Importance and Management of Soil Biology for Sustainable Agriculture

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Soils form on surface of the earth. Soils provide the base for cycling of matters and transfer of energy and hence, consider as nature's integrator. They interact reciprocally with the biosphere, hydrosphere, lithosphere and atmosphere (McGill, 2007). The interactions among these four spheres involve biological, chemical, biochemical, and physical transformations and biological and physical translocations. Soil organisms especially microorganisms are intimately involved in biological and biochemical transformations. Soil organisms are both sinks for elements and catalysts to speed transformations of elements. Hence, physiology and biochemistry of soil organisms is fundamentally important to understanding earth systems. Before understanding eco-physiology and biochemistry of soil organisms (What are they doing at ecosystem level?); it is essential to identify "Who are they and what are their biogeographic distributions at spatial- and temporal scales?"

The governments of various countries including India are becoming increasingly concerned about sustaining biodiversity and maintaining life support functions. Emphasis has been given by implementing several regional or national programmes to monitor soil quality and /or the state of biodiversity. Most monitoring programmes include microbiological indicators, because soil microorganisms have key functions in decomposition and nutrient cycling, respond promptly to changes in the environment and reflect the sum of all factors regulating nutrient cycling. Policy makers, as well as land users, need indicators and monitoring systems to enable them to report on trends for the future and to evaluate the effects of soil management.

Soil fauna

Members of the soil fauna are numerous and diverse and include representatives of all terrestrial phyla (Wolters, 2001; Coleman and Wall, 2007). Many groups of species are not described taxonomically and details of their natural history and biology are unknown (Fig. 1). For example, among the microarthropods only 10per cent of populations have been explored and perhaps 10per cent of species described (André *et al.*, 2002). So, soil biologists feel protection of biodiversity in ecosystems clearly must include the rich pool of soil species including micro-organisms, mesofauna, macro- and megafauna. Recent advance research on roles of soil biota and ecosystem processes generated data for some of these soil species individually or collectively and these findings indicated tight connections to biodiversity aboveground, major roles in ecosystem processes, and provision of ecosystem benefits for human well-being (Wall, 2004; Wall *et al.,* 2005).

In general, soil fauna are separated into four size classes: microfauna, mesofauna, macrofauna and megafauna. Swift *et al.* (1979) proposed the size classification of organisms in decomposer food webs by body width. This classification encompasses the range of body width for microfauna and mesofauna are less than 100-µm and between 100-µm to 2-mm, respectively. The range of body width for macro- and megafauna is from 2-mm upto 20-mm. However, there is considerable gradation in the classification based on body width. For example, the smaller mesofauna exhibit characteristics of the microfauna, and so forth. The members of Nematode, Protozoa and Rotifera are microfauna; the members of Acari, Collembola, Protura, Diplura, Symphyla, Enchytraeidae, Chelonethi, and Isoptera are mesofauna; the members of Opiliones, Isopoda, Amphipoda, Chilopoda, Diplopoda, Megadrili (earthworms), Coleptera, Araneida and Mollusca are within macro- and megafauna.

There is considerable overlapping in body width ranges of the members of the macro- and megafauna. The vast range of body sizes among the soil fauna emphasizes their effects on soil processes at a range of spatial scales. Three levels of participation have been suggested (Lavelle *et al.*, 1995; Wardle, 2002). The fauna, those alter the physical structure of soil and influence the rates of nutrient and energy flow are considered as “Ecosystem engineers”; for example: earthworms, termites, or ants. The microarthropods fragment decomposing litters and improve its availability to microbes and are considered as “Litter transformers”. And the third level of participation “Micro-food webs” includes the microbial groups and their direct micro faunal predators (nematodes and protozoans). The feeding habits of different groups of soil fauna and their possible role in soil processes are presented in the Table 1.

Soil fauna plays important role in assisting microbes in colonizing and extending their reach into the horizons of soils worldwide. Being soil faunas’ roles as colonizers, comminutors and engineers within soils, it is important to establish how soil fauna contribute to long-term soil sustainability with respect to global environmental issues.

