

Review Article

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Food Production through Traditional Agriculture: an Urgent Need to Improve Soil Health by Sustaining Soil Microbial Diversity

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ABSTRACT

Sustainability of soil system and crop productivity is the greatest challenges in the twenty-first century. The growing population pressurized modern agricultural practices to enhance food production. Green-revolution derived modern agriculture is characterized by the use of high-yielding crop varieties, inappropriate application of synthetic fertilizers and intensive water and energy resources utilization. Although, modern agriculture increased the food production several folds, but at cost of huge environmental degradation such as climate change, environmental pollution, degradation of soil health and biodiversity (soil microbial biodiversity). Soil microbial diversity is an important indicator of soil health that sustain various biogeochemical cycles in the soil system. The traditional agriculture has the novel capability of the environment and soil health management including soil microbial diversity. It enhances the spatial distribution of microbial diversity and its metabolic versatility which is vital for soil health. The tradition of India including various types of traditional agriculture practices because of its diverse weather. Mixed cropping, compost based cropping, agroforestry and livestock integrated agriculture practices are common in India since ages. The policy makers and scientific society are reevaluating the potential of these natural agriculture practices which fully depend on the biological and energy efficient inputs. The overall objective of this article is to highlight the potentials of traditional agriculture in respect to natural resource conservation including soil microbial system.

Keywords

Traditional agriculture, Microbial diversity, Soil health, Crop diversity, Food security

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Introduction

Traditional agriculture is the holistic perspective for the conservation of the soil health sustainability. It is a dynamic tool for the conservation of natural resources such as water and agro-ecosystem from landscape to family farms. These farming system are based on the ecological principle and the eco-friendly indigenous knowledge (Chhetry and

Belbahri, 2009). Traditional agriculture is organic in nature and involves the environment and existing natural resources for organic input. These are the ancient crop production system and practiced from hundreds of years to fulfill the food requirement. The large proportion of the rural community survived on the family farm system, which also contributes greater than half of the global food production (FAO,

2011; IFAD, 2012; Dogliotti *et al.*, 2014). The traditional agricultural practices can be defined as “a set of knowledge, practice and trust which develop by their adaptive nature and pass to the new one by cultural transmission and explain the relationship between living being with their environment” (Berkes *et al.*, 2000). The important feature of traditional farming is the adaptation to the local climate with spatial and sequential diversity which frequently obtained by double cropping, mixed cropping, use of local varieties with host-pathogen interaction, extensive use of local resources and tools for cultivation. The uniqueness of these practices are ecologically benign, publicly accepted, environmentally sound and economically feasible (Wezel *et al.*, 2011; Morelli, 2018). Such as mixed cropping, which is effective to minimize the risk of pest and mono-crop failure (Singh and Singh, 2017). Whereas, agroforestry and shifting cultivation promote nutrient cycle conservation ecologically and mainly practiced by the tribal of North-east India and state of Orissa and Maharashtra (Sinha, 1997; Murthy *et al.*, 2013).

The soil is an extremely heterogeneous and complicated micro-habitat. It considers one of the most complex and diversify ecosystems of the earth (Camenzind *et al.*, 2018), which is reflected in the spatial distribution and contains a vast diversity of microbes and their secreted metabolic versatility (Buckley and Schmidt, 2003). The microbial diversity of soil enhancing the soil quality, by the cycling of nutrient element and regulate carbon sequestration and emission. It plays a critical role in dynamics of soil organic matter, which shape the soil physical and biological properties and the underground water regime (Söderström *et al.*, 2014). The activity of microscopic diversity of soil enhanced the efficiency of nutrient uptake by the vegetation and endorses plant health by massive production. The rhizospheric soil mainly

comprises bacteria, protozoans, algae and fungi diversity, which actively participates in the cycling of every type of nutrient element (Schloter *et al.*, 2018; Kaurin *et al.*, 2018). The plant growth promoting rhizobacteria (PGPR), cyanobacteria and mycorrhiza have the dual advantage, one way they promote the growth of the crop, on the other hand, they also deliver immunity against the pathogen attack (Glick, 1995; Rasmann, 2017). These microbes directly contact with root surface or by root nodules formation. The root nodules boosted the growth of the plant by available the mineral nutrient and enhanced the phytohormone production and suppression of pest attack (Haas and Defago, 2005). Various PGPR strains have been used positively for crop inoculations, including members of *Azospirillum*, *Azotobacter*, *Bacillus*, *Enterobacter*, *Pseudomonas*, *Serratia* and *Xanthomonas* (Lucy *et al.*, 2004; Kumar *et al.*, 2017).

