Integrating aboveground–belowground responses to climate change

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A growing body of evidence clearly indicates that climate change is a major driver of ecosystem change and alter the structural and functional attributes of various systems. However, it is unclear that how above- and belowground parts will respond to climate change. Therefore, majority of the ecosystem models could not consider key variables modulating above- and belowground responses while modelling ecosystem response to climate change. Here we discuss the importance of integrating above- and belowground responses to climate change so that it would be helpful for ecosystem modelling and predicting their response to climate change.

Over the last few decades, there is a growing consensus that global climate change is a major driver of ecosystem change and evidenced to alter the structural and functional entities of various ecosystems[1]. Despite the mounting evidence of the impact of global climate change on aboveground responses such as species range and distribution, phenology, biomass, primary productivity and even vegetation–climate interactions at various scales[1–4], there is a dearth of knowledge on the impact of global climate change on above- and belowground responses and ecosystem functioning[2,5]. As a result, majority of the ecosystem models could not include key variables modulating above- and belowground interactions while modelling ecosystem response to climate change. The present note is aimed to highlight the importance of integrating above- and belowground response to climate change so that this integration would help in empirical ecosystem modelling and developing suitable strategies for the sustainable management of ecosystems under changing climate.

Although it has been generally perceived that increasing atmospheric CO_2

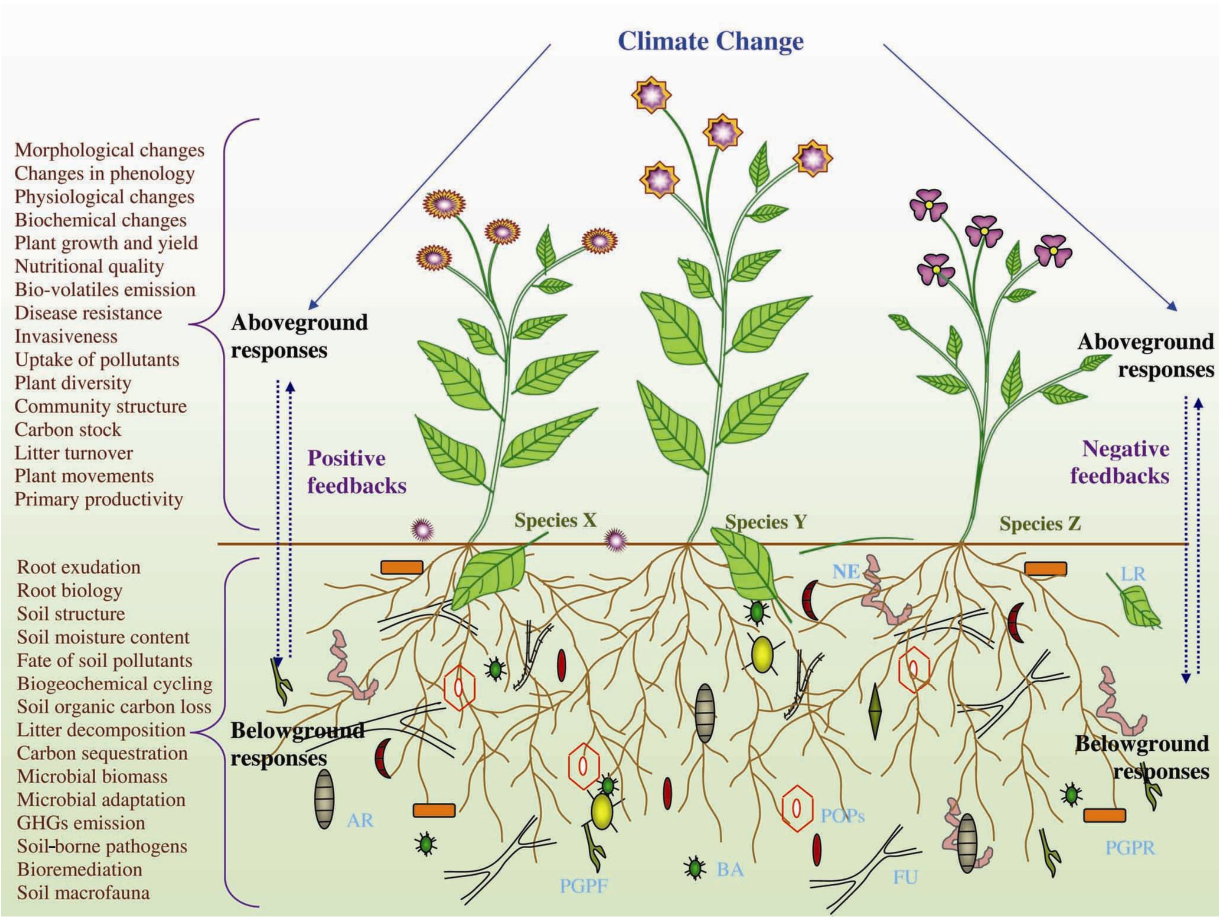

Figure 1. The potential impact of climate change on aboveground and belowground responses. It has been perceived that climate change may affect the morphology, phenology, physiology and biochemistry of the plant species, which in turn affect the root exudation, root biology, soil properties, soil organic content and microbial diversity. Therefore, integrated models are essential to understand the impact of climate change on ecosystem structure and functions. AR, Arthropods; PGPF, Plant growth promoting fungi; PGPR, Plant growth promoting rhizobacteria; NE, Nematodes; LR, Litter; POPs, Persistent organic pollutants; BA, Bacteria; FU, Fungi.

will enhance plant growth and photosynthetic rates and will increase the allocation of nutrients in above- and belowground parts, it is unclear how the changes will affect soil biology and biochemistry[6–8]. Since soil is one of the important life-supporting systems and the regulator of all elemental cycling in nature, attention should be paid to study the response of soil system to climate change and the subsequent changes in its aboveground counterparts and vice versa. Furthermore, it acts as a major sink of carbon[9]. However, one of the major impediments for predicting the impact of global climate change on the homeostasis of soil system is the paucity of empirical evidences from long-term studies conducted in different climatic and bio-geographical zones[6]. Furthermore, majority of the soil system models are based on limited observations and variables such as above- and belowground plant biomass, soil microbial biomass, microbial nutrient content, soil C and N ratio and its mobilization, immobilization, mineralization rates, etc.[10], and completely ignoring the microbial physiology under changing climatic conditions.