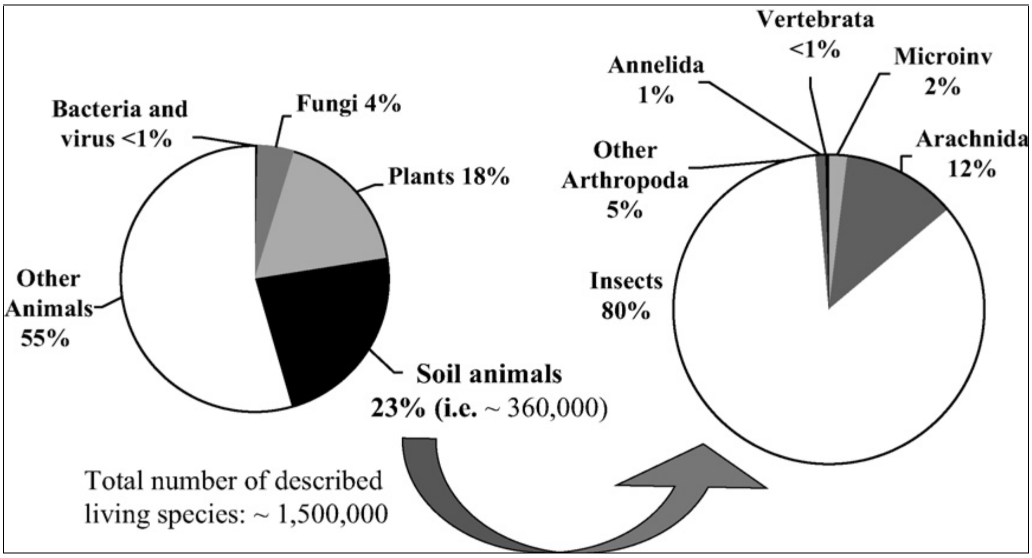

Fig.1. Importance of soil animals for (a) the global biodiversity and (b) relative importance of major taxa within soil communities worldwide (data adapted from Decaëns *et al.*, 2006).

Table 1: Population and feeding habits of soil fauna and their roles in soil processes

Soil faunal group	Population (numbers)	Feeding habit	Possible role in soil process
Protozoans (flagellates-, naked-, testate-, and ciliate amoebae)	10^2 g^{-1} in desert soil to 10^5 g^{-1} in forest soils.	Bacteria principal prey items. Phagotrophic with bacteria, fungi, algae and other fine particulate organic matter.	Nutrient turnover in the rhizosphere and production of plant-growth promoting substances.
Rotifera	Some cases numbers may exceed 10^5 m^{-2} in moist organic soils.	Vortex feeders, creating currents of water that conduct food particles, such as unicellular algae and bacteria.	Role of rotifers in soil processes is largely unknown.

Soil faunal group	**Population (numbers)**	**Feeding habit**	**Possible role in soil process**
Nematoda	330-4650 individuals per 250ml soil (Yeates *et al.,* 1999)	Bacteria feeders, fungal feeders, plant root feeders, top predators, omnivores and plant associates.	Nutrient turnover and soil organic matter decomposition dynamics.
Microarthropods (mainly mites and collembolans)	33-88 x 10^3 individuals m^{-2} in temperate forest floor; 130 x 10^3 individuals m^{-2} in conifer forest floor and less density in tropical forest floor.	Feeds on bacteria, fungi, mineral soil particles, organic matter, protozoa, and nematodes	In soil food web chain, microarthropods link the microfauna and microbes with mesofauna and in turn microarthropods are prey for macroarthopods, such as spiders, beetles, ants and centipeds. Thereby, microarthropods have significant impact on litter decomposition processes.
Enchytraeids (Known as potworms and classified as “microdrili” oligochaetes)	4,000-14,000 individuals m^{-2} in agricultural plots and >140,000 individuals m^{-2} in peat moor	Feeds on finely fragmented plant residues often enriches with fungal hyphae and bacteria (approx. 80per cent of the population is microbivorous and 20per cent of the population is saprovorous).	Significant effects on soil organic matter dynamics and on soil structure formation through fecal pellets. For example: enchytraeid fecal pellets constritutes nearly 30per cent of the volume of A_h horizon in Scottish grassland soils.
Macrofauna **Oligochaeta** (Earthworms) **Formicidae** (Ants) **Termitidae** (Termites)	Typical densities of earthworms in tropical forest and certain arable lands range from <100 to over 400 individuals m^{-2}. Ants’ population is generally large in tropical areas. In Amazonian rainforest ants population in excess of 8 million per hectare. Similarly, termite may constitute up to 75per cent of insect biomass and 10per cent of all terrestrial animal biomass in the tropics.	Feeding groups of earthworms: Epigeic, endogeic and anecic; Ants are major predator of small invertebrates and their activities also reduce the abundance of other predators such as spiders and carabid beetles; termites have three nutritional categories viz. wood-feeders, soil humus feeders and fungus growers.	Consider as “ecosystem engineers”. Effect on soil structure through formation of biogenic structure and burrowing activities. For example: earthworm casts above- and belowground; termite nets. Plays significant roles on soil food web and ecosystem processes, such as nutrient cycling, SOM decomposition dynamics and effects on microbial and other microfaunal community structure etc. Ants move large volumes of soil, as much as earthworms do.

