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Aggregate Associated C and Their Stability, and Mineralizable C and N under Different Agricultural Land Use Systems of Sub-Montaneous Districts of Punjab, North-West India

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ABSTRACT

The study was conducted in soils of sub-montaneous districts of Punjab", two sites were selected in 'lower Shiwaliks foothills of Punjab locally known as Kandi area' i.e Takarla from District Shaheed Bhagat Singh Nagar and Mukerian from District Hoshiarpur. The results showed that at Takarla the proportion of macroaggregates (0.25 to 2 mm) were higher in grassland and agro-forestry and proportion of microaggregates (0.1-0.25 mm) were higher in agro-forestry and cropland and in Mukerian, among the different land-uses, the macroaggregate (0.25 to 2mm) proportion was higher in grassland and crop and the proportion of microaggragates having size of <0.25 mm, were higher in agro-forestry followed by forestry, cropland and grassland. At Takarla and Mukerian macro-aggregate associated C ranged from73.0 to 1378.2 and 106.3 to 8203 mg kg^{-1}, respectively and micro-aggregate associated C ranged between 386.9 to 923.6 and 1249.7 to 2565.0 mg kg^{-1}, respectively. Macro-aggregates were richer in aggerate associated carbon at both the locations as compared to micro-aggregates. The cumulative carbon mineralized (C_{min}) in 43 days of incubation under different land-use systems in Takarla and Mukrian, respectively, ranged from 33.4 to 48.6 ans 42.8 to 85.8 mg kg^{-1} of soil. Amount of C was mineralized was highest in the grassland followed by forestry at Takarla and the agro-forestry followed by forestry at Mukrian. At Takarla and Mukerian after 43 days of incubation at field capacity moisture and 25° C temperature, the cumulative N mineralized (N_{min}) in 0-15 cm depth ranged from 70.0 to 109.7 and 63.0 to 116.7 mg N kg^{-1}, respectively, under different land-use systems and was highest under forest land-use at both the sites.

Key words: *Agricultural land use, Aggregation, Carbon sequestration, Soil organic carbon, Mineralizable carbon and nitrogen*

Novelty statement

Land-use influences potentially mineralizable C: a close relationship exists between content of biomass and soil organic C, usually considered the most important substrate for soil microorganisms.Land-use influences potentially mineralizable C through improvement in soil organic matter, soil physico-chemical conditions etc. Nitrogen mineralization, which is a useful indicator of soil quality, depends on soil, climatic and many land-use characteristics. It has been observed that land-use can affect soil quality and soil health indicators , which are inturn dependent on different crop management practices.

INTRODUCTION

The dynamics of carbon in the soil is not only important for productivity and sustainability of terrestrial ecosystems, but greatly contributes to global carbon cycles[9]. The soil acts as a source and sink of major carbon reserviour. Atmospheric carbon is witheld for long period of time in the soils and it is often referred to as being sequestered and thus soil carbon sequestration is important to reduce the atmospheric CO_2 concentration. The land-use has a great mpact on the SOC pools and fluxes. According to Lal[28], the deforestration and grassland conversion to arable land-use results in about 77 per cent land-use change, and hence, the depletion of SOM is due to conversion of natural to agricultural land-use[2]. Change in land use contributes to atmospheric C in two major ways i) C being released from brunt or decomposed biomass and ii) the C released following cultivation due to high mineralization as well as change in soil moisture and temperature regimes[29]. Shepherd *et al*[41]., reported that intensive tillage disturbs the soil structure and exposes the inaccessible SOM to microbial attack, and according to Zhang and Chen[52], tillage makes soil susceptible to water and wind erosion. Primary above ground biomass organic carbon inputs are removed by cultivation[53].

