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Studies on influence of different cropping systems on soil fertility sustenance in the vertic ustropept

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Abstract
A research work was initiated during 2018-19 at Tamil nadu agricultural University with different cropping sequences involving annual crops in three seasons with four cropping sequences along permanent fodder crops such as BN hybrid grass, desmanthus and cenchrus to study the influences of these cropping on soil quality parameters. The results are, the physicochemical do not influenced by cropping sequences. The higher level of organic carbon (5.88 g/kg), available nitrogen (265 kg/ha), available phosphorus of 22.3 kg/ha, available potassium of 598 kg/ha was registered in cowpea-ragi-green manure sequence. The higher value of active soil carbon (685 mg/kg) was recorded in bajra napier (BN) fodder grass. The cowpea-ragi-green manure (GM) recorded higher macro aggregates carbon (6.58 g/kg), higher micro aggregate associated carbon (8.66 g/kg), Higher soil dehydrogenase enzyme activity of 179.3 mg TPF/kg/24 hrs and alkaline phosphatase activity (58.25 PNP ug/g/hr) was observed in cowpea-ragi-GM. The microbial population, bacteria, fungi and actinomycetes are better expressed in cowpea-ragi-GM (52 cfu x 10-6 g/soil, 23 cfu x 10-4 g/soil and 13 cfu x 10-3g/soil.

Keywords: Cropping sequences, soil nutrients, carbon, microbial population, enzymes

Introduction
Agricultural intensification has led to a decline in soil quality by decreasing soil organic matter (OM) content, reducing the soil natural fertility, polluting the environment and negatively affecting the soil biota and changing the climate and soil environment also. To mitigate the change in climate, among the different means, ***s***oil also one of the key components of agricultural production system and it needs to be relooked in light of projected climate change for sustainable agricultural productivity.(Bama et al., 2019) [1]. In the present day agriculture, sustenance of soil fertility is a crucial one because of various soil degradation processes. Among different factors contributing for the soil fertility, land use change is an important factor which will influence the soil heath within the short term. In the land use management practices, choosing crop or cropping sequence play a major role in altering the soil quality. Doran and Safley. (1997) [2] reported that, soil quality is the continued capacity of soil to function as a vital living system.

Wani et al. (1994) [3] found that green manures and organic amendments in crop rotations provided a measurable increase in soil organic matter (SOM) quality and other soil quality attributes compared with continuous cereal systems. According to Bama and Babu (2016) [4], among the various forage crops, Cumbu napier hybrid grass removed higher carbon removal by above ground biomass and in the below ground biomass. Among the sources, farm yard manure. applied plot sequestered more below ground carbon. Karlen *et al*. (2003) [5] reported that the quality of the soil is concentrated more on managing dynamic properties of the soil and monitored mainly on the surface horizon (0 - 25 cm) of soil. Soil quality assessment is important for measuring soil changes over time, helping to identify effective management strategies and measure soil quality directly.

Parihar *et al*. (2018) [6] suggested that the different effects of cropping systems in modifying SOC might be related to the nature of component crops and the amount of residue retained under these cropping systems. Selvaraju (1994) [7] reported that the soil organic carbon (SOC) content can change as a result of the crop species being cultivated, cropping systems (including rotations), residue management practices, applications of fertilizers, tillage processes, and other management factors.

Total organic C in soil is comprised of several dynamic pools, broadly grouped as labile pool or active pool, slow pool and passive recalcitrant pool. Bama et al. (2017a) [8], reported that, bhendi-maize cropping sequence registered higher carbon stock of 11.24 t/ha/yr. They also stated that irrespective of manures and cropping sequence, minimum tillage recorded higher carbon stock of 10.92 t/ha/yr than conventional tillage 110.72 t/ha/yr. Mulching of in situ crop residue with 75% recommended dose of fertilizers and 25% N through organic is revealed higher C stock than mulch with 100% recommended dose of fertilizers.

The soil organic carbon can be differentiated in to different pools. Labile pools consist of soil microbial biomass carbon (C), water soluble C, water soluble carbohydrates. These pools have been used as sensitive indicators for judging C dynamics in soil in short to medium term basis. Carbon pools such as dissolved organic C, microbial biomass C and potassium permanganate (KMnO4) oxidizable C have received considerable attention due to their sensitivity to agricultural management practices (Culman et al., 2012) [9]. KMnO4-oxidizable organic C or LOC (labile organic carbon) and carbon concentrations within water-stable macro-aggregates and micro aggregates are suggested to be more sensitive indicators than bulk SOC. The soil carbon stock value indicated the capacity of the soil to hold the carbon. Bama et al. (2017b) [10]. Also reported that, higher value of passive carbon recorded in bhendi- maize+cowpea-sunflower sequence might be due to legume crop of cowpea addition in the sequence might be due to more residue addition from sunflower and bhendi crops as well as intercropping of maize with legume crop.

