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Soil biological properties as influenced by long term manuring and fertilization under finger millet - maize cropping system in Alfisols

Shruthi GS and Kadalli GGDOI: <https://doi.org/10.33545/26174693.2024.v8.i9Sa.2056>**Abstract**

Soil degradation and poor soil health have resulted from the extensive use of mineral fertilizers to generate high agricultural yields. As an alternative to mineral fertilizers, manure application can be an effective fertilizing approach for improving soil health and biodiversity. This study aims to assess the impacts of long-term manuring and fertilization on soil biological properties in an ongoing 33-year old long-term fertilizer experiment (LTFE) under finger millet-maize cropping system in Alfisols at Gandhi Krishi Vignan Kendra, University of Agricultural Sciences, Bengaluru, during 2020. The field experiment laid in a randomized complete block design having twelve treatments with three replications. The treatments were 50% NPK (T₁), 100% NPK (T₂), 150% NPK (T₃), 100% NPK + Hand weeding (T₄), 100% NPK + Lime (T₅), 100% NP (T₆), 100% N (T₇), 100% NPK + FYM (T₈), 100% NPK (-S) (T₉), 100% NPK + FYM + Lime (T₁₀), Control (T₁₁), Uncultivated land (T₁₂). The microbial biomass carbon, microbial biomass nitrogen and all enzyme activities *i.e.* dehydrogenase, urease activity and acid phosphatase were recorded more in the uncultivated land compared cultivated land followed by treatment receiving 100% NPK + FYM + Lime and 100% NPK + FYM, however lowest activities are observed in the imbalanced fertilizer applied treatments (100% N) and control. The microbial activities are more in uncultivated land compare to cultivated land and with increase in depth of the soil, all of the soil's biological properties decreased. Imbalanced use of chemical fertilizers had the harmful effect on soil biological health. The use of inorganic fertilizers in combination with organic manure provides an alternate strategy for managing soil fertility that is both sustainable and cost-effective.

Keywords: Long term fertilizer, enzymatic activities, microbial biomass, manure, inorganic fertilizers**Introduction**

Agriculture intensification with extensive use of chemical fertilizers has detrimental consequences on soils and the ecosystem, and poses problem on long-term sustainability. Overuse of fertilizers not only reduces fertilizer efficiency, but also causes environmental deterioration due to nutrient runoff and biodiversity loss (Zhang *et al.*, 2012) [42]. Mineral fertilizer application lowers soil pH, which may affect nutrient availability by decreasing the microbial activities (Cai *et al.*, 2015) [6]. Mineral fertilization was having negative impact on the bacterial and fungal community by reducing microbial diversity (Zhang *et al.*, 2012) [42]. This is due to mineral fertilizers hasten the mineralization of soil organic carbon (SOC), their continued usage might deplete SOC which is the source of food for microorganisms (Ju *et al.*, 2009). Mineral fertilizer can be replaced with manure as an alternative to mineral fertilizer application, which can improve soil biodiversity and quality (Jiang *et al.*, 2018) [21]. The soil respiration and enzyme activity play major role in maintenance of productive soil. Soil microorganisms are the primary decomposers of organic matter, resulting in the formation of humus and thus the release of a various nutrients. One of the most important measures of soil quality is the microbial population. Soil microorganisms also help to improve the efficiency of chemical fertilizers by affecting the nutrient cycle mechanisms in the soil. The application of inorganic fertilizers, manures, irrigation, insect control techniques, and other factors affect soil biological parameters quickly. The simple, economical, and quicker way to determine soil biological and biochemical

parameters related to organic matter decomposition and nutrient cycling, such as soil microbial population, microbial biomass C and N, and soil enzyme activity.

The activity of dehydrogenase can be used as an excellent predictor of soil quality. As respiratory chain enzymes, dehydrogenases play an important role in the energy production of soil microbes. The addition of organic matter to the soil boosted the activity of soil dehydrogenase (Singh *et al.*, 2007) [31]. Phosphatase plays an important function in phosphorus cycle, including phospholipid breakdown. The addition of organic matter to the soil boosted the activity of the phosphatase enzyme (Singh *et al.*, 2007) [31]. Urease enzyme took part in the hydrolysis of urea to carbon dioxide and ammonia in soil, and it is a key part of the nitrogen cycle. The maximum urease enzyme activity was observed when NPK was combined with manure application (Bhatt *et al.*, 2016) [4]. The activities of soil enzymes were positively associated with organic C and microbial population in the soil by Chhonkar and Tarafdar (1981) [11]. Nidaye and Dkhar (2000) reported soil enzyme activity has the potential to help in manage the ecosystems for long-term viability. Abbasi and Khizar (2012) [1] reported that application of urea resulted in a drop in MBC, whereas the use of farmyard manure as a soil amendment resulted in an increase in MBC. Microbial diversity, microbial biomass, and enzyme activity are improved by the application of manure by increase in SOM (Lupwayi *et al.*, 2019) [27] which involved in C, P, and N cycle. Improper nutrient management strategies, are one of the causes of increased soil degradation due to a decrease in SOC.