The intensity of land management strongly influences the quality and dynamics of soil aggregation as well as SOC[5,42]. Agro-forestry, if adopted at a rate of 2-4 per cent annually, could reduce carbon emission by about 38-66 million tonnes. The agro-forestry system can greatly help in sequestering the above and below ground soil carbon and thus help in mitigating the green house effect[1], and Gupta *et al*[19]., reported that SOC increased from 0.36 per cent under sole crop to 0.66 per cent under agro-forestry. Blanco-Conqui *et al*[4]., on the other hand, observed forest soils to have maximum potential for sequestrating SOC. Compared to cultivated soils, grassland soils have higher organic carbon concentration[25] and the minimal potential for erosion loss and have thus been identified as one of the potential sites to sequester C in the terrestrial ecosystem[12].

Land-use influences potentially mineralizable C and N through improvement in soil organic matter, soil physico-chemical conditions etc. As the soil carbon and nitrogen mineralization rates are regarded as useful soil health and quality indicators, therefore the present study was undertaken to study soil aggregation and organic carbon storage in different sized aggregates under various land use systems and to evaluate the mineralizable C and N under different land use systems in sub-montaneous districts of Punjab.

MATERIAL AND METHODS

Study area

The study was conducted in soils of sub-montaneous districts of Punjab”, two sites were selected in ‘*lower Shiwaliks foothills of Punjab locally known as Kandi area’* i.e Takarla from District Shaheed Bhagat Singh Nagar and Mukerian from District Hoshiarpur. At takarla site four land use sytems were located at 31°06'45.2"N and 76°22'39.7"E with height of 339 meter above mean sea level and at mukerian site four land use sytems were located at 31°56'29.50"N and 75°51'39.76"E with height of 365 meter above mean sea level.

Land uses

Four land use sytem: cropland, forestry, agro-forestry and grassland were selected. In crop lands characterized by addition of fertilizers and farm yard manure, the soil samples were collected under Maize-Wheat system. Forest land use systems characterized addition of organic matter through falling leaves, including those of tree species (Beri, Neem, Bamboo, Sharinh, Kikar, Tahli, Lantana and Subabul) in both sites whereas, Agro-forestry are characterized by Poplar-fodder (Bajra, Baru) / Wheat and Sagwaan / Toon, Bahera, Sarihn – Wheat / Barseem.

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On the other hand, Grassland are characterized by grass stands, at Takarla, grassland is 25 years and Mukerian is >50 years old.

Soil sampling and Soil analysis

Three spots were randomly selected from selected sites under each land use system. The soil samples were taken from four depths (0-15, 15-30, 30-60 and 60-90 cm), with three replication, in each land use system. The samples were brought to laboratory and were shade dried and then the samples were passes through 5 and 8 mm sieves, and those retained on 5mm sieve were analyzed for aggregate size distribution.

Size distribution of water stable aggregates

Wet sieving method of Yoder[51], (1936) was used for aggregate size determination. The 5-8 mm air dried clods were uniformly spread on the top of sieve nest having 2, 1, 0.5, 0.25 and 0.11 mm pore diameter, the sieve nest was oscillated up and down for 30 minutes at a frequency of 30 cycles per minute in water (free of salts) and then the water stable aggregates of different sizes were collected after oven dryong the respective sieves at 50°C. The each size fraction weight was expressed as percentage of total weight and stored in plastic containers for subsequent analysis of carbon.

Aggregated associated carbon

Oven dried (50°C) the different size soil aggregate fractions were ground with wooden pestle and mortar to less than 0.25 mm size and the aggregate associated carbon was estimated by Walkey and Black[49], (1934) rapid titration method.

