].

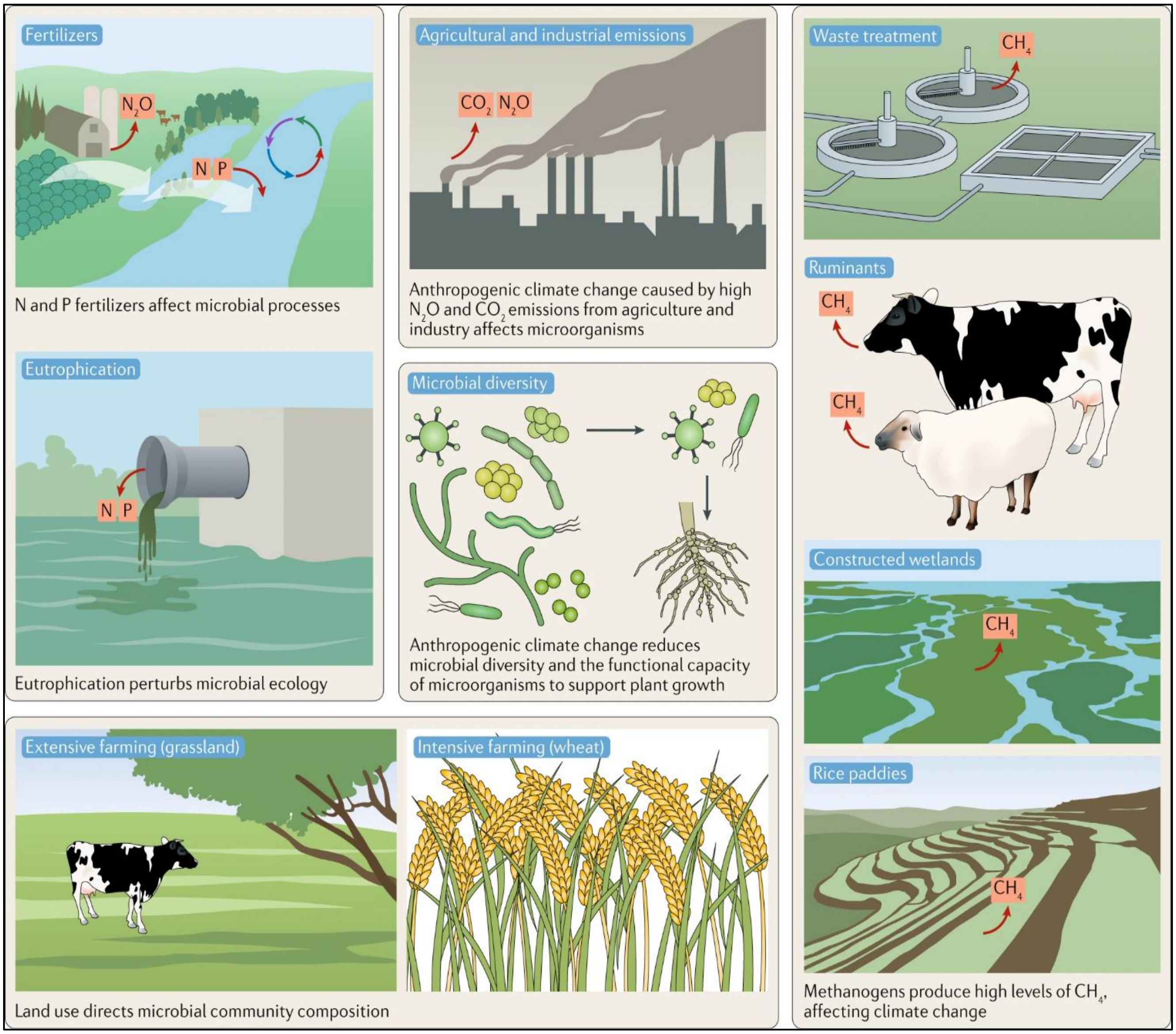

Figure 2: Agriculture and other human activities are shown that can affect microorganisms [Source: Nature Reviews Microbiology (2019)].

Concluding Remarks

The ongoing research efforts have clearly indicated the central role and global importance of microorganisms in climate change biology. Researchers have apparently established a consensus on the observations that responses of microorganisms will heavily impact and govern climate change. A positive and favorable scenario in the responses of microorganisms to the changing climate could essentially achieve an environmentally sustainable future.

References for further reading

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