These biological properties of soil have been extensively employed to investigate the effects of various soil and crop management strategies on soil health in a variety of habitats

(Nannipieri *et al.*, 1990; Aon *et al.*, 2001; Masto *et al.*, 2007; Trasar-Cepeda *et al.*, 2008) [34, 3, 31, 16]. Long term studies are useful for determining the effects of continued use of nutrient management strategies in crop production on soil productivity and quality of soil. Because soil biological and biochemical parameters are very sensitive to changes in land management methods, they are regarded valid indicators of soil quality (Gil-Sotres *et al.*, 2005) [16]. As a result, keeping track of changes in diverse soil biological properties could lead to a better understanding of nutrient availability and soil quality. Therefore, the present investigation was undertaken to examine the effect of long term manuring and fertilization on soil biological properties under finger millet- maize cropping system in Alfisols.

Materials and Methods

Experimental site and treatment details

The long-term fertilizer experiment was initiated in 1986 at Zonal Agricultural Research Station of University of Agricultural Sciences, GKVK, Bengaluru located in Eastern Dry Zone of Karnataka at an altitude of 930 meters above MSL, latitude of 13° north, longitude of 77° 33" east with finger millet – maize cropping system. The total rainfall at experimental site AICRP- LTFE, GKVK, Bengaluru was 1180 mm with maximum rainfall during July (242.8 mm) and minimum during January and Feb (0.0 mm) in 2020. The experimental soil was lateritic and sandy clay loam of texture with red colour. It belongs to the *Isohyperthermic* family of the sub group typic *kandic paleustalfs* of Vijayapura series. The pH of the soil is 6.17 (slightly acidic) with sandy clay loam in texture, low in organic carbon content (4.6 g kg⁻¹).

Table 1: Initial soil characteristics of experimental site, GKVK, Bangalore.

Subgroup		:	Kandi Paleustalfs	
Series		:	Vijayapura	
Taxonomy		:	Fine, mixed IsohyperthermicKandicpaleustalfs	
Mechanical composition				
Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
0 – 20	62.0	8.6	29.4	Sandy clay loam
20 – 36	52.1	11.7	36.2	Sandy clay
Chemical properties				
pH (1:2.5, soil : water suspension)			:	6.17
Electrical conductivity (EC, dS m ⁻¹)			:	0.059
CEC [c mol (p+) kg ⁻¹]			:	12.20
Organic carbon (%)			:	0.46
Available nitrogen (kg ha ⁻¹)			:	256.7
Available phosphorus (kg ha ⁻¹)			:	34.3
Available potassium (kg ha ⁻¹)			:	123.1

The available nitrogen (256.7 kg ha⁻¹) was low, available phosphorus (34.3 kg ha⁻¹) was medium and available potassium content (123.1 kg ha⁻¹) was low. Finger millet and hybrid maize crops were grown in sequence during Kharif and Rabi seasons, respectively. The chemical properties of initial soil sample (1986) of the experiment site were given in Table 1.

The current study is part of ongoing experiment being conducted at Gandhi Krishi Vignan Kendra (GKVK), University of Agricultural Sciences, Bengaluru during 2020. In a randomised block design with individual plot sizes of 16 m × 9 m, the experiment was carried out having eleven treatments which are replicated four times. However, for the present study only three replications and one more

additional treatment of fallow land were considered *i.e.* 50% NPK (T₁), 100% NPK (T₂), 150% NPK (T₃), 100% NPK + Hand weeding (T₄), 100% NPK + Lime (T₅), 100% NP (T₆), 100% N (T₇), 100% NPK + FYM (T₈), 100% NPK (-S) (T₉), 100% NPK + FYM + Lime (T₁₀), Control (T₁₁), Uncultivated land (T₁₂). The treatment details with NPK doses and fertilizer sources are given in Table 2. The recommended dose of NPK used in finger millet was 100 : 22 : 42 kg ha⁻¹ and maize 100 : 33 : 82 kg ha⁻¹. All eleven treatments employed chemical weed management, with the exception of 100% NPK + HW. About 15 t ha⁻¹ of well decomposed farmyard manure (FYM) on dry weight basis was mixed into the soil 10-15 days just before the transplanting of finger millet crop to treatments T₈ and T₁₀.