Importantly, soil response to changing climatic conditions is essential to understand the productivity of the soil and the real rate of trace gases emission from the soil. It is also essential to understand the carbon sequestration capacities and turnover in the soil[11,12]. While most of the ecosystem models predicted that warming climate will have a positive feedback on the microbial decomposition of soil organic matter (SOC)[11], field experiments clearly showed an initial loss in soil carbon followed by gradual decline and stabilization due to the lower rate of SOC decomposition[12]. This was mainly due to the fact that in simulation models, soil carbon response to warming climate is predicted on the basis of the first-order decay of SOC by soil microbes, whereas in the case of field experiments, the gradual stabilization in microbial decomposition rate has been attributed to the microbial adaptation to climate change and particularly due to their strategy for using various forms of soil carbon or due to their enhanced carbon use efficiency. This indicates that soil carbon response to warming climate is strongly dependent on microbial physiology and adaptation rather than temperature alteration[12–14]. As a result, new models are integrating SOC turnover with microbial biomass and extracellular enzymes and investigating the role of microbial catabolic enzymes on the conversion of polymeric SOC to dissolved organic carbon (DOC)[12,14].

However, more empirical studies on above- and belowground interactions are essential to substantiate the impact of warming climate on microbial responses and soil carbon sequestration. Moreover, the response of nutrient cycling to warming climate not only depends on the microbial physiology or their efficiency in using different forms of soil C, but several additional tipping elements are required for modelling the impact of climate change on soil carbon pool (Figure 1). Among the important aspects in this line are the plant–microbe interactions and associated microbial functional diversity changes in soil in response to warming climate. Previous studies showed that increasing atmospheric CO_2 will have fertilization effect on plants and will enhance the DOC content in rhizospheric soil through enhanced root exudation[6,15]. As a result, it is expected to have a shift in microbiome in rhizospheric soil. Moreover, there are other factors to be considered which will have a direct impact on the soil system, such as the presence of various chemical pollutants, soil moisture content, soil macro fauna, etc.[15,16]. Therefore, we postulate that the warming climate will significantly affect the mobility of pollutants and nutrients in the soil system, which in turn will have a potential impact on soil microbial communities and diversity. The changes in microbial community will also affect the plant–microbe interactions, biomass and primary productivity. Therefore, integrated understanding of above- and belowground responses is essential to predict the impact of climate change on ecosystem structure and functions and modelling their response to changing climate.

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