Traditional agriculture is the low-input and natural farming system. It basically depends on the natural resources and local tools for input. This technique maintains the soil health with soil microbial diversity for future food production and food security. The soil nutrient and water are essential component of soil, because roots of the plant comprise the essential parts for nutrient and water uptake. The plant and microbial diversity of the topsoil mainly depend on nutrients and the photo assimilated plant roots. Additionally, plants available the soil organic matter (SOM) by decomposition of leaf litters and root exudates. For the supply and recycling of nutrient in rhizosphere, symbiotic association of different microbial community and saprotrophic fungi are necessary. These are the reasons for the microbial biodiversity, microbial biomass, enzyme activity and respiration should be considered as the excellent indicator of healthy soil (Paz-Ferreiro *et al.*, 2016). Change in the

microbial biodiversity in the soil system is an early alarm of soil amelioration.

The green revolution in India has brought tremendous growth in agriculture production by the use of the high yielding varieties, expansion of irrigation technology, promotion of synthetic fertilizer and pesticide. This revolution increased the production of the crop by enhanced cropping intensity of mono-crops which made country self-dependent in food production. The percentage of population below the poverty line in rural region of India reduces from 53% in 1978 to 27% in 1999 (Mohan, 2006). But it has two sides, one way it increases the production, on the other hand, it harms the agro-ecosystem adversely by extensive use of chemical fertilizer and pesticides (Srivastava, *et al.*, 2016). The chemical based agriculture accumulated a large amount of nitrate in the water with high level of heavy metal contamination. At the same time, to complete the high input requirement of the modern agriculture there has been an increase in by factor 56, 22 and 34 times of tractors, pump sets and use of fertilizer (Bhalla and Singh, 2009). The modern agricultural technologies and high chemical input disturbed and contaminated natural cropping system. That leads to disappearance of soil microbial diversity and disrupt the agro-ecosystem. Agricultural intensification is evident as one of the major threats to global biodiversity (CBD, 2010; Abberton *et al.*, 2016). Visualizing the degradation rate of the agricultural ecosystem is the urgent need to reduce the over-exploitation of natural resources for sustainable use of these natural resources, and hand over of resources to the future generation. The main focus of this article is to highlight the potential of traditional agricultural practices towards conservation of the soil microbial system and sustainability of the agriculture system. This study also shows the environmental feasibility of natural system

and awareness among the people about the importance of these traditional practices.

Ecological extent of traditional agriculture practices

The traditional farming has a distinctive feature in respect of microbial diversity as well as sustainable agriculture production (Fig. 1). It encompassed the great dissimilarity between natural and semi-natural plantation (Plieninger *et al.*, 2006). The sustainability of traditional agriculture connotes towards the quality of agriculture product with the rhizospheric soil condition. The traditional agriculture practices performed in many forms, but its fundamental feature is to expel the use of the industrial tactic and promote maximum use of local tools with natural and local resources. These practices are effective for more agronomic production as well as the soil conservation in local climatic condition. It increases soil organic carbon with the recovery of soil structure, mitigates greenhouse emission by leguminous cultivation and reducing the oxidation of assimilated soil carbon (Balota *et al.*, 2004; Chivenge *et al.*, 2007; Friedrich *et al.*, 2009; Lal, 2009; Chenu *et al.*, 2018). Traditional agriculture increasing the nutrient and microbial diversity of soil with high soil moisture. This soil moisture reduces erosion of cultivated soil. The activity of soil enzyme increases transformation of unobtainable nutrient to active and available form (Yadav *et al.*, 2013; Menezes-Blackburn *et al.*, 2016). The organic compost mainly comprises bacteria and fungi with fresh humic substances that are not only rich in microbial biomass but also stimulates the activity of microbes (Bitew and Alemayehu, 2017). It also helps in diminishing attack of nematodes and moderating the influence of pesticide by sorption (Yadav *et al.*, 2013). The number of earthworm population considerable as important in organic farming in context to

modern cultivation. The earthworm has dual ability to restore soil fertility with significant increases in crop production.