Lime has been applied based on lime requirement following the method given by Shoemaker *et al.* (1961) at 15 days before sowing of finger millet crop to the treatments T₅ and T₁₀. However, if the soil pH exceeds 6.00 then lime was applied @ 500 kg ha⁻¹. After 25 to 30 days of sowing / transplanting of crops, 50 percent of the recommended nitrogen dose, 100 percent of the recommended P and K doses were applied as a basal, and the remaining 50 percent nitrogen dose was administered in two equal splits as a top

dress. Diammonium phosphate (DAP) is applied as a source of P and N along with urea and muriate of potash (MOP) as a source of K in sulphur free treatment [T₉]. The single superphosphate was not used to avoid S for treatment T₉. In rest of the treatments (except T₉), urea, single super phosphate (SSP) and MOP are used as sources of NPK, respectively. Neither any chemical fertilizer nor any organic manure is used in absolute control treatment (T₁₁).

Table 2: Details of the Treatments (Main Treatments)

Treatment	NPK dosage (kg ha ⁻¹)		Fertilizer Source
	Finger millet	Hybrid maize	
T ₁ : 50% NPK	50 - 11 - 21	50 - 16 - 41	Urea, SSP, MOP
T ₂ : 100% NPK	100 - 22 - 42	100 - 32 - 82	Urea, SSP, MOP
T ₃ : 150% NPK	150 - 33 - 63	150 - 48 - 123	Urea, SSP, MOP
T ₄ : 100% NPK + HW	100 - 22 - 42	100 - 32 - 82	Urea, SSP, MOP
T ₅ : 100% NPK + lime	100 - 22 - 42	100 - 32 - 82	Urea, SSP, MOP, lime
T ₆ : 100% NP	100 - 22 - 00	100 - 32 - 00	Urea, SSP
T ₇ : 100% N	100 - 00 - 00	100 - 00 - 00	Urea
T ₈ : 100% NPK + FYM	100 - 22 - 42	100 - 32 - 82	Urea, SSP, MOP
T ₉ : 100% NPK (S-free)	100 - 22 - 42	100 - 32 - 82	Urea, DAP, MOP
T ₁₀ : 100% NPK + FYM + lime	100 - 22 - 42	100 - 32 - 82	Urea, SSP, MOP, lime
T ₁₁ : Control	00 - 00 - 00	00 - 00 - 00	-----
T ₁₂ : Fallow land	00 - 00 - 00	00 - 00 - 00	-----

Soil sampling, processing and analysis

After the maize crop was harvested, composite soil samples were collected from each plot using a soil tube auger, taken at two depths of 0-15 and 15-30 cm. Soil samples for the treatment fallow land were collected in three places near experimental plots that had not been cultivated. The collected soil samples were air-dried, ground to pass through 2 mm sieve and were subjected for analysis of biological properties of the soil. Soil microbial biomass carbon (SMBC) and nitrogen (SMBN) was estimated by fumigation-extraction method as proposed by Carter (1991) in which Ninhydrin-reactive N, as a measure of microbial biomass carbon released during soil fumigation by using ninhydrin reagent. The dehydrogenase activity in the soil was determined by the reduction of 2,3,5-triphenyl-tetrazolium chloride to 1,3,5-triphenylformazan (TPF) given by Casida *et al.* (1964) [9]. The acid phosphatase enzyme activities were determined as per the method given by Eivazi and Tabatabai, 1977 [14] using p-nitrophenyl phosphate tetrahydrate solution of pH 6.5. The urease activity was determined by following the method described by Watts and Crisp (1954) by using tris-hydroxymethylaminometane (THAM) buffer.

Statistical analysis

For the interpretation of results, the data obtained in the laboratory studies will be subjected to statistical analysis using the technique of analysis of variance for randomised block design as outlined by Gomez and Gomez (1984). The level of significance used in “F” and “t” test was P = 0.05. Critical difference (CD) values were calculated for the P = 0.05 whenever “F” test was found significant.

