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Short Communication

Soil microbial biomass: A key soil driver in management of ecosystem functioning

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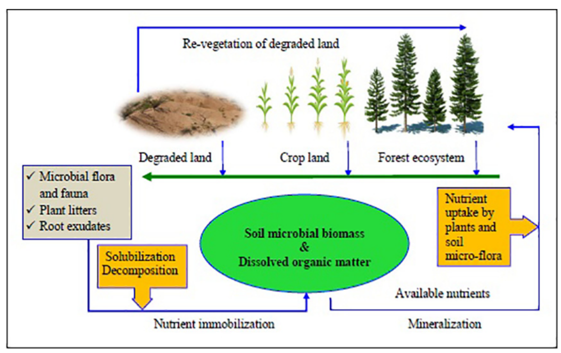
HIGHLIGHTS

- Soil microbial biomass as a key ecological driver has been described.
- Soil microbial diversity and biomass play key roles in the ecosystem services.
- Soil micro-flora N uptake is an adaptation for short-term storage of N in terrestrial ecosystems.
- Soil microbial biomass is key ecological driver in rehabilitation of degraded lands.

GRAPHICAL ABSTRACT



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ABSTRACT

Although patterns of microbial diversity and biomass have been described and reviewed at local and regional scales, a unifying driver, or set of environmental drivers affecting soil microbial biomass (SMB) pattern at global level is still missing. Biomass of soil microbial community, known as SMB is considered widely as the index of soil fertility and ecosystem productivity. The escalating soil stresses due to land degradation and climatic variability are directly correlated with loss of microbial diversity and abundance or biomass dynamics. Therefore, alleviating soil stresses on microbial communities with ecological restoration could reduce the unpredictability and turnover rates of SMB. Thus, the key ecological factors which stabilize the SMB and minimize its turnover, are supposed to play an important role in the soil nutrient dynamics and productivity of the ecosystems. Because of the existing public concern about the deleterious impacts of ecosystem degradation, there is an increasing interest in improving the understanding of SMB, and the way, it contributes to restoration and functioning of ecosystems.

1. Microbial biomass under different ecological regimes and ecosystem types

Functioning of ecosystems rely on the flux of chemical signals, carbon, and nutrients across the trophic levels, mainly mediated by microbial interactions in the soil-plant-animal food web (Seneviratne, 2015). Soil microbial diversity and abundance/biomass play key roles in the ecosystem sustainability by maintaining essential functions of soil health, through carbon and nutrient turnover. Even after disturbances, an ecosystem with a higher microbial diversity and biomass may have a higher capacity to sustain the ecological processes through microbiological buffering. There is now increasing evidence that aboveground (plant litter quantity and quality) and belowground (soil

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microbial flora and fauna diversity) are key drivers that play fundamental roles in controlling ecosystem processes and stability (Wardle et al., 2004). However, understanding ecological linkages between above- and belowground abiotic and biotic (including SMB) attributes is still a key challenge for our knowledge on the stability and functioning of ecosystem processes. Therefore, given the importance of SMB dynamics in defining ecosystem properties, the understanding as to how SMB respond to unexpected rise in biotic and abiotic drivers and loss of plant species diversity seems a research priority that would shed light on the performance of diverse ecosystems.

Among the various ecological drivers, microbes (N_2-fixers, P-solubilizers, growth hormone producers, etc.) and their SMB pools may be considered as major ecological impetus in controlling the diverse ecosystem functions globally (Table 1). Soil carbon (C) and nitrogen (N) together with phosphorus (P) and soil pH are the key drivers that may limit the functioning of various nutrient deprived ecosystems (Bru et al., 2011; Carnicer et al., 2015). In strongly soil N deprived ecosystems such as Arctic and Alpine Tundra and Temperate forests, nutrients release after soil micro-flora (SMB) death has been pointed out as an important source of plant nutrient N (van der Heijden et al., 2008). So, it is suggested that uptake of N by soil micro-flora might be an adaptation that may have developed for short-term storage of N in several terrestrial ecosystems, thus reducing the loss of N from the soil of nutrient poor ecosystems. It is also important to mention here that the chemical composition of plant residues (litter and fine roots) from diverse plant species in an ecosystem could be unpredictable and therefore, different microbial communities might be evolved to decay and decompose the variety of litter types. As many microbial communities have restricted bio-geographic distributions (N_2-fixing rhizobia in tropical forests and mycorrhizae in boreal temperate forests) it is suggested that variations in the size of SMB can impact to variability of the functioning of various ecosystem types.

Table 1
Microbes as key ecological drivers regulating functioning of diverse ecosystems.
Source: van der Heijden et al. (2008) Ecol. Lett. 11: 296–310.