(Population density data adapted from Coleman and Wall, 2007).

Soil micro organism

Ecosystem functioning is governed directly by soil microbiota, although they are affected by the activities of soil animals living alongside (Schimel, 2007). The functional processes such as nutrient cycling, residue decomposition, soil structure formation, and plant interactions, both positive and negative are regulated by soil microbiota communities and thereby, they regulate the productivity and health of agricultural systems (Kennedy and Papendick, 1995; Pankhurst *et al.,* 1996; Harris, 2009). Recent advance findings on soil biochemistry, microbial eco-physiology and biogeochemical cycles have strongly indicated that soil organisms especially microbiota perform the biogeochemical transformations that determine ecosystem C and N cycling rates (Paul, 2007). For example, dynamics of C and N are known to interact closely during decomposition due to simultaneous assimilation of C and N by the heterotrophic soil microbiota (Sall *et al.*, 2007). Therefore, it is necessary to determine microbiota diversity and quantification of variability in the microbiota community composition to better understand their functional role on regional and landscape level differences in biogeochemical cycling.

Exciting achievements on molecular microbial ecology during the past two decades made it clear that the most important gene for prokaryote phylogeny is the 16S ribosomal RNA (rRNA) gene (length of the gene approximate 1500 bases), which is present in all cells. This gene possesses regions in which sequences are conserved, facilitating sequence alignment for homology between organisms, and the variable and hypervariable regions, which enable discrimination between organisms. Woese *et al.* (1990) divided prokaryotes into two major domains, the Archaea and the Bacteria using the 16S rRNA gene analysis approach. This discovery is regarded as one of the most important events in the history of microbial ecology. Analysis of 16S rRNA sequences those retrieved from various natural habitats led to identification of several phylogentic groups within the domain bacteria (Table 2).

Table 2: 16S rRNA based phylogenetic groups of bacteria, their habitat and metabolism

Bacterial group	Environmental origin	Metabolism
Aquificales	Extreme environments (hot, sulphur pools, thermal vents)	Microaerophilic, chemolithotrophic, can oxidise hydrogen and reduced sulfur
Thermodesulfobacterium	Thermal vents	Sulfate reducers, autotrophic or organotrophic, anaerobic
Thermotogales	Hot vents and springs (moderate pH and salinity)	Sulfur reducers, organotrophic, some produce hydrogen
Coprothermobacter	Anaerobic digesters, cattle manure	Heterotrophic, methanogenic, sulfate reduction
Dictyoglomus	Hot environments	Chemoorganotrophic
Green non-sulfur bacteria and relatives	Wide range but few cultured	Anoxygenic photosynthesis, organotrophic
Actinobacteria (high G+C gram-positives, including actinomycetes)	Soil, some are pathogens	Aerobic, heterotrophic-major role in decomposition
Planctomycetes	Soil and water	Obligate aerobes
Chlamydia	Intracellular parasites	Heterotrophic
Verrucomicrobia	Freshwater and soil; few cultured	Heterotrophic
Nitrospira	Soil and aquatic environments	Autotrophic nitrite oxidizers, facultative heterotrophs