Results and Discussion

Dehydrogenase activity

The dehydrogenase activity among different fertilizer treatments at different depths varied significantly due to long term application of inorganic fertilizers and organic manures in finger millet-maize cropping sequence over 33

years of cultivation is presented in Table 3. Among different treatments uncultivated land recorded significantly higher dehydrogenase activity (80.43 and 39.04 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively) followed by 100% NPK + FYM + Lime (72.71 and 34.55 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM (67.81 and 31.96 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively) compared to control and only inorganic fertilizer treated plots. This would imply that the activity of dehydrogenase had a direct relationship with the organic matter content of the soil. The significantly lower dehydrogenase activity was recorded in treatments with imbalanced application of fertilizer 100% N (32.96 and 14.37 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively), followed by 100% NP (43.10 and 21.64 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively) and control (40.39 and 18.69 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively). Application of lime 100% NPK + Lime (59.50 and 27.24 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM + Lime (72.71 and 34.55 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively) increases the dehydrogenase activity compared to without lime treatment 100% NPK (56.49 and 24.06 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM (67.81 and 31.96 µg TPF g⁻¹ 24 h⁻¹ at 0-15 and 15-30 cm soil depth respectively).

Dehydrogenase activity is higher in no-till soil due to presence of higher organic matter, less disturbance to microbes than ploughed soil. FYM alone or in combination with inorganic fertilizers resulted in a considerable increase in dehydrogenase activity due to that the addition of an organic source, microorganisms utilize the native pool of organic carbon as a source of carbon, which acts as substrate for dehydrogenase (Rai and Yadav, 2011 and Nath *et al.*, 2012) [35]. The decrease in enzymatic activities in sub surface layer of soil could be attributed to the lower organic matter content with increase in soil depth (Martens *et al.*, 1992) [29]. The application of fertilizers affects the microbial

activity in turn reduces the enzyme activity (Kandeler *et al.*, 1999) [23]. When nitrogenous fertilizers are applied to soil alone, dehydrogenase activity, which is a measure of soil microbial activity, is greatly influenced by the presence of nitrate, which serves as an alternative electron acceptor, resulting in low activities (Casida *et al.*, 1964) [9]. This could be reason for the dehydrogenase activity in the soils of the alone N treated treatment was the lower. Application of lime, in combination with a balanced NPK, promoted the activity of microorganisms to use the local pool of organic carbon as a source of carbon, which functions as a substrate for dehydrogenase, and also liming increases pH, which is advantageous to microbiological growth.

Acid phosphatase activity

Perusal of the data on acid phosphatase activity (Table 3) revealed that among different treatments significantly higher acid phosphatase activity was recorded in uncultivated land (121.14 and 49.90 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) followed at par with 100% NPK + FYM (110.23 and 47.80 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively). The significantly lower acid phosphatase activity was recorded in control (80.93 and 32.60 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) followed by 100% N (89.72 and 34.91 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NP (90.13 and 36.94 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively). Application of lime decreased the acid phosphatase activity non significantly both in 100% NPK + Lime (90.24 and 38.38 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NPK+FYM + Lime (99.85 and 45.17 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) when compared to

respective treatments without lime 100% NPK (94.37 and 42.86 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM (110.23 and 47.80 μg of PNP g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively).

The activities of acid phosphatase enzyme was more in uncultivated land when compared to cultivated land due to higher organic matter availability as a result of less disturbance to the microbial activity in turn increases the phosphatase activity. Similar results were reported by Dick and Tabatabai (1984) [13]. The increased acid phosphatase activity in combined application fertilizers with organic manure treatment than others is due to increased availability of substrates like organic phosphorous, organic carbon, and microbial biomass as a result of continuous application FYM over the years (Singh *et al.*, 2007) [31]. Mishra *et al.* (2008) [32], while analysing the results of a long-term study in *Alfisols*, also reported low activities of the phosphatases enzymes in soil due to imbalanced use of chemical fertilizers which affect microbial growth. The application of lime reduced the acid phosphatase activity in soils of both soil depth which was associated with increase in bacteria but decreases the number of fungi. Similar results are reported by Halstead *et al.*, 1963. Casida (1959) [19, 8] reported that fungi produce enzyme capable of dephosphorylating organic phosphorous compounds in soil.

Urease activity

The urease activity among different fertilizer treatments at different depths varied significantly due to long term application of inorganic fertilizers and organic manures in finger millet-maize cropping sequence over 33 years of cultivation is presented in Table 3 and Fig. 3.

Table 3: Effect of long term manuring and fertilizer application on the soil enzyme activities after 33 years of finger millet – maize cropping sequence.

