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ASSESSMENT OF BIOLOGICAL INDICATORS OF SOIL HEALTH UNDER DIFFERENT LAND USE SYSTEMS IN AN ULTISOL IN KERALA

A.M. Nithya and Betty Bastin

Department of Soil Science and Agricultural Chemistry, College of Horticulture Vellanikkara, Thrissur, Kerala, KAU P.O 680656, Mob: 9061376610, 9480296002, E-mail:nithoosam@gmail.com, Corresponding Author: A.M Nithya

Abstract: *Assessment of soil quality is essential for determining the sustainability of land use systems (LUS). It is generally accepted that intensive agricultural production leads to decline in soil quality. Hence it is highly essential to monitor soil quality. The present investigation had been undertaken in the main campus of Kerala Agricultural University,(KAU) Vellanikkara. The objective was to evaluate soil quality under different long term management in an Ultisol (Vellanikkara series) based on biological indicators. Five fields were selected namely natural forest, rubber plantation, cocoa field, STCR experimental field and tapioca field. All the land use systems except forest had adopted routine and continuous management practices for more than nine years. Sampling sites were selected depending on the variation in slope in each field. From each field, five sites were selected and from each site, three spots were identified .Composite soil samples were collected from each spot from three depths namely 0-15 cm, 15-30cm and 30-60 cm. Samples were analysed for total count of bacteria, fungi and actinomycetes. Activities of soil enzymes i.e. dehydrogenase, urease, phosphatase and asparginase were also estimated. The number of earth worms per sqm in each field was recorded along with survey for the presence of termite mounds. Population of bacteria and actinomycetes was found to be the highest in forest whereas fungal population was found to be the highest in cocoa garden. The total microbial population (TMP) and enzyme activity were found to be the highest in forest followed by cocoa field. Forest also harboured the maximum population of earth worms and termites. Among the different land use systems, forest was superior in biological soil health.*
Keywords: *Land use system, Total microbial population, Kerala Agriculture University*

Introduction: The goal of soil quality research is to learn to manage soil for long term productivity and environmental integrity. Focusing on soil quality has added a focus on the dynamic and biological characters of soil. A number of soil biological properties respond to changes in agricultural practices, showing potential use as indicators of soil quality [1,2]. Biological indicators of soil quality that are commonly measured include soil organic matter, respiration and microbial biomass (total bacteria and fungi). Soil organic matter plays a key role in soil function, determining soil quality, water holding capacity and susceptibility of soil to degradation [3,4]. In addition, soil organic matter may serve as a source or sink to atmospheric CO_2 [5] and an increase in the soil C content is indicated.

The biological activity in soil is largely concentrated in the topsoil, the depth of which may vary from a few to 30 cm. In the topsoil, the biological components occupy a tiny fraction (<0.5%) of the total soil volume and make up less than 10 % of the total organic matter in the soil.. Despite their small volume in soil, microorganisms are key players in the cycling of nitrogen, sulfur, and phosphorus, and the decomposition of organic residues. They affect nutrient carbon cycling on a global scale [6].

Among the biological properties, soil microorganisms are very sensitive to external perturbations and can act as sensors for monitoring soil response, and more generally soil quality. Soil microbial biomass, soil enzymes and basal soil respiration are among the most important biological parameters and have proven to be powerful tools in monitoring soil quality [7,8]. Soil organisms are assumed to be directly responsible for soil ecosystem processes, especially the decomposition of soil organic matter and the cycling of nutrients [9]. These processes are regarded as major components in the global cycling of materials, energy and nutrients. Soil enzyme activities change much sooner than other parameters, thus providing early indications of change in soil health and involve simple procedures [10]. In addition, soil enzyme activities can be used as measures of microbial activity, soil productivity, and inhibiting effects of pollutants [11].

Soil fauna communities, including soil inhabiting invertebrates, are known to improve soil structure by decreasing bulk density, increasing soil pore space, , increased aeration and drainage, increased water holding capacity, litter decomposition and improving soil aggregate structure. In healthy soils invertebrates are abundant.