Mineralizable C (Laboratory incubation studies)

Mineralizable C was determined by CO_2 evolution method in aerobic condition. One-hundred-gram soil sample was weighed in 500 ml conical flasks. The sample moisture content was brought to field capacity and maintained throught the course of study by weighning the containers and replenishing the moisture lost. The CO_2 evolved during the incubation period was trapped in vials containing 0.1 *N* NaOH. The flasks were sealed completely with the help of rubber corks to prevent any loss of CO_2. The samples were then incubated at 25° C for 43 days. The vials containing alkali (inside the flasks) were frequently replaced by fresh ones. The CO_2 absorbed in NaOH was precipitated with $BaCl_2$ and estimated by titrating against 0.1 *N* HCL using phenolphthalein as an indicator[26]. It follows the reaction:

$$2OH^- + CO_2 \rightarrow CO_3 + H_2O$$
$$Ba_2^+ + CO_3 \rightarrow BaCO_3\,(solid)$$

During the first four days the CO_2 measurements were taken daily, but during the subsequent four days of incubation the measurements were made alternately, and the measurements during the subsequent 43 days were made based on the amount of CO_2 evolved.

Mineralizable N (Laboratory incubation studies)

The potentially mineralizable N was estimated by Keenys[24], method. Ten-grams of air dried soil was taken in plastic bottles. The sample moisture content was brought to field capacity and maintained throught the course of study by weighning the containers and replenishing the moisture lost. The incubation of sampls was made at 25°C temperature and field capacity moisture for 3, 7, 14, 21, 28 and 42 days separately. The mineralized N was extracted with 2*M KCl* solution. The method involved shaking of the samples by adding 100 ml (at 1:10 ratio, soil: extractant) of 2*M KCl* solution for one hour. The steam distillation method was used for estimation of mineralized nitrogen (NH_4+NO_3). The potentially mineralizable N was determined by subtracting initial concentration (at zero-day incubation) of mineral N from the final concentration of the respective day.

Statistical analysis

The data was analyzed using analysis of variance technique[32] and the significance of treatments was tested using completely randomized design (CRD) at 5% level of probability.

RESULTS

Water Stable aggregates

At Takaria distribution of aggregates in different size clsses i.e >2 mm, 1 to 2 mm, 0.25 to 0.5 mm and 0.11 to 0.25 mm in surface soils is presented in Table 1. It was observed that the proportion of macroaggregates of size class 0.25 to 2 mm was higher in grassland and agro-forestry and proportion of microaggregates of size 0.1 to 0.25 mm was higher in agro-forestry and cropland.

The 0.25 to 0.5 mm size class of macroaggregates was highest in proportion. The total water stable aggregates (% WSA), in the surface soil ranged from 9.61 to 17.52. In surface soils, the macroaggregates i.e WSA >0.25 mm, were highest (36.28 %) in grasslands followed by agro-forestry (11.68 %), forestry (5.43%) and cropland (3.48 %), whereas, th microaggregates i.e WSA < 0.25 mm, were maximum in agro-forestry (36.93 percent) and minimum in forestry (14.87 %). In Mukerian, among the different land-uses, the macroaggregate proportion (0.25 to 2 mm) was higher in grassland and cropland (Table 2). Proportion of micro-aggregates (0.1-0.25 mm) was higher in agro-forestry and forestry. The macroaggregate size class 0.25-0.5 mm was highest in proportion among the macroaggregates. The total water soluble aggregates (WSA) in surface soils ranged from 13.36 to 16.70, and the macroaggregates having size WSA> 2 mm were highest (52.93 %) in soils of grasslands followed by cropland (19.07 %), agro-forestry (5.75 %) and forestry (2.81 %). The smaller macro-aggregates (WSA 1-2 mm and 0.5 - 1.0 mm) were highest in cropland as compared to other land-uses, and in 0.25 - 0.5 mm WSA fraction and microaggregates, WSA< 0.25 mm, highest value was observed soils of agro-forestry followed by forestry, cropland and grassland.