Treatments	Dehydrogenase		Acid phosphatase		Urease	
	μg of TPF g^{-1} of soil 24 h^{-1}		μg of PNP g^{-1} of soil h^{-1}		μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1}	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁ : 50% NPK	50.12	22.23	90.47	40.55	29.20	12.28
T ₂ : 100% NPK	56.49	24.06	94.37	42.86	29.96	13.93
T ₃ : 150% NPK	58.49	24.53	97.38	44.74	30.65	14.11
T ₄ : 100% NPK+ HW	53.60	23.41	92.47	41.48	29.66	12.36
T ₅ : 100% NPK+ Lime	59.50	27.24	90.24	38.38	31.40	15.31
T ₆ : 100% NP	43.10	21.64	90.13	36.94	27.99	11.20
T ₇ : 100% N	32.96	14.37	89.72	34.91	26.95	10.91
T ₈ : 100% NPK+ FYM	67.81	31.96	110.23	47.80	34.46	15.81
T ₉ : 100% NPK(S-free)	49.94	21.76	90.88	42.20	30.58	13.09
T ₁₀ : 100% NPK+ FYM+ Lime	72.71	34.55	99.85	45.17	37.58	19.10
T ₁₁ : Control	40.39	18.69	80.93	32.60	27.66	11.09
T ₁₂ : Uncultivated land	80.43	39.04	121.14	49.90	42.32	21.09
SE $\pm$	2.93	2.12	4.08	3.51	1.94	1.17
CD at 5%	8.59	6.21	11.97	10.30	5.68	3.44

Among different treatments uncultivated land recorded significantly higher urease activity (42.32 and 21.09 μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) followed by 100% NPK + FYM + Lime (37.58 and 19.10 μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM (34.46 and 15.81 μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) compared to control and all inorganic fertilizer alone treated plots. The significantly lower urease activity was recorded in 100% N (26.95 and 10.91 μg of

$\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) followed by control (27.66 and 11.09 μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively). Application of lime increased the urease activity non significantly both in 100% NPK + Lime (31.40 and 15.31 μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM + Lime (37.58 and 19.10 μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) when compared to corresponding treatments without lime 100% NPK (29.96

and 13.93 μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM (34.46 and 15.81 μg of $\text{NH}_4^+\text{-N}$ g^{-1} of soil h^{-1} at 0-15 and 15-30 cm soil depth respectively).

Significantly higher urease activity in uncultivated compare to cultivated land was due to higher organic matter availability and less disturbance in uncultivated land, which promotes microbial activity, which in turn raises urease activity. The urease enzyme activity was significantly and positively correlated with organic C and microbial population in the soil. The highest urease activity in manure treated soil over control and decrease with long-term addition of minerals (Dick *et al.*, 1988) [12]. Significantly lower urease activity observed in imbalanced fertilizer application due to the lack of sufficient amount of organic substrate required for microbes to carry out urease activity in fertilizer treated soil (Islam *et al.*, 2019) [20]. Application of lime along with fertilizers increases the urease activity by promoting microbial activities in soil.

Microbial biomass carbon

The data on microbial biomass carbon (MBC) among different fertilizer treatments and at different depths varied significantly due to long term application of inorganic fertilizers and organic manures in finger millet-maize cropping sequence over 33 years of cultivation and is presented in Table 4.

Among different treatments microbial biomass carbon was significantly higher in treatment uncultivated land (324.76 and 231.85 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively) followed 100% NPK + FYM + Lime (286.53 and 215.94 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM (262.16 and 201.53 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively). The significantly lower content of microbial biomass carbon was recorded in control (195.92 and 140.72 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively) and found at par 100% N (205.18 and 151.57 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively).

The significant decline in MBC in cultivated soils than uncultivated soil is due to agricultural use. The disturbance caused by cultivation changes the size, composition, and activity of the microbial community (Angers *et al.*, 1993 [2], Fauci and Dick 1994 [15] and Granatstein *et al.*, 1987 [17]. Uncultivated soil, on the other hand, has less organic matter degradation, which increases organic carbon and act as source of food for microorganisms in turn promotes microbial activity. The higher MBC value due to the combined application of FYM and NPK fertilizer is attributable to a higher turnover of root biomass produced under the FYM + NPK treatment (Moharana *et al.*, 2012) [33]. These findings are also consistent with those of Grego *et al.* (1998) [18]. Higher stress caused by insufficient or no nutrient utilization in control and unbalanced fertilization limited the crop output and hence carbon substrate (root exudates), resulting in a loss in biomass carbon. The MBC of the surface layer was much greater than that of subsurface soil. The downward migration of soluble OM from top soil, is critical for maintaining subsoil microbial activity which in turn sustains microbial biomass carbon. These findings are also consistent with (Chantigny, 2003) [10].