Continuous cultivation of crop land may pause threat to soil health by impairing the physical and biological properties of soil. The present study will throw light on the effect of long term management under different land use systems in an Ultisol in Kerala. The objective was to evaluate soil quality under different long term management in an Ultisol (Vellanikkara series) based on biological indicators.

Materials and Methods

The present investigation on" Assessment of biological indicators of soil health under different land use systems in an Ultisol in Kerala'' was carried out in the Department of Soil Science and Agricultural Chemistry, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2012-2013.

Five fields from different land use systems were selected in the main campus of Kerala Agricultural University attached to College of Horticulture, Vellanikkara. Geographically, the area is situated at latitude 10^o 32'' N, longitude ranging from 70^o 17'' E and at an atitude of 72 m above mean sea level. Experimental site has a humid tropical climate. In general the soil is a lateritic and acidic (Vellanikkara series) and belong to Kandiustult great group. Soil samples were collected during summer season from a rubber plantation, cocoa field, STCR experimental field, tapioca field and natural forest. Area of individual field was 3600 $m^{2.}$ Sampling sites per field: 5 .Depths of sampling: 3 viz., 0-15 cm, 15-30 cm and 30-60 cm. Replications: 3.Total samples/ field: 45. A brief description of the fields under the different land use systems are given below.

Rubber Plantation (R): This areahas been under rubber cultivation for the last 20 years and is (Block-8).In this plot routine application of fertilizers was done based on package of practices recommendation by KAU.

Cocoa Garden (C): This area has been put under cocoa cultivation for the last 20 years and is located in Block- 34. Regular fertilizer application based on package of practices recommendation by KAU was followed here.

STCR Experimental Field(S): This area was under continuous cultivation for STCR experiments on vegetables and other crops for the last 13 years and is included in Block- 17. The site has been used for the formulation of STCR fertilizer prescription equations for crops like maize, banana, vegetables like brinjal, chilli amaranthus, bhindi, salad cucumber and spice crops like ginger and turmeric based on the STCR methodology of experiments [12].

Tapioca Field (T): This area was under tapioca cultivation for the last 10 years and is located inBlock-12. Here also routine application of fertilizers was done based on package of practices recommendation by KAU.

Natural Forest (F): This forest area consisted of bamboo, teak, mahogany, jack, banyan and someshrubs .This land is under mixed crop stand for about 25 years and is located in Block- 8 of the University. Sampling sites were selected depending on the variation in slope in each field (Table.1). From each field, five sites were selected and from each site three spots were identified (1m apart) and composite samples were collected by sampling around each spot. Soil samples were collected from all three depths namely, 0-15 cm, 15-30 cm and 30-60 cm using spade and core sampler. Number of samples/ field is 45and the total no. of samples is 225. Collected samples were analyzed for different physical, chemical and biological characteristics.

Table I. Categorization of sites based on slope

Fields	Slope (%)				
	Site-1	Site-2	Site-3	Site-4	Site-5
Rubber	3.39	5.24	10.5	14.05	19.44
Cocoa	8.75	10.5	12.30	15.80	19.44
STCR	3.24	5.24	6.99	8.75	14.05
Tapioca	3.49	5.24	6.99	8.75	12.30
Forest	10.51	12.28	14.5	15.84	19.44

Total count of bacteria, fungi and actinomycetes were found out.

The method used for the enumeration was serial dilution and plate count technique as described [13].Ten grams of soil was added to 90 ml of sterile water and agitated for 20 minutes. One ml of the solution was transferred to a test tube containing 9 ml sterile water to get 10^{-2} dilution and similarly 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} dilutions were also prepared. Suitable media (15-20 ml) was poured on the corresponding medium. Plates were incubated at 28+2 ^{0}C.

Results and Discussion

The pyhisicochemical characteristic (range) of the soils collected from the different land use systems are given in table (II)

Observations were taken as and when the colonies appeared (For bacteria-2-3 days, fungi-5-7 days and actinomycetes-3-14 days). The four different enzyme activities were found using different extraction method

Statistical Analysis: The data generated were analyzed using correlation. The total number of earth worms per sq m in each field was counted and recorded. Each field was also surveyed for the presence of termite mounds [14].