Ecosystem type	Microbes	Microbial functions
Tropical savannah, some grasslands and tropical forests	Symbiotic, free living and endophytic N-fixing bacteria	Support plant productivity by supplying different limiting nutrients (N) to the plants. Endophytes enhance growth and competitive ability of their host plants.
Deserts and boreal forests	N-fixing cyanobacteria	Contribute to the N economy of ecosystems via N cycling and accumulation under extremely limited N_2-fixation situations. Helps in degraded land restoration.
Tropical, temperate and boreal forests, grassland and savannah ecosystems	Arbuscular mycorrhizal (AM), Ectomycorrhizal (EM) and Ericoid mycorrhizal (ERM) fungi	Enhanced P uptake of host plant species when plant productivity is strongly limited by P availability. Provide resistance to plants against diseases, drought and other environmental stresses in nutrient poor and degraded ecosystems.
Natural ecosystems	P-solubilizing bacteria	May constitute up to 40% of the cultivable population of soil bacteria. However, significance of bacteria in natural ecosystems is still in enigma and further studied are still warranted.
Tropical forests	Nitrifying and denitrifying bacteria	Indirectly reduce plant productivity because about 50% of available soil N is lost from the ecosystem by nitrification and denitrification processes

The rise in unpredictable climate shift and anthropogenic perturbations are the critical drivers to regulate the existence and survival of indigenous microbial diversity, and consequently, the essential soil functioning of the ecosystem. The macroclimate, topography and soil quality (pH, organic C and N, moisture, etc.) are the key drivers in controlling SMB dynamics across different ecosystems and locations (Wardle, 1992). The temporal dynamics of SMB is likely to be the key factor in determining the extent of release of immobilized labile nutrients due to microbial cell deaths, and the availability of nutrients released crucial to plant growth and ecosystem functioning (Wardle, 1998). The factors that provide viability to the soil microbial community therefore, are assumed to enhance soil nutrient conservation in the form of higher SMB size owing to the reduced release of immobilized nutrients. While studying the effect of climatic disturbances on ecosystem types, we may expect SMB to have lesser temporal variability owing to lesser disturbances.

Along a large geographical area, climate variability, land use types and the dominant vegetation composition might be the key factors for SMB variability across different ecosystem types. Differences in the quantity and quality of substrate (organic C and N) inputs caused by varying plant residue types (litter and fine roots) and the associated nutrient specificity can be crucial drivers to influence the SMB across the ecosystem types. Thus, the higher SMB in soil of scrub stand than other ecosystems might be attributed mainly to the greater availability of organic matter via vegetation cover with giant plant species. However, in case the temporal data on SMB from different ecosystems across the globe were quantitatively analyzed, more persistent and less disturbed ecosystems had higher SMB values than the most disturbed one (Wardle, 1998), though the temporal variability of different ecosystem types was substantially comparable. This indicates that temporal SMB variability is solely governed by the dominant vegetation and land use type, but the nutrient turnover along with other edaphic factors can be more effective than those in regulating the temporal SMB variability. However, it is suggested that shifts in plant species composition during land use change, can influence the microbial community composition dynamics and SMB basically by changing soil organic nutrient status (Zhang et al., 2016). But it is still unclear as to why SMB is not so responsive to large-scale disturbance regimes, such as invasions of alien species into new territories, climate change due to atmospheric CO_2 elevation, greater soil nitrogen deposition and land use changes (Wardle et al., 2004), and therefore, further studies in this regard, will enhance our understanding about temporal microbial community compositions and biomass variability.

Although nutrient status, seasonality, soil factors, temperature, and other factors, are important drivers to control functioning of dry tropical forest ecosystem, SMB could be one of the vital factors affecting productivity in the tropical dry deciduous forests, as observed in the Vindhyan plateau (Singh et al., 2010). In India, the previous investigations regarding SMB across the tropical dry deciduous forest ecosystems have been conducted by selecting only one or the other sites on a temporal scale, and without deciphering differences in SMB status and its role in distribution and variations of the dominant vegetation composition. It may be hypothesized that alterations in soil properties due to land uses and anthropogenic activities would correspond to differences in the SMB size and turnover rates and consequently, to loss of vegetation cover and ecosystem productivity. However, the experimental evidence for such arguments is still warranted.

In nutrient poor ecosystems, SMB acts as the major reservoir of available nutrients, and plays very crucial roles in the survival of plants (Singh et al., 2016a, 2016b; Vimal et al., 2017). In the dry tropical deciduous forest ecosystem, nutrient withdrawal from the senescing leaves and its immobilization in the SMB has been considered as the nutrient conserving adaptations in response to nutrient paucity, and thus SMB