Microbial biomass nitrogen: The data on microbial biomass nitrogen (MBN) among different fertilizer

treatments and at different depths varied significantly due to long term application of inorganic fertilizers and organic manures in finger millet-maize cropping sequence and is presented in Table 4. Among different treatments, microbial biomass nitrogen in soil was significantly higher in treatment T₁₂: uncultivated land (37.89 and 27.05 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively) followed at par 100% NPK + FYM + Lime (34.12 and 25.19 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NPK + FYM (33.43 and 23.14 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively). Significantly lower content of microbial biomass nitrogen was recorded in control (22.86 and 16.42 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively) and followed at par with 100% N (23.94 and 17.68 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively) and 100% NP (25.31 and 17.95 mg kg^{-1} at 0-15 and 15-30 cm soil depth respectively).

Uncultivated soil had less organic matter degradation, compared to cultivated land which increases organic carbon, which is a source of food for microorganisms, which in turn promotes microbial activity. The most prominent components contributing to the rise in soil MBN were clearly readily metabolizable carbon and nitrogen in FYM, as well as increased root biomass and root exudates related to increased crop growth. This conclusion is consistent with the findings of Manna *et al.* (2013) [28], who found that combining inorganic and organic fertilizers had a substantial impact in increasing MBN (Kumari *et al.*, 2011) [24]. Imbalanced fertilization limited the crop production and hence nitrogen substrate (root exudates), resulting in a loss in biomass nitrogen.

Table 4: Effect of long-term manuring and fertilizer application on soil microbial biomass carbon and nitrogen (mg kg^{-1}) under finger millet-maize cropping sequence.

Treatments	Microbial biomass carbon		Microbial biomass nitrogen	
	(mg kg ⁻¹ soil)			
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T ₁ : 50% NPK	236.90	181.70	27.64	21.20
T ₂ : 100% NPK	257.95	197.42	30.09	22.84
T ₃ : 150% NPK	258.51	198.35	30.59	22.96
T ₄ : 100% NPK+ HW	251.22	196.48	29.31	21.89
T ₅ : 100% NPK+ Lime	248.13	195.73	28.95	20.03
T ₆ : 100% NP	216.97	153.82	25.31	17.95
T ₇ : 100% N	205.18	151.57	23.94	17.68
T ₈ : 100% NPK+ FYM	262.16	201.53	33.43	23.14
T ₉ : 100% NPK (S-free)	243.92	192.55	28.46	22.46
T ₁₀ : 100% NPK+ FYM+ Lime	286.58	215.94	34.12	25.19
T ₁₁ : Control	195.92	140.72	22.86	16.42
T ₁₂ : Uncultivated land	324.76	231.85	37.89	27.05
SEm±	8.81	7.54	2.04	1.66
CD at 5%	25.85	22.11	5.97	4.88

Conclusion

The present study demonstrates that in comparison to using NPK fertilizers alone, using an optimal dose of NPK (100%) combined with FYM in a finger millet-maize cropping system improved soil microbial status at both depths. This treatment increased the biomass of microorganisms and the activity of several enzymes in the soil, both of which are significant in nutrient cycling. All enzyme activities (dehydrogenase, urease activity and acid phosphatase) and

microbial biomass carbon and nitrogen were recorded more in the uncultivated land compared cultivated land followed by treatment receiving 100% NPK + FYM + Lime and 100% NPK + FYM, however the continuous cropping without application of manure and imbalanced fertilizer application recorded lowest biological activities. The soil health gets deteriorated due to continuous cultivation without application of fertilizers. With the depth of the soil, all of the soil's biological properties decreased. It may thus be inferred that the balanced application of organic manure and chemical fertilizers, as well as effective weed management, is critical for maintaining finger millet-maize system production and soil biological health in *Alfisols*.