Aggregate associated carbon

The soil carbon was estimated in macroggregates having size range of, >2 mm, 1 to 2 mm, 0.5 to 1.0 mm and 0.25 to 0.50 mm, and microagregate (0.1 to 0.25 mm). Macro-aggregates showed higher C cntent than micro-aggregates (Table 3 and 4). At Takarla, in cropland C concentration was highest in micro-aggregates (0.1to 0.25 mm) followed by size fraction of 0.25 to 0.5 mm, in forestry C content was higher in 0.25 to 0.5 mm size fraction followed by 0.1 to 0.25 mm size fraction. Agro-forestry possessed higher C content in 0.1- to 0.25mm size fraction followed by >2mm size fraction and in grassland >2mm size fraction possessed more C content followed by 0.25 to 0.5 mm size fraction. On the other hand in Mukerian, 0.25 to 0.5mm size fraction contained more C in all land-use systems except in grassland (Table 4.10). Micro-aggregates had lower C as compared to macro-aggregates and it ranged between 386.9 to 923.6 mg kg^{-1}, highest in agro-forstry followed by forestry, grassland and cropland in Takarla. On the other hand in Mukerian, micro-aggregates ranged between 1249.7 to 2565.0 mg kg^{-1}, highest in forstry followed by cropland, agro-forestry and grassland.

Effect of different agricultural land-use systems mineralizble C

At Takarla, in 43 days of incubation the cumulative carbon mineralized (C_{min}) varied from 33.4 to 48.6 mg C kg^{-1} soil in surface soils (Table 5). Higher amount of C was mineralized in the agro-forestry followed by forest. Application of organic sources resulted in increased Cmin in the surface soils. Amount of cumulative C_{min} in agro-forestry was significantly higher than cropland and grassland. Insignificant difference was found between forestry and agro-forestry. Irrespective of the land-use, cumulative amount of C mineralized decreased with time, and thus the active to slow mineralizing C pool tranisition was not observed. It was found that the cumulative C-release increased appreciably from 0 to 14th day of incubation, ranging from 26 to 35.8 mg C Kg^{-1} soil (0-15 cm), and then the increase was less upto completion of incubation period. Subsequently, C mineralization rate gradually declined during 5th and 6th week of incubation.

At Mukrian, in 43 days of incubation the cumulative carbon mineralized (C_{min})

varied from 33.4 to 48.6 mg C kg^{-1} soil in surface soils ranged from 42.8 to 85.8 mg C kg^{-1} soil in surface samples (Table 6). The greatest amount of C was mineralized in the grassland followed by forestry. No significant difference was found between cropland and agro-forestry. C mineralization during first fourteen days of C mineralization ranged from 24 to 35 mg C Kg^{-1} soil in the 0-15 cm depth. Subsequently, C mineralization rate gradually declined during 5th and 6th week of incubation. The mineralized C release increased with the time of incubation, but the increase was less as the time of incubation increased.

Effect of different agricultural land-use systems on mineralizable N

The nitrogen mineraltion rate was faster during intial few days of incubation followed by a slow rate during subsequent days of incubation. Amount for mineralizable NH_4^+ was more during initial period, after that mineralizable NO_3^- was more at both sites. At Takarla , after 43 days of incubation at field capacity moisture and 25º C temperature, under different land-use systems the cumulative N mineralized ranged from 70.0 to 109.7 mg N kg^{-1}. The amount of N mineralized was more under forestry, followed by agro-forestry, cropland and grassland. At Mukerian, the cumulative amount of N mineralized (N_{min}) under different land-use systems in the 0-15 cm soil depth ranged from 63.0 to 116.7 mg N $kg^{-}1$. The amount of N mineralized was higher under forestry.