Important traditional agricultural practices (TAP) of India

The history of Indian agriculture rich in traditional farming. It covers various types of traditional agriculture practices, which work as the natural, low-input and energy efficient system. This system comprises numerous biodiverse, climate resilience, energetically proficient and socially accepted practices. In these practices, farmers diversify the farm system by age-old practices of agroforestry, mixed or intercropping, cover crops and livestock-based farming (Anbalagan *et al.*, 2016; Rao *et al.*, 2018; Ram *et al.*, 2017). The diverse weather of the country also responsible to create various types of traditional agriculture practices. After the modernization and mechanization of agriculture, most of the rural and tribal community is still practicing traditional agriculture. Mixed cropping, agroforestry, livestock-based farming and grazing-based agriculture performed in every part of the country. Although, shifting cultivation, alder based farming system in jhum cultivation and zabo system famous in Northeast India (Ramakrishnan and Patnaik, 1992; Rathore *et al.*, 2010; Singh *et al.*, 2014). Whereas, aquaforestry, farming below the sea level, Kaipad and Pannendu practice in the south and coastal areas (Kumar and Ramakrishnan, 1990; Dagar *et al.*, 1991; Sathyanathan, 2010; Vanaja, 2013; Bhushan *et al.*, 2014).

The traditional practices are known for their novel importance in the environmental safeguarding from synthetic fertilizer contamination of agro-ecosystem. These also providing the livelihood and nutrition to the people along with strategies to mitigate the impact of climate change (Koohafkan and

Altieri, 2010). The agroforestry based agriculture are less prone threat as compared to modern and monocropping (Altieri and Nicholls, 2017). As the result of weighty ecological properties, maximum scientist's society acknowledges the traditional agriculture activities as the tool for to solve the various environmental threats, and economic crisis in future (Denevan 1995; Altieri, 2004). In this report, we discuss some of the agriculture practices which are used by the most part of the country to enhance the soil quality, microbial diversity, sustainability and environmental safeguarding of the society.

Organic compost based-agriculture practice

Organic composting is the process of microbiological degradation and recycling of waste into organic fertilizer (Singh and Singh, 2018). It is a non-polluting and environmentally safe method of waste management. These practices are very effectual in waste management generated after harvesting. It increases the soil organic matter on the degraded soil and reflect as a novel tool for restoration of polluted soil (Ren *et al.*, 2017; Singh and Singh, 2018). It release nutrient element for biogeochemical cycling and humus for moisture maintenance in the cultivated system (Lim *et al.*, 2016). Waste such as agriculture waste, garbage and crop residue used for biodegradation, have a different composition of C/N ratios with available N, P, K (Masunga *et al.*, 2016; Singh and Singh, 2017). The manure infusion in farming improves long-term fertility of soil with large productivity. Active compost has various types of microbial diversity such as bacteria (mesophilic or thermophilic), Actinobacteria, fungi, protozoans and rotifers. These participatory microbes release several kinds of hydrolytic enzyme and helpful in depolymerization and mineralization of waste (Kandeler *et al.*, 1999; Marx *et al.*, 2001). The

demineralized nutrient elements are available for crop roots as nutrient and SOM content increase the moisture content and prevent the soil erosion. Organic matter of compost is important for traditional as well as modern agriculture to achieve sustainable agricultural production. It contains desirable aspects in soil such as cation exchange capacity (CEC), high water holding capacity, sequestration of an organic and inorganic contaminant which collectively enhanced the physical, biological and chemical assets of soil (Padmavathamma *et al.*, 2008).

Livestock-based agriculture practice

Animal husbandry integrated agriculture is one of the oldest practices. This practice is considered the backbone of cultivation in tropical and developing country. These interactions create opportunities for diminishing extensive mechanization of the field and repair the recoupling of a different nutrient cycle of agro-system (Krall and Schuman, 1996; Hendrickson *et al.*, 2008). About 50% of world meat production and 90% of people's other requirements in developing country fulfilled by livestock (Thornton and Herrero, 2001). Crop-livestock system is the cyclic process in which animal produce milk and meat. Whereas, livestock's excreta used as FYM input for agriculture system and crop residue as a food requirement for livestock. Integrate livestock farming is loyal for maintenances of diversity in agriculture, field resources management and food security that help in improving the resilience of the agriculture system towards climate change (Singh and Singh, 2017). The FYM produced by the livestock is rich in soil nutrient, organic matter, soil microbial biomass, soil aeration and cation exchange capacity which diminishes degradation of soil with pest and disease management (Magdoff and Weil, 2004; Zhang *et al.*, 2012; Liu *et al.*, 2013; Singh and Singh, 2017).