Acidobacterium	Wide range of environments, including soil	Acidophilic or anaerobic (very few cultured)
Synergistes	Anaerobic environments (termite guts, soil, anaerobic digesters)	Anaerobic
Flexistipes	Animals	
Cyanobacteria	Aquatic but found in soil	Oxygenic, photosynthetic, some fix N_2
Firmicutes (Low G+C gram-positive)	Soil, water, some are pathogens	Aerobic or anaerobic (rarely photosynthetic)
Fibrobacter		
Green sulphur bacteria	Anaerobic and sulphur containing muds, fresh water and marine	Photosynthetic, anaerobic, autotrophic or heterotrophs
Bacteroides-Cytophaga-Flexibacter group	Wide variety, including soil, dung, decaying organic matter	Aerobic, microaerophilic or facultatively anaerobic, organotrophs, some strict anaerobes (*Bacteroides*)
T hermus/ Deinococcus	High-temperature environments, nuclear waste	
Spirochetes and relatives (Spirochetes and leptospira)	Wide range	Chemoheterotrophic
Fusobacteria	Pathogens	Anaerobic
Proteobacteria	"Classical" gram-negative bacteria	Hetertrophic, chemolithotrophic, chemophototrophic, anaerobic (most) or aerobic, some photosysnthetic, some fix N_2
Adapted from Killham and Prosser (2007)		

Biodiversity and scale of investigations to study function and abundance of soil biota

The idea of biodiversity values, a concept which had previously restricted to the limited aesthetic and touristic aspects of wildlife. In the year 1992, the International Convention on Biodiversity in Rio de Janeiro focused on "the forgotten environmental problem" of biodiversity erosion and made the first clear reference to the values of living species. Biodiversity was defined as "the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within and between species, and of ecosystems" (Heywood and Baste, 1995). Thus, biodiversity values refer to direct or indirect, economic or non-economic interests, a given species or ecosystem may represent for human populations (Decaëns *et al.*, 2006). These values are generally split into intrinsic and instrumental (use) values. The instrumental values can divided into direct and indirect economic values. Obviously, each of these values carries different weights, and cannot be considered as being weighted equally in terms of justification for species or ecosystem conservation.

Adequate experimental design and sampling strategy are important considerations before starting any analysis in soil biology. Fine-scale approaches such as pico- and nanoscale investigations related to microbial diversity and microbial eco-physiology are used to reveal the structure and chemical composition of organic substances and microorganisms as well as to investigate the interactions between the biota and humic substances. These fine-scale approaches can identify soil organisms, unravel their relationships, determine their numbers, and be used to measure the rates of physiological processes. Such results gradually boost our understanding of chemical and biological processes and structures at larger scales. Microscale investigations refer to either on soil aggregates or on microhabitats characterised by high turnover of organic materials (e.g. the rhizosphere, drilosphere, and soil-litter interface). High-activity areas are heterogeneously distributed within the soil matrix. Biologically active hot-spots may make up less than 10per cent of the total soil volume, yet may represent more than 90per cent of the total biological activity (Beare *et al.*, 1995). Therefore, interpretation of data on the abundance and function of soil biota must include some physico-chemical and biological properties in the study sites (Table 3), such that up-scaling of data from microscale to the plot or regional scale can be done using the unified concepts in soil biology.

Table 3: Physical, chemical, and biological properties that help to interpret on the function and abundance of soil biota

Physical and chemical properties of soil		**Biological properties of soil**
Topography	Particle size and type	Plant cover and productivity
Parent material	CO_2 and O_2 status	Vegetation history
Soil type and soil pH	Bulk density	Abundance of soil animals
Moisture status	Temperature: range and variation	Microbial biomass and activity
Water infiltration	Rainfall: amount and distribution	Organic matter inputs and roots present
Adapted from Kendeler *et al.* (2007)		

Criteria for indicators of soil quality

Soil quality is an important component of sustainable agriculture, because a healthy, functioning soil is fundamental to sustainable crop and livestock production and a healthy environment. Soil quality does not depend just on the physical and chemical properties of soil, but it is very closely linked to the biological properties of soil. Many soil properties affect soil quality, and most are influenced by microbiological processes. Soil properties affected by the size and composition of the microbial biomass include water holding capacity, infiltration rate, crusting, erodibility, aggregate stability, susceptibility to compaction, nutrient cycling, available nitrogen, nutrient capacity, and soil organic matter content.