Table 1: Aggregate size distribution in relation to different land-use systems in 0-15 cmsoil layer at Takarla

Land-use	**Water stable aggregates (WSA) %**					**Total WSA (%)**	**MWD (mm)**
	>2mm	**1 - 2mm**	**0.5 - 1.0 mm**	**0.25 - 0.5 mm**	**0.1 - 0.25 mm**		
Cropland	3.48	2.91	3.54	13.37	30.07	53.37	0.59
Forestry	5.43	4.75	7.73	15.25	14.87	48.03	0.81
Agroforestry	11.68	3.29	3.13	16.27	36.93	71.3	1.21
Grassland	36.28	8.99	2.91	21.07	17.17	86.42	3.07
CD (0.05)	1.88	3.386	3.549	NS	5.874		0.142

Table 2: Aggregate size distribution in relation to different land-use systems in 0-15 cm soil layer at Mukerian

Land-use	**Water stable aggregates (WSA) %**					**Total WSA (%)**	**MWD (mm)**
	>2mm	**1 – 2 mm**	**0.5 - 1.0 mm**	**0.25 - 0.5 mm**	**0.1 - 0.25 mm**		
Cropland	19.07	8.55	11.23	23.78	14.88	77.51	1.99
Forestry	2.81	4.64	6.44	28.76	24.16	66.81	0.73
Agroforestry	5.75	1.26	3.55	33.75	36.70	81.01	0.88
Grassland	52.93	5.24	3.36	4.69	9.44	75.66	3.98
CD **(0.05)**	3.602	2.803	4.509	4.925	5.478		0.190

Table 3: Effect of different land-use systems on aggregated associated C (mg kg^{-1}) at 0-15 cm soil depth at Takarla

Land-use	**AAOC (mg kg^{-1}) at soil depth (0-15 cm)**				
	>2mm	**1 - 2mm**	**0.5 - 1.0 mm**	**0.25 - 0.5mm**	**0.1 - 0.25mm**
Cropland	97.3	104.9	73.0	180.3	386.9
Forestry	295.4	279.7	369.1	610.4	535.0
Agro-forestry	612.1	178.5	149.5	610.4	923.6
Grassland	1378.2	369.0	97.7	634.9	405.1
CD (0.05)	158.01	180.7	166.0	266.9	327.4

Table 4: Effect of different land-use systems on aggregated associated C (mg kg^{-1}) at 0-15 cm soil depth at Mukerian

Land-use	**AAOC (mg kg^{-1}) at soil depth (0-15 cm)**				
	>2mm	**1 - 2mm**	**0.5 - 1.0 mm**	**0.25 - 0.5mm**	**0.1 - 0.25mm**
Cropland	2039.4	983.1	1159.0	2290.1	1321.1
Forestry	403.7	708.2	863.3	3280.0	2459.3
Agro-forestry	436.9	106.3	234.2	2112.6	2027.1
Grassland	8203.2	823.6	501.7	668.8	1249.7
CD (0.05)	713.9	362.2	530.0	804.2	825.1

Table 5: Effect of different land-use systems on cumulative mineralizable C (mg kg^{-1}) at 0-15 cm soil depth at Takarla

Days	**Cropland**	**Forestry**	**Agro-forestry**	**Grassland**
3rd	6.0	6.2	11.8	4.6
7th	15.8	20.2	24.4	14.8
14th	29.8	30.2	35.8	26.0
21st	35.6	38.4	42.4	31.2
28th	37.2	39.0	48.6	32.6
43rd	39.2	41.0	48.6	33.4

Table 6: Effect of different land-use systems on mineralizable C (mg kg^{-1}) at 0-15 cm soil depth at Mukerian

Days	**Cropland**	**Forestry**	**Agro-forest**	**Grassland**
3rd	4.9	3.0	4.0	1.0
7th	10.2	11.2	8.8	4.0
14th	31.4	28.0	24.0	35.0
21st	34.4	38.0	26.0	56.0
28th	47.2	52.6	32.8	73.8
43rd	51.8	64.6	42.8	85.8

Table 7: Physico-chemical properties of soils at Takarla and Mukerian under different land-use systems on