Agroforestry-based agriculture practice

In agroforestry practice, crop species are cultivated in integration with tree species. The planted tree species may be fruit or fodder, depends upon the requirement of farmer. Agroforestry enhanced the biodiversity both above and below ground of the cultivated soil. The geographical coverage of agroforestry is 111,554 km² in India, which is 3.39% of the total geographical area of India (FSI, 2013). The combination of tree, crops and animal husbandry in the agroforestry has great significance to soil conservation. It improves quality of soil, erosion reduction, soil moisture with promoted water holding capacity which likely develops the biodiversity of soil and carbon sequestration (Garrett and McGraw, 2000; Garrity, 2004; Williams-Guillen *et al.*, 2008; Nair *et al.*, 2009; Abbas *et al.*, 2017). The incorporation of the plant that biologically fixes atmospheric nitrogen is most common in agroforestry. But non-nitrogen fixing plant also known for the expedition of the physical, chemical and biological feature of soil. It accumulating organic stock on the land surface by leaf litter and store soil carbon by sequestration and balanced the nutrient cycling in agrosystem (Jose, 2009). It is the special quality of agroforestry that develop agriculture sustainability, less dependent on the external chemical fertilizer and pesticides. Which reduce the adverse impact on soil system and environment (Moonen and Bàrberi, 2008; Radhakrishnan and Varadharajan 2016). In the silvopastoral system of agroforestry have special application of livestock, in which legume herbs/grasses planted with shrub or trees, make available the green fodder and ecological profits (Isaac *et al.*, 2005; Reis *et al.*, 2010). It also enhanced under soil N and C nutrient accumulation with healthy microbial diversity as compared to sole cultivation system (Arevalo *et al.*, 1998; Montagnini *et al.*, 2003; Tiessen *et al.*, 2003). Several social

and economic policy and profitability of farmer also received by agroforestry such as household earning, sustainability of crop system, soil conservation, adaptation and revenue from the local market (Mercer and Hyde, 1992; Alavalapati *et al.*, 2001).

Pasture cover or grazing based agriculture practices

Pasture cover is one of the dominating type terrestrial land use practices in most part of the world and covers 40% of ice-free area of the earth (White *et al.*, 2000). It provide a rich source of microbial and arthropods biodiversity. The tufts of the pasture provided a favorable temperature for microbial growth and the overall microbial diversity was found just double in these pasture cover microsite than bare microsite (Mathieu *et al.*, 2009). Pasture were supply green feeding for grazers and deliver various ecosystem services such as carbon assimilation, water purification, recreational and aesthetic value in the form of ecotourism (Dignam *et al.*, 2016). In many temperate nations of the world, legume plant cultivation with pasture is vital for the production of milk, fodder and meat. Because perennial legume is useful to for increase food quality, nitrogen enhancement by atmospheric microbial nitrogen fixation (Ledgard, 2001; Woodfield and Clark, 2009). The cattle of New Zealand dairy businesses are achieved about 90% of nutrient and fodder requirement from grazing of pasture (Bocquier and González-García, 2010). Pasture cover reduces the grazing pressure on forest and minimizes the degradation of the forest by reducing the grazing pressure of new one (seedling and sapling) of the tree. Pasture is considered as the serial in between the large forest and small spot of open forest, and farmyard manure of the animal dung is act as the nutrition for these forests. The dung of the animal with the combination of the dry leaf of plant and grass after decomposition act as the

nutritive additive for soil. In Himalayan region of India, a dry leaf of forest and grasses of pasture are spread on the sheds of animal for making the warm in winter. At the end of the season, the bedding material of shed is decompose with mixed-up urine and dung of animal, farms farmyard manure for agriculture additive.

Traditional agriculture practices: integrating biophysical and social science for innovative system

Traditional agriculture is crucial to conserving the soil health and fulfill the requirement of high production demands by using the local resources and technique. These agriculture practices are holistic in nature because of its multidimensional importance in the agriculture fields, such as the health of environment, climate change and soil fertility (Pulido and Bocco, 2003). They improve the SOM with SOC by sequestration and biomass assimilation of crop residue into the field and mitigate the huge amount of GHGs (Aguilera *et al.*, 2013; Sanz-Cobena *et al.*, 2017). Agroforestry system of traditional agriculture expandthe mitigation activities of the system towards the climate change and produces 3-4 times more biomass as compare to tree-less cultivation with the large input of carbon as the nutrient (IPCC, 2000; Gattinger *et al.*, 2012; Smith and Wollenberg, 2012; Tuomisto *et al.*, 2012).