Indicators of soil quality must fulfil several criteria and these criteria are relate mainly to: (i) their utility in defining ecosystem processes; (ii) their ability to integrate physical, chemical and biological parameters; and (iii) their sensitivity to management and climatic variations (Doran, 2000). These criteria apply to soil organisms, which are thus useful indicators of sustainable land management. Ideally, soil organisms and ecological indicators should be:

1. Sensitive to variations in management;
2. Well correlated with beneficial soil functions;
3. Useful for elucidating ecosystem processes;
4. Comprehensible and useful to land managers;
5. Easy and inexpensive to measure.

Management of soil biota community and their activity

At the core of ecosystem health is soil quality, defined as “the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health”. The major issues of soil health are:

1. productivity – ability of soil to enhance plant and biological productivity;
2. environmental quality – the ability of soil to attenuate environmental contaminants, pathogens, and offsite damage;
3. plant and animal health – the interrelationship between soil quality and plant, animal, and human health.

A major attribute of healthy soil is the level of soil organic matter (SOM), which controls many of the physical and chemical parameters of soil. For example, SOM can influence bulk density, water holding capacity and retention, and soil temperature, and buffer the soil pH and electrical conductivity and can influence biological activity. However, SOM can be rapidly lost through oxidation and by wind and water erosion. Most of the 1965 million hectares (Mha) of degraded land worldwide suffers from low organic matter content. Thus, single most overriding factor for increasing soil quality and ecosystem health is increasing the level of SOM through apt agricultural management practices. On a global basis, agricultural practices cause significant and extensive soil disturbance and soil contamination, with concomitant contributions to the loss of biodiversity (Wood *et al*., 2000). More sustainable agricultural practices, including organic management and reduced tillage, enhance soil diversity and fertility (Mäder *et al*., 2002); and soil dwelling animals are, in general, more abundant in organic than in conventional farming systems (Bengtsson *et al*., 2005). Reduction in soil disturbance can stimulate soil microbial biomass and improve its metabolic efficiency, resulting in better soil quality, which in turn, can increase crop productivity. Some of the important alternative agricultural management approaches currently practicing throughout the world for promoting biological activities in soils are discussed here:

Organic agriculture

Organic agriculture aims to integrate human, environmental, and economically sustainable production system. The term organic does not necessarily refer to the types of inputs to the system but more to the holistic interactions of the plants, soil, animals and humans in the system. Organic agriculture management promotes maintaining SOM levels for soil fertility, providing plant nutrients through microbial decomposition of organic materials and biofertilizers, and control of pests, disease, and weeds with crop rotations, natural control agents (biopesticides), and pest-resistant plant varieties. Currently, crop and soil scientists from different parts of world are working together to develop crop variety, which can efficiently uptake of organic forms of nutrients from soil. Since, organic systems are often low nutrient systems, with respect to N, P, and K, the cycling of SOM by microorganisms is important because plants rely on nutrients solely from SOM.

Biodynamic agriculture

Biodynamic farming is a system of organic farming that includes crop diversification, use of green manures, and use of compost and manures improved by biodynamic preparations. The biodynamic preparations consist of selected plant and animal substances that undergo fermentation for a year or so and then are used to enhance compost and manure used in the farming operation. These preparations can also be applied directly to soil as a spray to enhance biological activity. The use of biodynamic preparations is the main difference between biodynamic farming and traditional organic agriculture. Part of the biodynamic philosophy is that a healthy, active soil microbial population will enhance plant-microbe interactions and nutrient cycling and reduce soil pathogens.