References

- Abbasi MK, Khizar A. Microbial biomass carbon and nitrogen transformations in a loam soil amended with organic-inorganic N sources and their effect on growth and N-uptake in maize. *Ecological Engineering*. 2012;39:123-132.
- Angers DA, Bissonnette N, Legere A, Samson N. Microbial and biochemical changes induced by rotation and tillage in a soil under barley production. *Canadian Journal of Soil Science*. 1993;73:39-50.
- Aon MA, Cabello MN, Sarena DE, Colaneri AC, Franco MG, Burgos JL. Spatio-temporal patterns of soil microbial and enzymatic activities in an agricultural soil. *Applied Soil Ecology*. 2001;18(3):239-254.
- Bhatt B, Chandra R, Ram S, Pareek N. Long-term effects of fertilization and manuring on productivity and soil biological properties under rice (*Oryza sativa*)–wheat (*Triticum aestivum*) sequence in Mollisols. *Archives of Agronomy and Soil Science*. 2016;62(8):1109-1122.
- Bolton K, Banik SK, Dey B. Dehydrogenase and phosphatase activities in rice field soils. *Soil Biology and Biochemistry*. 2004;16(3):423-424.
- Cai Z, Wang B, Xu M, Zhang H, He X, Zhang L. Intensified soil acidification from chemical N fertilization and prevention by manure in an 18-year field experiment in the red soil of southern China. *Journal of Soils and Sediments*. 2015;15(2):260-270.
- Carter MR. Ninhydrin reactive-N released by the fumigation extraction method as a measure of microbial biomass under field conditions. *Soil Biology and Biochemistry*. 1991;23:139-143.
- Casida LE. Phosphatase activity of some common soil fungi. *Soil Science*. 1959;87:305-310.
- Casida LE, Klein DA, Santaro T. Soil dehydrogenase activity. *Soil Science*. 1964;96:371-376.
- Chantigny MH. Dissolved and water-extractable organic matter in soils: a review on the influence of land use and management practices. *Geoderma*. 2003;113:357-380.
- Chhonkar PK, Tarafdar JC. Characteristics and location of phosphatases in the soil-plant system. *Journal of the Indian Society of Soil Science*. 1981;29(2):215-219.
- Dick RP, Rasmussen PE, Karle EA. Influence of long-term residue management on soil enzyme activities in relation to soil chemical properties of a wheat-fallow system. *Journal of Soil Biology and Biochemistry*. 1988;6(2):159-164.
- Dick WA, Tabatabai MA. Kinetic parameters of phosphatases in soils and organic waste materials. *Soil Science*. 1984;137:7-15.
- Eivazi F, Tabatabai MA. Phosphatases in soils. *Soil Biology and Biochemistry*. 1977;9(3):167-172.
- Fauci MF, Dick RP. Soil microbial dynamics: short-term and long-term effects of inorganic and organic nitrogen. *Soil Science Society of America Journal*. 1994;55:125-129.
- Gil-Sotres F, Trasar-Cepeda C, Leirós MC, Seoane S. Different approaches to evaluating soil quality using biochemical properties. *Soil Biology and Biochemistry*. 2005;37(5):877-887.
- Granatstein DM, Bezdicek DM, Cochran VL, Elliot LF, Hammel J. Long-term tillage and rotation effects on soil microbial biomass, carbon, and nitrogen. *Biology and Fertility of Soils*. 1987;5:265-270.
- Grego S, Marinari S, Moscatelli MC, Badaluco L. Effect of ammonium nitrate and stabilized farmyard manure on microbial biomass and metabolic quotient of soil under *Zea mays*. *Agricoltura Mediterranea*. 1998;128:132-137.
- Halstead RL, Lapensee JM, Ivarson KC. Mineralization of soil organic phosphorus with particular reference to the effect of lime. *Canadian Journal of Soil Science*. 1963;43:97-106.
- Islam M, Kader M, Bhuiyan MS, Chowhan S, Talukder JA, Rahman MM. Effect of long-term fertilization on soil respiration and enzyme activities in floodplain soil. *International Journal of Research in Agronomy*. 2019;2(2):29-34.
- Jiang G, Zhang W, Xu M, Kuzyakov Y, Zhang X, Wang J. Manure and mineral fertilizer effects on crop yield and soil carbon sequestration: A meta-analysis and modeling across China. *Global Biogeochemical Cycles*. 2018;32(11):1659-1672.
- Ju XT, Xing GX, Chen XP, Zhang SL, Zhang LJ, Liu XJ. Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proceedings of the National Academy of Sciences*. 2009;106(9):3041-3046.
- Kandeler E, Palli S, Stemmer M, Gerzabek MH. Tillage changes microbial biomass and enzyme activities in particle size fractions. *Soil Biology and Biochemistry*. 1999;31:1253-1264.
- Kumari G, Mishra B, Kumar R, Agarwal BK, Singh BP. Long-term effect of manure, fertilizer, and lime application on active and passive pools of soil organic carbon under the maize-wheat cropping system in an *Alfisols*. *Journal of the Indian Society of Soil Science*. 2011;59(3):245-250.
- Li J, Cooper JM, Li Y, Yang X, Zhao B. Soil microbial community structure and function are significantly affected by long-term organic and mineral fertilization regimes in the North China Plain. *Applied Soil Ecology*. 2015;96:75-87.
- Li JJ, Zhou XM, Yan JX, Li HJ, He JZ. Effects of regenerating vegetation on soil enzyme activity and microbial structure in reclaimed soils on a surface coal mine site. *Applied Soil Ecology*. 2015;87:56-62.
- Lupwayi NZ, Zhang Y, Hao X, Thomas BW, Eastman AH, Schwinghamer TD. Linking soil microbial biomass and enzyme activities to long-term manure applications