Table II. Some important pyhisicochemical characteristic (range) of the soils collected from the different land use systems.

Soil parameter	Rubber	Cocoa	STCR	Tapioca	forest
pH	5.06-5.098	4.13 to 5.71	5.01 to 5.48.	5.01 to 5.46	5.11 to 5.64
EC	0.02-0.08	0.04 to 0.12dS m^{-1}.	0.03 to 0.09 dS m^{-1}.	0.04 to 0.06 dS m^{-1}	0.04 to 0.09 dS m^{-1}
Organic carbon	0.75 to 1.21 %	0.48 to 1.41%.	0.33 to 0.98 %.	0.24 to 1.10 %	0.65 to 1.23%.
Bulk density	1.42 to 1.62 Mg m^{-3}	1.46 to 1.63 Mg m^{-3}	1.51 to 1.64 Mg m^{-3}.	1.52 to 1.64 Mg m^{-3}.	1.46 to 1.63 Mg m^{-3}
Water holding capacity	26.9-49.11	28.31 to 44.61 %	22.11 to 36.44 %.	21.81 to 36.38 %.	26.90 to 49.11 %

**Overall range of the values of the three surface layers up to 60cm depth Number of samples/ field is 45and the total no. of samples is 225*

Organic Carbon: Among the different land use systems, organic carbon content of soil was highest in the forest and lowest in tapioca field. In all the fields, with increase slope percentage the content of organic carbon decreased. The organic carbon content was high in forest soil due to the high annual litter fall return to the soil. This was in accordance to the finding [15,16].

Fungal Population: Among the different land use systems, fungal count of soil was found to be the high in the cocoa garden and lowest in forest and rubber plantation (Table III). Generally, the fungal count of soil showed a decreasing tendency with increase in depth.

Table III. Fungal population(x 10^{6} cfu g^{-1}) **(mean) of soil samples of the different fields**

F 0-15	71	70	68	61	60
F 15-30	42	40	30	33	28
F 30- 60	12	9	8	6	6
R 0-15	75	64	61	60	58
R 30-60	33	25	23	21	18
R 30-60	12	12	11	8	6
C 0-15	79	72	71	70	68
C 15- 30	32	29	24	21	23
C 30-60	18	12	11	16	14
S 0- 15	62	58	56	54	51
S 15-30	46	49	42	41	40
S 30-60	24	22	21	18	11
T 0-15	73	71	68	62	58
T 15-30	31	29	27	24	19
T 30- 60	14	11	8	13	8

Bacterial Population: Among the different land use systems, bacterial count of soil was found to be the highest in the natural forest and lowest in cocoa garden (Table IV).

Table IV. Bacterial population(x 10^{6} cfu g^{-1}) **(mean) of soil samples of the different fields**

Depth (cm)	Site-1	Site-2	Site-3	Site-4	Site-5
F 0-15	61	58	56	54	42
F 15-30	39	39	38	34	31
F 30- 60	14	11	13	9	8
R 0-15	44	42	39	38	31
R 30-60	29	28	24	21	18
R 30-60	16	14	12	9	8

C 0-15	42	41	40	39	36
C 15- 30	39	32	33	15	22
C 30-60	10	10	8	3	6
S 0- 15	46	41	33	32	30
S 15-30	26	24	23	22	21
S 30-60	19	16	15	14	12
T 0-15	39	38	38	36	34
T 15-30	24	26	22	22	21
T 30- 60	13	17	11	9	8

Table V. Actinomycetes population (x 10^5 cfu g^{-1}) **(mean) of soil samples of the different fields**