Traditional practices are the result of the several generation survival and often originated as the result of long spell observation of nature behavior (Martin *et al.*, 2010). These practices provide new ideas for conniving climate smart-agriculture. Because these practices comprised of the preservation of natural resources with rational microbial diversity management. These practices encompassed intercropping, or mixed cropping with different varieties and cultivars,

rotation of crops types, cover crops with composting and green manuring. The great scientist Darwin was also concluded that, the sustainability and stability of a system are fully dependent on the diversity of system. These practices have the ability to constitute a new model for future cultivation, but due to large production load of increasing population, these practices discarded (Malézieux, 2012). The new researchers need to invent in the area of sustainability of future agriculture and conservation of these natural systems of agriculture. They will develop a new innovative technique which is a hybrid of these systems as explained in figure 2.

To develop these new techniques, firstly observe the functional activity of the species and also characterized the natural interaction between existing animals and vegetation species of the ecosystem. The local community has knowledge of the local natural system and scientist community needs to transform this traditional knowledge into new innovative and multidisciplinary knowledge system. It is a combination of agro-ecological knowledge of scientific community and traditional knowledge of the local community. This combination should be applied as new climate-smart approach for sustainable food production ensures global food security and environmental quality.

Fig.1 A simplified explanation of traditional agriculture application in soil microbial diversity