Integrated plant nutrient supply (IPNS) system

The basic concept of IPNS is the promotion and maintenance of soil fertility for sustaining crop productivity through optimizing all possible resources (both renewable and non-renewable), such as organic, inorganic and biological components in an integrated manner appropriate to each farming situation in its ecological, soil and economic possibilities. The principal aim of IPNS is efficient and judicious use of all major resources of plant nutrients in an integrated manner, so as to get maximum yield without any deleterious effects on physicochemical and biological properties of soil. Major components of IPNS are FYM/compost, green manures, crop residues/recyclable wastes, synthetic fertilizers, biofertilizers, biological control agents, biopesticides.

The performance of IPNS practice in terms of nutrient uptake and balance, soil physical, chemical and biological properties of rice-legume-rice (RLR) rotation in acidic rice soil under rainfed production system in the northeastern alluvial plains of Assam was evaluated recently by Thakuria *et al.* (2009). The IPNS formulation was comprised of *Azospirillum* (Azo), *Rhizobium* (Rh), phosphate solubilizing bacteria (PSB) with phosphate rock (PR), compost and muriate of potash (MOP) and recycled crop residues. The IPNS practice favoured higher cumulative grain yields of crops (by 7-16per cent per RLR rotation), increased uptake of N and P by crops compared to that in compost alone or Urea:SSP:MOP plots. Apparent loss of soil total N and P at 0-15 cm soil depth was minimum and apparent N gain at 15-30 cm depth was maximum in the IPNS plots. The IPNS practice improved Zn nutrition of crops, minimized loss and maximized gain of total organic C content in soil at 0-15 cm and 15-30 cm depth, respectively and also improved water stable aggregation and distribution of soil aggregates in 2000-250 μm and 250-53 μm classes. Authors suggested that fungal/bacterial biomass-C ratio seems to be more reliable indicator of C and N dynamics in acidic soils than total microbial biomass-C. The IPNS plots haboured higher numbers of earthworms' casts compared to Urea:SSP:MOP alone. This study revealed that changes in bacterial community compositions in soils due to differences in nutrient management regimes, and these changes were seen to occur according to the states of C and N dynamics in acidic soil under RLR rotation. Likewise, Ouédraogo *et al.* (2007) also proposed that the effect of soil fauna on soil carbon build-up and crop performance can be optimised by using high quality organic matter or supplementing low quality organic matter with inorganic nitrogen in semi-arid West Africa.

No or reduced tillage

The practice of no/ or reduced tillage counteract the destructive effects of conventional/ or intensive tillage systems. In general, total soil C and N increased in the no-till soils. Converting fields under conventional tillage to a less disturbed state significantly increased the numbers of fungi and bacteria and dehydrogenase enzyme activity in soils. Nutrient cycling as measured as potentially mineralizable N increased by 35per cent in the no-till system (Doran, 1980). Bacterial-feeding nematodes, fungivore/ saprophyte mites, and predatory nematodes and mites were more abundant in organic-no till plots, supporting a soil food web with abundant organisms at higher trophic levels (Sánchez-Moreno *et al.,* 2009). They also observed that cover crops, crop residues and composts as surface mulches, together with lack of physical disturbance, were sufficient to support and maintain this structure. Conventional farming systems, with high C/N crop residues and much lower organic matter input supported fungal-mediated food webs mainly composed of fungal feeding nematodes and algivorous mites. Hungria *et al.* (2009) studies the impact of soil-tillage systems (no-tillage, conventional tillage, and no-tillage using a field cultivator every 3 years) on soil biological properties. Major differences in biological properties were attributed to differences in tillage practices; on average no-till soil had higher content of total carbon (19per cent), total nitrogen (21per cent), microbial biomass-C (74per cent), and microbial biomass-N (142per cent) over that in conventional tillage. Basal respiration of soil responded promptly to soil disturbance. The authors suggested that the turnover of C and N in microbial communities in tropical soils is rapid, reinforcing the need to minimize soil disturbance and to balance inputs of N and C.