Soil fundamental properties can be influenced by soil aggregation which causes effect on soil health studies by changing soil structure, water retention and movement, organic matter stabilization and nutrient cycling. Tisdall and Oades (1982) [11]. Observed the highest water stability of soil aggregates in the maize mono crop due to its rooting pattern which account the importance of roots and fungal hyphae in soil stabilization aggregates. It is also supported by Mandal et al. (2007) [12].that the plant roots can stabilise soil particles directly or favour soil aggregation through microbial activity. It was also supported by Hema et al. (2019) [13]. Ferreras et al. (2006) [14]. Reported that the higher rate of amendments increased the proportion of water-stable aggregates.

Mi et al. (2016) [15]. Opined that the particulate organic carbon was not susceptible to the different management methods and also suggested that the most efficient management practice to improve soil carbon sequestration in present soil conditions is the integrated use of cattle manure and NPK fertilisers. Chan et al. (2001) [16]. Examined that the water stable aggregated organic carbon fractions were also most susceptible to change because of various crop and nutrient management practices.

Soil microorganisms play crucial roles in ecosystem functioning and fertility maintenance by regulating several key biogeochemical processes in soil. To bridge the soil microbial community and soil substrate availability (Nannipieri et al., 2018) [17]. Enzyme activities are indicative of microbial functioning in the soil system. Fraser et al. (1988) [18]. Reported that the combination of cropping (oat/clover) and manure application stimulated microbial numbers and activity. He also stated that, the increased levels of SOC and possibly greater inputs of available soil C from oat/clover contributed to greater microbial activity in surface soil.

Another study by Bama et al. (2017 b) [10]. Reported that, organic source of nutrients sequestered more carbon in deeper depth than inorganic or intergrated nutrient management in the forage cropping sequences. Bama et al. (2017c) [19]. Conducted experiment on tillage and crop establishment methods and found that, zero tillage recorded higher soil carbon stock than crop establishment method combined with minimum or conventional methods. Another study with different cropping sequences, Bhendi-maize + greengram – Greenmanure improved the passive carbon as well as carbon stock might be due to high organic carbon accumulation in that cropping sequence (Bama et al., 2017a) [8]. Bama and Latha (2017) [20] reported that enforcing the standardization of analytical methods for carbon sequestration studies and explained about the role of land use and management on soil carbon fractions.

Bama et al. (2020) [21] reported that green manure included sequence registered higher soil quality parameters. Irrespective of cropping sequences of fodder maize, FYM applied plots @25 t/ha recorded higher nutrient status, organic carbon and microbial population. However, for sustainable soil health, three crops of fodder maize with inclusion of green manure (dhaincha) and FYM @25t/ ha showed better results in terms of increased nutrient status (17 % increase of OC and 13,16 and 8 % of N,P and K over initial status,) and soil microflora.

Bama et al. (2013) [22] indicated that, the higher organic carbon content of 1.12 per cent recorded in FYM applied plot followed by poultry manure applied treatment (0.99%) from the initial carbon status of 0.62 per cent. Bama (2016) [23] reported the higher nutrient uptake in organics applied treatment than inorganics and the INM applied soil recorded higher SOC of 0.80 per cent. Bama (2017) [24] reported that, higher SOC in the FYM applied fully on nitrogen equivalent basis than other organic sources. Bama and Babu (2016) [4] For improving the carbon storage in agricultural soil, cropping with forages have great oppourtunity to fix carbon due to undisturbed cultivation for long period. Yazhini et al. (2019) [25] observed that, higher soil carbon pools were seen in the legume included maize based cropping sequences. In the deltaic zone of Tamil Nadu. Hema et al (2019) [26] reported that, active pools of SOC viz., labile carbon(LC) and water soluble carbon (WSC) and soil carbon stock(SCS) after 6 years of treatment in the application of 100% organics in brinjal recorded higher values.