- and their nonlinear legacy. *Pedobiologia*. 2019;74:34-42.
28. Manna MC, Bhattacharyya BP, Adhya TK, Singh M, Wanjari RH, Ramana S, *et al*. Carbon fractions and productivity under changed climate scenario in soybean-wheat system. *Field Crops Research*. 2013;145:10-20.
 29. Martens DA, Johanson JB, Frankenberger WT. Production and persistence of soil enzyme with repeated addition of organic residues. *Soil Science*. 1992;153:53-61.
 30. Martinez E, Domingo F, Rosello A, Serra J, Boixadera J, Lloveras J. The effects of dairy cattle manure and mineral N fertilizer on irrigated maize and soil N and organic C. *European Journal of Agronomy*. 2017;83:78-85.
 31. Masto RE, Chhonkar PK, Singh D, Patra AK. Soil quality response to long-term nutrient and crop management on a semi-arid Inceptisol. *Agriculture, Ecosystems & Environment*. 2007;118(1-4):130-142.
 32. Mishra B, Sharma A, Singh SK, Prasad J, Singh BP. Influence of continuous application of amendments to maize-wheat cropping system on dynamics of soil microbial biomass in Alfisols of Jharkhand. *Journal of the Indian Society of Soil Science*. 2008;56:71-75.
 33. Moharana PC, Sharma BM, Biswas DR, Dwivedi BS, Singh RV. Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year-old pearl millet-wheat cropping system in an Inceptisol of subtropical India. *Field Crops Research*. 2012;136:32-41.
 34. Nannipieri P, Grego S, Ceccanti B, Bollag J, Stotzky G. Ecological significance of the biological activity in soil. *Soil Biochemistry*. 1990;6:293-355.
 35. Nath DJ, Ozah B, Baruah R, Barooah RC, Borah DK, Gupta M. Soil enzymes and microbial biomass carbon under rice-toria sequence as influenced by nutrient management. *Journal of the Indian Society of Soil Science*. 2012;60:20-24.
 36. Sharma KL, Das SK, Mandal UK, Ghosh H, Manna MC, Thomsen AG. Effect of permanent cover crops on soil quality in the rainfed region of central India. *Australian Journal of Soil Research*. 2005;43(2):117-125.
 37. Tarafdar JC, Claasen N. Organic phosphorus-compounds as a phosphorus source for higher plants through the activity of phosphatases produced by plant roots and microorganisms. *Biology and Fertility of Soils*. 1988;5:308-312.
 38. Thakur S, Manna MC, Pande DP. Enzyme activities and microbial biomass in soil as influenced by composted rice straw, rice hulls, and inorganic fertilizers in a Vertisol after 10 years of rice-wheat cropping. *Bioresource Technology*. 2008;99(13):4936-4942.
 39. Tilak KVBR, Ranganayaki N, Pal KK, De R, Saxena AK, Nautiyal CS. Diversity of plant growth and soil health supporting bacteria. *Current Science*. 2005;89(1):136-150.
 40. Vance ED, Brookes PC, Jenkinson DS. An extraction method for measuring soil microbial biomass-C. *Soil Biology and Biochemistry*. 1987;19:703-707.
 41. Xiang SR, Doyle A, Holden PA, Schimel JP. Drying and rewetting effects on C and N mineralization and microbial activity in surface and subsurface California grassland soils. *Soil Biology and Biochemistry*. 2008;40:2281-2289.
 42. Yu H, Ding W, Luo J, Donnison A, Zhang J. Long-term effect of compost and inorganic fertilizer on activities of carbon-cycle enzymes in aggregates of an intensively cultivated sandy loam. *Soil Use and Management*. 2012;28(3):347-360.
 43. Zak JC, Willig MR, Moorhead DL, Wildman HG. Functional diversity of microbial communities: a quantitative approach. *Soil Biology and Biochemistry*. 1994;26:1101-1108.
 44. Zhou X, Wang Y, Huang P, Li G, Liu S, Luo Y. Effect of organic and inorganic fertilization regimes on the enzymatic activities of subtropical paddy soils. *Journal of Soils and Sediments*. 2015;15(3):659-669.