Site	**Soil pH and EC (dSm^{-1})**	**Cropland**	**Forestry**	**Agro-forestry**	**Grassland**	**CD (0.05)**
Takarla	**pH**	7.83	7.90	8.07	8.20	0.146
	EC (dSm^{-1})	0.22	0.14	0.18	0.13	0.037
	Soil organic C (g kg^{-1})	2.95	5.00	4.32	3.14	1.119
	Clay (percent)	14.33	15.37	11.60	6.73	0.573
	CEC (Cmol kg^{-1})	10.83	10.22	9.42	7.43	0.981
	Bulk density (g cm^{-3})	1.67	1.17	1.38	1.51	0.014
Mukerian	**pH**	7.75	7.69	7.83	7.95	0.079
	EC (dSm^{-1})	0.20	0.14	0.17	0.13	0.020
	Soil organic C (g kg^{-1})	11.76	14.97	8.97	15.88	2.265
	Clay (percent)	13.77	14.80	9.80	15.37	0.538
	CEC (Cmol kg^{-1})	12.54	12.65	10.14	9.78	0.647
	Bulk density (g cm^{-3})	1.62	1.32	1.47	1.56	0.023

Table 8: available N, P and K (kg ha^{-1}) content of soils under different land-use systems on

Available NPK		Cropland	Forestry	Agro-forestry	Grassland	CD (0.05)
Site Takarla	**Available N (kg ha^{-1})**	132.23	234.78	153.82	89.06	17.606
	Available P (kg ha^{-1})	21.44	13.45	15.86	11.23	1.618
	Available K (kg ha^{-1})	286.67	79.17	55.83	39.17	115.208
Site Mukerian	**Available N (kg ha^{-1})**	124.14	199.70	97.15	264.47	17.046
	Available P (kg ha^{-1})	18.56	10.89	9.40	13.10	1.204
	Available K (kg ha^{-1})	149.17	72.50	87.50	56.67	8.703

- **M.sc. work done during 2011-14 under the chairmanship of Dr. A. S Toor and co-guide Dr. D.K Benbi at Division of soil science, Punjab Agricultural university Ludhiana**

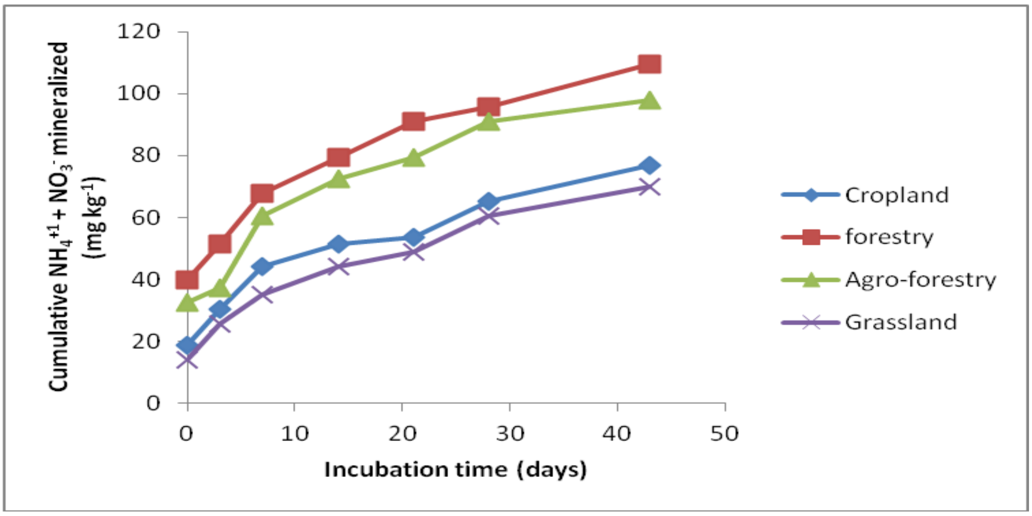

Fig. 1: Effect of different land-use systems on cumulative mineralizable N (NH$_4^+$ + NO$_3^-$) (mg kg^{-1}) at 0-15 cm soil depth at Takarla