Soil biota as bio-indicator of soil health

Members of the different trophic levels of the soil food-web network have close relationships with their food sources and with other soil animals that may constitute their prey or their predators (Ingham *et al.*, 1985; Yeates and Wardle, 1996; Fu *et al.*, 2005). For example, nematodes exhibit complex and numerous interactions with other soil organisms. In the recent years, soil biologists paid more attentions towards development of soil food web indices (Ferris *et al.*, 2001). Soil food web index is developed based on available knowledge about soil animals' relationships and the food web functions of component taxa. Some soil biota indices viz. the Enrichment Index (EI) and the Channel Index (CI) are indicators of organic matter decomposition pathways. The EI, based on the prevalence of fast-growing enrichment opportunistic nematodes, is an indicator of rapid, bacteria-mediated, organic matter decomposition (high EI) process, while the CI, based on the prevalence of fungal-feeding in relation to other microbivorous nematodes, is an indicator of slower organic matter decomposition mediated by fungi (high CI). The Basal Index (BI) is derived from the abundance of persistent microbial-feeding nematodes; high BI values indicate short and depleted soil food webs. The Structure Index (SI) weights the prevalence of omnivore and predatory nematodes in the soil food web as an indicator of long and complex soil food webs with high connectance and numerous trophic links. Soil food web indices have been used to infer soil food web responses to soil disturbance (Okada *et al.*, 2004). Conventional-standard tillage treatments had high abundances of fungal- and plant-feeding nematodes and algivorous mites, associated with high values of the Basal and Channel Index. Therefore, soil biota-based soil food web indices are useful indicators to predict soil functional processes.

Exploiting soil biota activities in hill agriculture of the Northeastern region of India

The Northeastern region of India falls under the Indo-Burma mega-biodiversity hot spot and the region habours enormous diversity of native flora and fauna, and also consider as nature's gene centre for several economically important plant species (Bujarbaruah, 2004). Soil biota biodiversity of this region is yet to be explored. At this moment, we do not have data relating to the contribution of soil biota on sustainability of managed systems in the Northeastern region of India. There are opportunities on "How to exploit soil biota activities to maintain soil sustainability in hill agriculture". These are:

1. Several traditional farming systems existed in the northeastern region of India are organic in nature by default except those which are practiced in valley lands. The available 37 million tones (MT) of dung from livestock population, 9 MT crop residues, vast resources of weed biomass, and forest litter from 171.08 lakh hectare forest lands can be utilized for converting into compost/FYM (Bujarbaruah, 2004). Application of these organic matter inputs into soil will enhance soil biota activity and hence, it helps improving soil fertility status.
2. Mechanised agriculture in hill slope is not commonly practiced. Reduced tillage is a common practice in hill agriculture. Growing of cover crops, and residue incorporation and reduced tillage is a common recommended practice in hill agriculture. Implementation

of this concept will certainly help in build up of soil biota community as well as enhancement of their activities.
3. Promotion of mixed cropping will certainly enhance soil microbiota and faunal bio-diversity and their activities.
4. Conversion of inorganic input intensive farming practices to systematic organic input intensive farming practices will lead to build up of soil biota biodiversity.

Research priorities

It has been perceived that there is a need to establish long-term trials on representative benchmark sites to evaluate the effects of agricultural management practices on soil biodiversity and ecosystem function at various temporal and spatial scales. Benchmark sites should represent the dominant soil types, major agro-ecological regions including dominant cropping systems. Resulting data on abundances of soil biota will be valuable for identifying the temporal and spatial scales at which biodiversity change most significantly affects ecosystem function. There is also a need for systematic studies which describes relationships between the composition or structure of decomposer soil biota communities and the type and intensity of agricultural management employed. Inventories of decomposer biota in undisturbed natural habitats and adjacent management systems including arable cropping, pastoral lands and forest tree plantations should be undertaken as a first measure. Attention must be given to characterising all dominant groups including microflora and fauna (beyond those assumed to be key functional groups), at different levels of taxonomic resolution.

Results of these descriptive studies should be combined with experiments focused on specific aspects of agricultural management (tillage type and intensity, fertilizer rate and form, crop residue management, crop rotation, etc.) as they influence the diversity-function relationships. This information will be useful in devising agricultural management practices which promote specific functions through management of soil biota. Understanding the links between plant diversity and decomposer biodiversity will be an important step towards exploiting maximum benefits of soil biota on achieving soil sustainability.

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