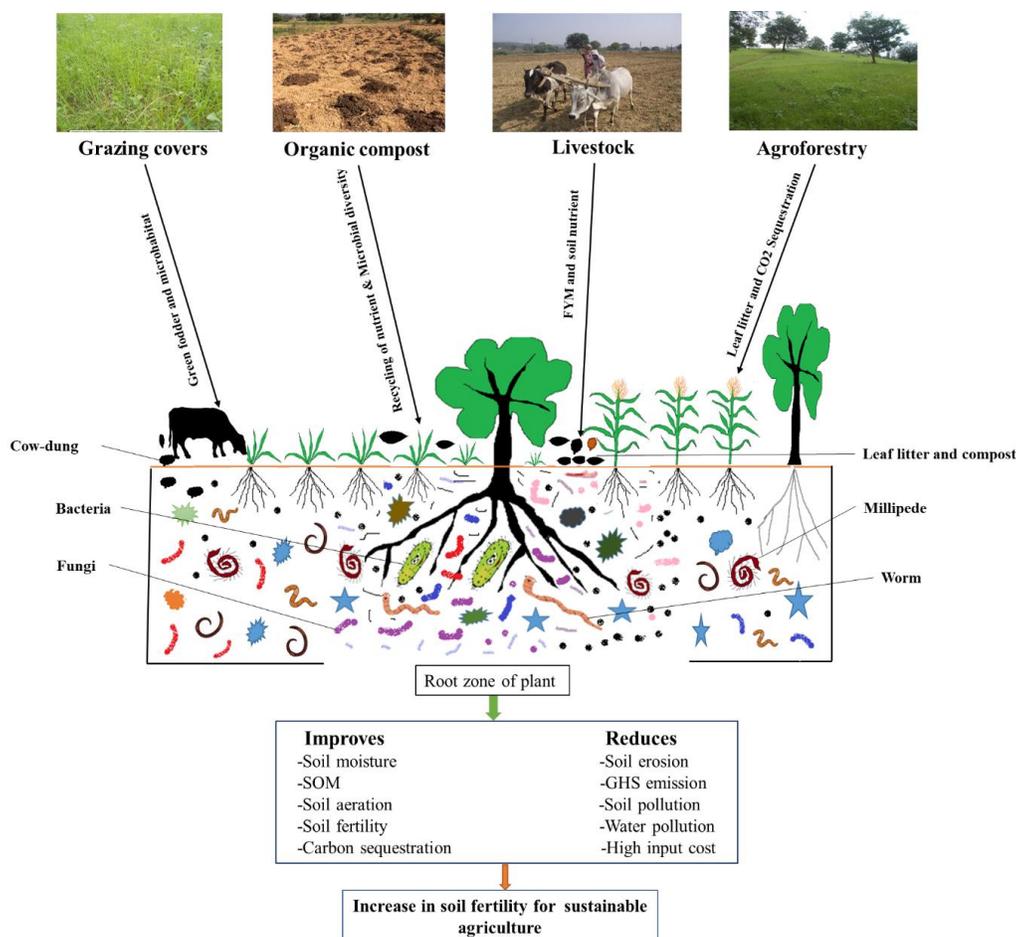
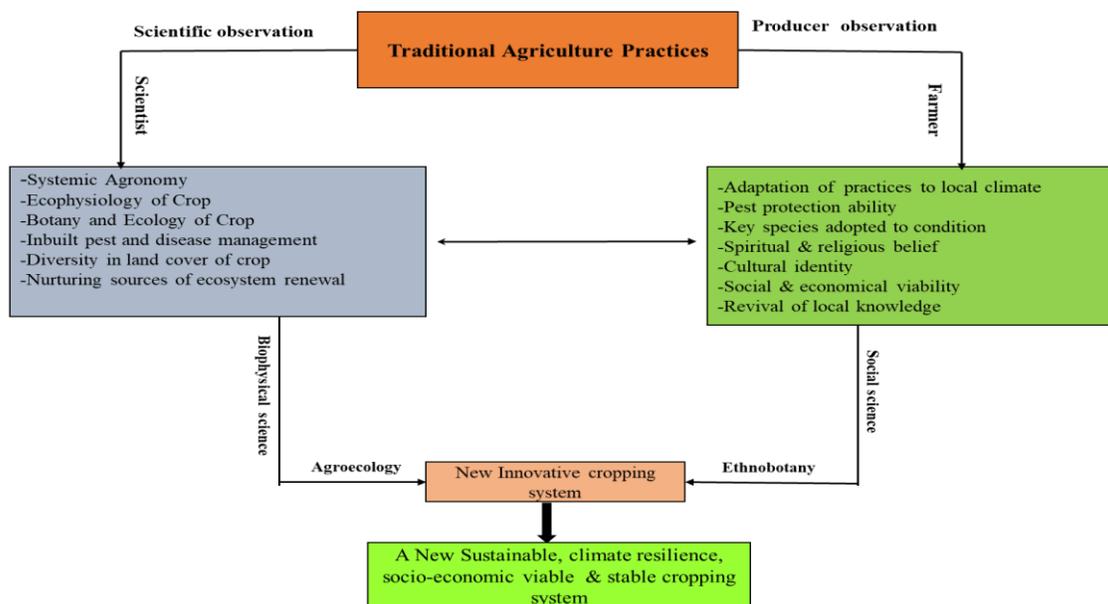


Fig.2 A diagrammatic framework for the mimic of traditional natural system



In conclusion traditional agriculture practices are very old agriculture practices. Agroforestry, livestock-based agriculture, mixed cropping, composting based-agriculture and grazing integrated practices are some of the prominent practices of the traditional agricultural system. These practices have capabilities to conserve belowground diversity of soil. Soil microbial diversity is an essential component of the soil health. Compost based farming rejuvenates the biogeochemical cycle of the nutrient element. Whereas, integration of livestock in farming decreases the mechanization of the field with availability of farm-yard manure (FYM) input. Agroforestry produces diversity on the field as well as below of the field, and enhance the soil organic carbon by carbon sequestration. The grazing field provides fodder for livestock with carbon assimilation and water purification by the root system. Traditional agriculture is also helpful in slashing of climate change, health safety of farmer, conservation of input energy and natural resources management. This is widely famous in the marginal farmers due to their low and locally existing input cost and great energy efficient output. Agroforestry,

livestock-based agriculture, mixed cropping, composting based-agriculture and grazing integrated practices which are commonly practiced in India can be used as the model for the future sustainability of agriculture. Besides enhancing the soil microbial diversity, traditional agriculture practices are also having potential capability to adapt and mitigate the climate change. These practices would be an excellent alternative to the farmer toward environmental friendly and climate adaptive agro-ecosystem. There is an urgent need to explore traditional agriculture practices with a comprehensive and inclusive research for increasing food production in a healthy soil system characterized by biodiversity richness. This inclusion of traditional agricultural practices would be better alternative to modern agriculture in the current scenario of declining environmental health.

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