Depth (cm)	Site-1	Site-2	Site-3	Site-4	Site-5
F 0-15	75	72	69	66	60
F 15-30	42	40	39	38	25
F 30- 60	20	21	18	17	12
R 0-15	70	69	67	64	58
R 30-60	42	39	34	29	24
R 30-60	25	18	14	12	9
C 0-15	68	66	62	58	54
C 15- 30	28	26	23	21	20
C 30-60	16	14	11	11	9
S 0- 15	60	54	52	43	42
S 15-30	26	24	22	19	19
S 30-60	17	12	11	15	16
T 0-15	62	58	58	54	53
T 15-30	24	22	21	21	19
T 30- 60	13	12	14	11	9

Actinomytes population:- Generally the actinomycetes count of soil showed a decreasing tendency with increase in depth. The value ranged from 12 to $75x10^{-5}$ cfu g^{-1}. (Table-V) and predominance of each microbes in different fields were also generally given(Table:- VI)

Table VI. Predominance of microbes in the different fields

Field	**Predominant microflora**
Tapioca	Fungi
Rubber plantation	Actinomycetes
Cocoa field	Fungi
STCR field	Fungi
Forest	Actinomyctes

Fungal population was always higher in surface soil, which might be due to high amounts of C_{org} (carbon organic), higher aeration and favourable moisture. The decline in fungal population numbers with increasing depth observed in this study agreed with the findings [17] and variation in physico-chemical properties of soil might play an important role in this feature [18]. According to fungi grow slowly with increasing depths due to shortage of mineral nutrients and compaction of soil. Significant decrease in C_{org}(carbon organic) and N_{tot} (nitrogen total) with increasing depth might be due to low organic matter availability at greater depths. The predominanance of microbes in different fields were found out. The actinomycetes population was found to be high in forest field and rubber plantation and fungi was found to be highest in cocoa field, STCR experimental field and tapioca field.

Enzyme Activity

Asparginase: Among the different land use systems, asparginase enzyme activity of soil was found to be the highest in the forest and lowest in tapioca field

Dehydrogenase: Among the different land use systems, dehydrogenase enzyme activity of soil was found to be the highest in the natural forest and lowest in STCR experimental field The dehydrogenase enzyme activity of soil was found to be the highest in the natural forest when the different fields were compared. In the forest ecosystem the dehydrogenase enzyme activity of soil showed a decreasing tendency with increase in depth. The value ranged from 211.65 to 462.14 µg of P- nitrophenol released g^{-1} of soil hr^{-1}.The highest value was observed in 0-15 cm (Site-2) and lowest value observed in 30-60 cm depth (site-3).The dehydrogenase acitivity has been often linked with the levels of available organic carbon substrates in the soil, as they serve as the source of electrons and H^+ for accomplishing reduction reaction. The higher level of dehydrogenase activity observed under forest, might be due to high organic carbon, litter accumulation, and nutrient status [20].

The activities of enzymes in almost all fields markedly decreased with depth. This decrease in enzyme activity with depth was associated with decrease in organic matter. The level of enzyme activity increased with increase in organic carbon content in soil. This may be related to the population dynamics of microflora. The decrease in dehydrogenase and phosphatase activity with depth is important because dehydrogenase is considered as an indicator of total microbial activity and phosphatase as the indicator of the rate of hydrolysis of organic P [21].

4.3.5.3 Urease: Among the different land use systems, urease enzyme activity of soil was found to be the highest in the natural forest and lowest in rubber plantation Urease is unique among soil enzymes because it affects the fate and performance of fertilizer urea. Urea when added to the soil as fertilizer, is rapidly hydrolyzed to ammonium carbonate in most soil through the activity of soil urease and is responsible for the rapid release of ammonia when urea is applied. Urease is a constitutive enzyme found in large number of microorganisms especially in ureolytic bacteria and fungi [22]. In the forest field, the mean urease enzyme activity of soil showed a decreasing tendency with increase in depth. The value ranged from 401.76 to 664.65ppm of urea hydrolysed g^{-1} of soil hr^{-1}. The highest value was observed in 0-15cm (site-4) and lowest value in 30-60 cm depth (site-5). In the rubber plantation to the mean urease enzyme activity of soil showed a decreasing tendency with increase in depth. The value ranged from 168.16 to 588.54 ppm of urea hydrolysed g^{-1} of soil hr^{-1}. In the cocoa garden also, the mean urease enzyme activity of soil showed a decreasing tendency with increase in depth. The value ranged from 249.09 to 639.88 ppm of urea hydrolysed g^{-1} of soil hr^{-1}. In the STCR experimental field the mean urease enzyme activity of soil showed a wide range of decreasing tendency with increase in depth. The value ranged between 272.64 to 484.86 ppm of urea hydrolysed g^{-1} of soil hr^{-1}. The tapioca field also the trend was the same as above. The value ranged from 272.14 to 588.41 ppm of urea hydrolysed g^{-1} of soil hr^{-1}.