Jarvan *et al.* (2014) [27] resulted that the cattle manure applied in organically managed crop rotation increased the numbers of total bacteria and cellulose decomposing bacteria, and the soil dehydrogenase activity. Bhattacharyya *et al.* (2016) [28] found that the application of organic manures not only add nutrients to the system but also create an atmosphere for better growth and activity of soil organisms, leading to efficient mineralization of crop nutrients which evident by higher activity of fluorescein diacetate, dehydrogenase and alkaline phosphatase under the organic system. Campbell *et al*. (1999) [29] opined that the differences in water soluble carbon pools in soils under different cropping systems indicate differing patterns of root exudation between crop species and soil inputs of both amount and type of C. Based on the above literatures, cropping sequences are more important, particularly selection of crops for the rotation are definitely influences the soil quality (Bama, and Somasundaram, 2017) [30] Inclusion any legume in the sequence will improve the soil quality. Hence, this research work has been carried out with the different cropping sequences in a tropical ecosystem of irrigated uplands by including legumes in the cropping sequences.

Materials and methods

To study the impact of different cropping sequences on soil quality and to assess the better cropping sequence which has the high potential to maintain the soil quality, soil samples were collected during 2018-19 from the field experiment conducted at TNAU, Coimbatore. The initial soil samples were collected and analysed for its nutrient content. The initial soil analysis showed that, soil texture consists of sand (36.5 percent), silt (27.5 percent), clay (35.9 per cent) and comes under clay loam. The soil characteristics analysed are, pH (1:2.5) of 8.40,Electrical conductivity of 0.72 dS/m, exchangeable sodium of less than 4 per cent, soil organic carbon of 5.52 g/kg, available nitrogen content of 232 kg/ha, available phosphorus content of 21.1 kg/ha, available potassium content of 565 kg/ha. The soil samples were analysed for its nutrient contend as per the standard procedure. Treatments included are seven different cropping systems. Four cropping sequences with green manure as one of the crop in the sequence in all annual crops sequence. Along with annual crops, fodder crops such as BN hybrid grass, desmanthus and cenchrus were cultivated as totally seven treatments. Soil samples were collected after completing all three crops in one year in the case of annual crops.

Results and discussion

The physico chemical characters such as soil reaction and electrical conductivity (EC) reveal that there is no statistical difference observed due to the different cropping sequences. But available nutrient status and organic carbon were influenced by cropping sequences. The higher soil organic carbon was recorded in cowpea-ragi-green manure (5.88 g/kg) which is on par with BN hybrid grass grown soil (5.80 g/kg) and desmanthus grown soil (5.82g/kg). The higher value might be contributed by higher residue addition in these treatments (table1). Similar results was suggested by Selvaraju (1994) [31], that crop species or cropping systems (including rotations) and residue management practices played major role in the SOC content change. Romheld and Kirkby (2010) [32] reported that strengthening of the microbial population by the retention of plant biomass, which has increased decomposition of crop residues and accretion of SOC. Das et al. (2014) [33] discussed the fact that the leaves fall on the field by pulses also contribute to the timely maintenance of greater soil C. Mandal *et al*. (2007) [12] reported that C input higher than critical level is most likely to maintain the critical level of SOC and maintain a good soil health in subtropical regions of the Indian subcontinent cropping systems and management practices. Subbian (2008) [34] stated that crop rotation is useful for retaining the SOC content by cultivating large residues producing plants (table1).

Higher available nitrogen content was recorded in cowpea – ragi- green manure cropping sequence (265 kg/ha) which is on par with desmanthus grown soil (252 kg/ha). The lower value was recorded in the maize-sunflower-green manure (234 kg/ha) which is on par with BN hybrid grass. This might be due to the presence of higher plant residues which increases soil nutrient status through enhancing soil microbial activities. The conversion of organically bound N to inorganic form can easily occurred by enhancing soil microbial biomass carbon (SMBC) with the addition of crop residues.

However BN hybrid recorded higher available phosphorus of 22.3 kg/ha which is on par with cowpea-ragi-green manure (21.7 kg/ha). During the decomposition of organic matter by microbial activity, the organic acids released, which was useful to improving the soil fertility in soil available phosphorus content by solubilisation of native phosphates. Wang et al. (2011) [35] reported the possibility for enhancing microbial activity, decreasing water-soluble P fixation and greater the organic phosphorus mineralization by using crop residues.