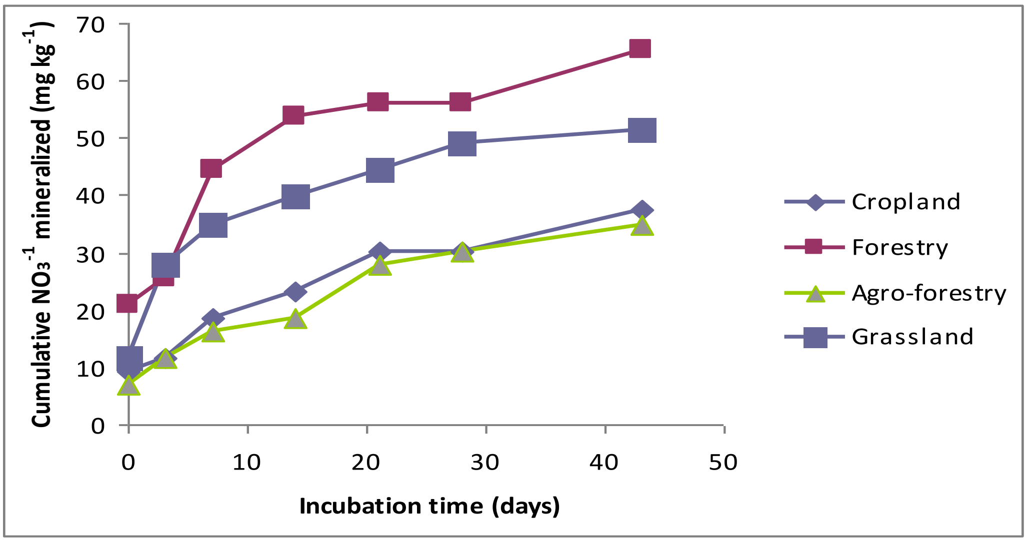

Fig. 2: Effect of different land-use systems on cumulative mineralizable N (NH$_4^+$ NO$_3^-$) (mg kg^{-1}) at 0-15 cm soil depth at Mukerian

DISCUSSION

The higher amount of water soluble aggregates (WSA< 0.25 mm) was reported by Gejic *et al*[14]., in surface layers of agricultural soils than forest gleyic fluvisols surface soils, this might be attributed to the breakdown of macroaggregates by tillage[27] and due to impact of rain drops and harvesting[20]. The use of agro-chemicals is reported to reduce the soil microbial activity, and thus causing adverse effects on soil aggregation[23]. Smaller macro-aggregates (WSA 1-2mm and 0.25 - 0.5mm) were highest in grassland as compared to other land-uses, might be due to highest root density of grasses, and higher soil organic carbon in these soils which results in slower water movement in to the soil aggregates[25]. According to Chenu *et al*[10]., the particulate soil organic matter from crop residues is more wetable than from forest or pasture. The stability of the soils under grasslands than in other land-use systems was recorded by Kukal *et al*[25]. Blanco-Canqui and Lal[3] reported that due to deep root system of forests, they improve the soil aggregation by tranfering the SOC from surface to deeper soil layers, as compared to grasslands having root system confined to surface layers only. Golchin *et al*[16]., reported that the virgin soils and soils under long-term pasture had greater aggregate stability than the cultivated soils. Agro-forestry possessed high percentage of WSA. More the roots in a soil, greater is the amount of water stable aggregates, as the roots when decompose, the fragments act as a central nucleon of water stable aggregates[33]. Significant higher water stable aggregate (>0.25 mm) content due to FYM and wheat straw application, was observed by Yang *et al*[50]. Campbell *et al*[8]., also reported that aggregate stability was more in cultivated system as compared to no-tillage system. Tillage influenced the aggregate size and their stability through changes in SOC content.