The study showed that an increased urease activity was prevalent in the forest ecosystem followed by cocoa garden. This increase in urease activity may be attributed to desirable soil characteristics and associated beneficial elements. A significant and positive correlation of urease with CEC, available N, available P and available K also indicated the role of organic manures in the availability of nutrients which ultimately resulted in higher activity of urease. This was evidently due to the higher activity of substrate nitrogen (urea), which promoted urease activity. The higher values registered for urease under different ecosystems could be attributed to the high organic matter addition through litter fall, which served as a good source of energy, carbon and nutrients for ureolytic microorganisms. In general, there was a decrease in urease activity with higher dose of fertilizer addition except for nitrogen.Since nitrogen was supplied as urea, an increase in urease activity was generally expected as the substrate concentration was high. Further addition of nitrogen might have increased the population of ureolytic organism initially which resulted in high urease synthesis. Reported increase in the activity of urease with addition of urea [23].

4.3.5.4 Phosphatase: Among the different land use systems, phosphatase enzyme activity was found to be highest in cocoa garden and lowest in tapioca field It was noted that under the forest ecosystem, where there was lack of a fertilizer programme, a higher phosphatase activity was noticed. This could be attributed to the release of P from organic matter by acid phosphates associated with the dead and living cells through internal cell metabolism and energy transformation reaction. This was in accordance with the finding [24]. The high activity observed in rubber plantation and cocoa garden might be due to the protection of phosphatase produced by the adsorption and stabilization mechanism brought about by a higher level of organic colloids than the other ecosystems studied. Similar mechanism of enzyme protection in soil sytem by organic fraction had been reported [25].

The decrease in phosphatase enzyme activity in STCR experimental field and tapioca field could be attributed to the reduced activity of phosphorous solubilising organisms in response to a high available P. Thus the maximal activity of phosphatase could be observed only in fields receiving maximum organic phosphatase. This was in accordance of result obtained [26]. The decrease in phosphatase activity observed at high dose of K application might be attributed to the higher sensitivity of active P- solublizing flora to the higher concentration of K.

Earth Worms and Termite Mound: The highest number of earth worms was found in forest field (38 nos m^{-2}) followed by cocoa garden (26 nos. m^{-2}), rubber plantation (22 nos m^{-2}), STCR experimental field (16 nos. m^{-2}) and tapioca field (15 nos. m^{-2}) On surveying the whole area under each field, it was found that the highest number of termite mounds was in forest field (12) followed by cocoa garden (6), rubber plantation (5), STCR experimental field (nil) and tapioca field (nil) hr^{-1}.

Conclusion: In this investigation, an attempt has been made to evaluate the soil health under different land use systems in an Ultisol (Vellanikkara series) based on biological indicators. The samples were taken from different blocks in KAU campus identified as different fields. Altogether 225 samples were collected from 3 depths from five different ecosystems. The salient results obtained in the present work are summarized below.

The total microbial population was found to be highest in forest followed by cocoa. The count was highest in surface samples and it was due to the high organic matter content in the surface layer.The enzyme activity was also found to be highest in forest field followed by cocoa field. The activity was highest in surface samples and it was due to the high organic matter content in the surface soil layers. The earthworm activity and termite activity was found to be the highest in forest field followed by cocoa garden.

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