Higher available potassium was recorded in cowpea-ragi-green manure (598 kg/ha). This might be due to contributions from the decomposition of plant residues and direct addition of potassium to the soil available pool. The similar result was given by Prasad et al. (2010) [36].

Table 1: Impact of Integrated farming system on physico chemical properties and available nutrient status of post harvest soil samples

Cropping pattern	pH	EC (dS m^{-1})	Organic carbon (g/kg)	Available nutrient(kg/ha)		
				Nitrogen	Phosphorus	Potassium
Initial	**8.40**	**0.72**	**5.52**	**232**	**21.1**	**565**
Cowpea (G) –ragi-GM	8.32	0.75	5.88	265	21.7	598
Maize-sunflower-GM	8.40	0.78	5.65	234	21.2	575
Prosomillet-chillies-GM	8.32	0.80	5.65	242	20.8	586
Pearl millet-cotton-GM	8.35	0.84	5.62	248	20.6	584
BN hybrid grass	8.40	0.72	5.80	225	22.3	452
Desmanthus	8.41	0.82	5.82	252	21.0	553
Cenchrus sp.	8.34	0.60	5.60	228	21.8	542
CD(p=0.05)	NS	NS	0.22	13	1.1	26

The soil carbon consists of labile or actively cycling carbon pool and non labile or resistant/passive pool. The passive pool changes slowly by microbial activities but labile carbon will change rapidly. The labile decomposable material serves as an energy source for microbes and maintaining soil quality. Due to intensive cropping of current situation, there is a critical need for the development of best cropping that enhances the build up of SOC so that it can sequester more carbon and in turn has potential to mitigate the increasing CO_2 concentration in the atmosphere.

The results obtained from the fractions of soil carbon viz., $KMnO_4$ Carbon (labile carbon) and passive carbon in the prominent cropping sequence is given in table 2. The results showed that, the high value of the $KMnO_4$ oxidisable C (685 mg/kg) i.e amenable to management practices was recorded in fodder grass which is on par with in Desmanthus grown soil (664 mg/kg) and then prosomillet-chilli-GM cropping sequence. The passive carbon (5236 mg/kg) is high in cowpea-ragi-GM, though higher active C recorded in BN hybrid grass. The lower passive carbon registered in cenchrus sp grown soil. Yang *et al*. (2012) [37] hypothesized that long-term cropland abandonment or intensive cultivation using a double cropping system with balanced and imbalanced fertilization in combination with or without organic amendment may influence different labile carbon fractions due to differences in organic matter inputs and disturbance. Bama and Babu (2016) [4] reported that, among the different forage crops, Cumbu Napier grass had higher carbon sequestration potential of above ground biomass which removed 336.7 t CO2/ha than multicut fodder sorghum (148.7 t CO2/ha). The higher below ground biomass in Cumbu Napier grass removed 7.73 t CO2/ha from the atmosphere than Lucerne (4.21 t CO2/ha). The soil physical properties and microbial populations were also favourable in the grass type fodder. Among the nutrient sources, the FYM favoured higher carbon fixation in the soil than poultry manure, integrated nutrient management and inorganics alone. In addition, the Cumbu napier fodder crop stored 9.2 g/kg of soil organic carbon over initial SOC status of 6.5 g/kg followed by multicut fodder sorghum accumulated (8.7 g/kg). The soil carbon stock was worked out to be 18.63 t/ha/year in Cumbu napier grass than by multicut fodder sorghum 17.62 t/ha.

The particulate organic carbon separated n three forms as macro (>250 µm), micro (250-53µm) and intra micro (<53 µm) (table3). The results shows that, among the cropping sequences, cowpea-ragi-GM recorded higher macro aggregates carbon (6.58 g/kg) which is on par with all fodder crops grown soil such as fodder grass (6.02 g/kg), desmanthus (6.20g/kg) and cenchru (6.10 g/kg). Higher micro aggregate recorded in cowpea-ragi-GM (8.66 g/kg) and same trend as that of macro aggregate associated carbon. The application of organic fertilizers is an important practice in increasing soil aggregate stability and C sequestration (Ahmad et al., 2008) [38].Manure and organic fertilizer application increased the accumulation of macro aggregate protected C and appears to sequester more organic C. Hema et al. (2019) [13] reported that macro-aggregates under different land-use and soil management conditions were C-rich compared to micro-aggregates. Ghosh *et al*. (2018) [39] reported that long-term fertilization also significantly affected SOC within microaggregates in both soil layers.