The stabilization of organic carbon in soil might be attributed to higher soil organic carbon in pastures[34] and the deep forest biomass could be responsible for higher sub-surface SOM accumulation in forest land-use.the forest subsoil has about 45 per cent of total SOC of the profile[22]. The continous breakdown of macroaggregates by rain drops and the lower lower organic matter returns due to low vegetative cover might be responsible for higher amount of microaggregates in surface soil layers.

The highest stability of aggregates under grassland could be due to highest amount of SOC as obtained from the higher root density in the surface soils[12]. In grazed pasture soils, 70-80 per cent of the above ground biomass is grazed and excreta returned as organic inputs. Pasture roots also contribute organic carbon to the soils[35,36] whereas in cultivated soils, most of the organic inputs are from crop debris. According to Smith[45], the crop lands have small input of C, as the carbon is added only when the crop is grown. The small inputs might also be due to removal of biomass by harvesting, tillage operations and change in temperature and moisture regimes of soil.

Organic sources increased C accumulation in different aggregates, but the effect was more for macro than microaggregates, which could be ascribed to binding together of microaggregates and physical protection of macroaggregates[18], Tripathy and Singh[46], and Senapati[40], reported similar results. The organic matter content in the aggregates is dependent on intra-aggregate particulate organic matter (iPOM). The iPOM fraction is more in macroaggregates due to slower decomposition due to physical protection in macro-aggregates. The lower aggregate stability in crop land systems is in accordance with the findings of Bremer *et al*[4]., and Martens *et al*[31]., who found that aggregate stability is greatly influenced by tillage operations. The greater stability of microaggregates than macroaggregates might be due to protection of SOM against microbial decay by microaggregates, Six *et al*[43]., and Denef *et al*[11]., found that the formation of these microaggregates within macroaggregates results in no turn over of latter, so dependen on tillage and management practices. So SOM sequestration and the management of soils are depended on degree of micro-aggregation rather than micro-aggregation and this carbon associated with micro-aggregates is associated with clay and silt particles. The micro-aggregate associated carbon is more protected from degradation and thus helps in long-term soil carbon sequestration[37]. The higher value of C_{min} in agro-forestry, due to the availability of easily decomposable organic matter and also readily available nutrients provided a conducive environment for microbial activity, resulting in a higher rate of respiration[30,38]. The increased C mineralization may be due to exposure of particulate organic matter as a result of wetting and drying cycles, and the mineralization of soil microbial biomass[48]. According to Huang *et al*[21]., the change in activity of soil microorganisms being more active in intial stages to relative stability at later stages, and change in carbon sequestration small and strong potential to large and weak potential at later stages. In accordance to our results, Smith and Paul[44], compared three different systems, reported that biomass increased in the order: cultivated soils < forest soils < grassland soils. Based on the findings of Schnurer *et al*[39]., who observed a close relationship between content of biomass and soil organic C, usually considered the most important substrate for soil microorganisms. The amount of potentially mineralizable C (an indicator of labile and easily decomposable C) is dependent on the vegetation type and the plant litter which ultimately supply the organic matter to the soil, and the labile carbon is higher in grass land vegetation than other land-use systems.

Stevenson, and Orchard and Cook, also observed increase in nitrogen mineralization rate after rewetting the soil samples, which could be due to killing of microbial biomass and exposure of particulate organic matter to mineralization due to wetting and drying cycles[47,48]. The capacity of soil organic matter to supply the inorganic nitrogen is dependent on potentially mineralizable N content; the major portion of available inorganic nitrogen is derived from mineralization of orgaic matter[7]. Gregorich *et al*[17]., defined mineralizable nitrogen and mineralizable carbon as the portions of soil organic carbon and nitrogen that can be readily decomposed. Mineralization of N from coarse organic residue pool may have contibuted to net N mineralization under field condition[13]. Crop sequence can affect the quantity and quality (C/N ratio) of crop roots and residues produced[15] which may affect mineralization-immobilization turnover and its contribution towards increasing SOM.

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