Table 2: Influence of different cropping sequences on soil carbon fractions

Cropping pattern	Labile C) (mg/kg)	Passive carbon (mg/kg)
Cowpea (G) –ragi-GM	644	5236
Maize-sunflower-GM	632	5018
Prosomillet-chillies-GM	586	5064
Pearl millet-cotton-GM	555	5055
Fodder grass (CO (BN) 5)	685	5115
Desmanthus	664	5156
Cenchrus sp.	652	4948
CD(p=0.05)	35	NS

GM-green manure

Table 3: Influence of different cropping system on soil aggregate associated carbon (g kg^{-1}) in different seasons

Cropping pattern	>250µm sieve size Macro aggregate associated carbon	250-53µm sieve size Micro aggregate associated carbon	<53µm sieve size Intra micro aggregate associated carbon
Cowpea –ragi-GM	6.58	8.66	09.32
Maize-sunflower-GM	5.72	8.05	08.02
Prosomillet-chillies-GM	5.11	7.90	09.10
Pearl millet-cotton-GM	5.50	7.01	08.69
Fodder grass (CO (BN) 5)	6.02	8.10	10.20
Desmanthus	6.20	8.21	10.52
Cenchrus sp	6.10	8.02	09.80
CD(p=0.05)	0.45	0.65	0.80

At the end of one year cropping cycle, biological property of the experiment revealed that, soil microbial population viz., bacteria, fungi and actinomycetes are better expressed in cowpea-ragi-GM (52 cfu x 10-6 g/soil, 23 cfu x 10-4 g/soil and 13 cfu x 10-3g/soil) which is closely followed by desmanthus grown soil (52 cfu x 10-6 g/soil, 22 cfu x 10-4 g/soil and 12 cfu x 10-3g/soil) (table4). Soil enzymes are better short time indicator of soil fertility. Fraser et al. (1988) [18] reported that the combination of cropping (oat/clover) and manure application stimulated microbial numbers and activity. He also stated that, the increased levels of SOC and possibly greater inputs of available soil C from oat/clover contributed to greater microbial activity in surface soil. Subbian *et al*. (2008) [34] suggested that the amount of biological nitrogen fixation depends on soil and climatic conditions and also reported that the addition of organic manure or biosolids enhances proliferation of mycorrhizal fungi.

The soil enzymes especially soil dehydrogenase activity indicating the organic matter status. Higher soil dehydrogenase enzyme activity of 179.3 mg TPF/kg/24 hrs, alkaline phosphatase activity (58.25 PNP ug/g/hr) was observed in cowpea-ragi-GM (Table4) which was on par with fodder grass in alkaline phosphatase activity and on par with desmanthes in dehydrogenase activity. This might be due to the presence of higher plant residues in the soil which improves SOC and in turn microbial communities and which enhances soil phosphatase and other soil enzyme activities. Dalal (1982) [40] also mentioned that the phosphatases activities in soils are mainly caused by extracellular enzymes linked to soil constituents and to the cellular particles of the deceased microbial cells. The higher microbial population enhances the phosphatase activity by the addition of plant residues, act as a carbon source for microbes. The phosphatase activity in soil is affected by the total amount of C and its degree of availability in the crop residues.

Conclusion

The research work carried out with different cropping sequences reveals that, for fertility point of view, the cowpea-ragi-green manure cropping may be better to immediate availability of nutrients, microbial population and enzyme activity. In the environmental point of view, to sequester more carbon in mineral associated carbon/passive carbon, the fodder crops, BN hybrid or desmanthus crops are better.

Table 4: Influence of cropping sequences on soil biological properties

Cropping pattern	Bacteria (cfu x 10^{-6}) g/soil	Fungi (cfu x 10^{-4}) g/soil	Actinimycetes (cfu x 10^{-3}) g/soil	Alkaline phosphatase (PNP ug/g/hr)	Soil dehydrogenase activity mg TPF/kg/24 hrs
Cowpea (G) –ragi-GM	52	23	13	58.25	179.3
Maize-sunflower-GM	42	16	9	52.20	157.0
Prosomillet-chillies-GM	42	14	10	50.20	166.2
Pearl millet-cotton-GM	44	14	10	49.25	168.5
Fodder grass (CO (BN) 5)	50	20	11	57.05	170.4
Desmanthus	52	22	12	55.21	176.3
Cenchrus sp.	48	18	10	50.60	162.2
CD (at5 %)	4	2	2	4.5	15.2

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