Forage Res., **42** (3) : pp. 149-157 (2016) **http://forageresearch.in**

PERENNIAL FORAGES AS A TOOL FOR SEQUESTERING ATMOSPHERIC CARBON BY BEST MANAGEMENT PRACTICES FOR BETTER SOIL QUALITY AND ENVIRONMENTAL SAFETY

K. SATHIYA BAMA AND C. BABU

Department of Agronomy
Tamil Nadu Agricultural University,
Coimbatore (T. N.), India
**(e-mail : ksoilscience@gmail.com)*

(Received : 15 October 2016; Accepted : 27 December 2016)

SUMMARY

For improving the carbon storage in agricultural soil, cropping with best mangement practices is important. Among crops, forages have great oppourtunity to fix carbon. As well as the undisturbed cultivation for long period, poses to select these crops for carbon sequestration studies.The objective of this paper is to study the impact of various nutrient sources on biomass yield and carbon sequestration potential of various perennial fodder crops. An experiment was initiated with three different perennial forage crops viz., legume fodder (Lucerne CO 1), grass fodder [Cumbu Napier hybrid grass CO(CN)4] and cereal fodder [sorghum CO(FS)29]. The nutrient requirement met through different sources viz., farm yard manure (FYM), poultry manure (PM), INM and inorganics. The results showed, among the different forage crops, Cumbu Napier grass had higher carbon sequesteration potential of above ground biomass which removed 336.7 t CO_2/ha than multicut fodder sorghum (148.7 t CO_2/ha). The higher below ground biomass in Cumbu Napier grass removed 7.73 t CO_2/ha from the atmosphere than lucerne (4.21 t CO_2/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.

Key words : Carbon sequestration, Cumbu napier hybrid grass, multicut fodder sorghum, lucerne, organics, inorganics

Projected changes in climate will affect many physical and biological systems across the globe (IPCC, 2000). The impacts of changes in temperature, precipitation and climatic events can be expected to be significant on agriculture. Because the agriculture comprises a substantial proportion of the world's land cover while providing the main livelihood and food base for a growing population, it requires a major effort of adaptation and mitigation. The farmers already face a wide range of environmental challenges will require adoption of novel technologies and modified farming systems. It has been estimated that the concentration of atmospheric CO_2 has increased from 280 ppm in 1900 to 390 ppm in 2009 which closely associated with global warming effects such as temperature rise of 0.4 to 2.0^{o}C (IPCC, 2001). In order to reduce the green house gas (GHG) emissions, several strategies have been evolved particularly for agricultural production systems.

Soil is considered a source and a sink for CO_2 sequestration (Smith *et al.*, 2005). Researchers viewed an acre of pasture can sequester more carbon than an acre of forest. In addition, most of the forage grasses are of multi-cut type and they serve as vegetative mulch and zero tilled conditions for a period of 3-5 years depending on the soil fertility and availability of water. Inclusion of perennial species in farming systems seems to be a feasible option to help mitigate the extensive impacts of these threats. To increase the production of biomass and maintain soil fertility, the organic sources are correct choice. Manure can be a valuable source of nutrients for forage crops. It is a complete fertilizer, containing varying amounts of all the major plant nutrients as well as essential micronutrients.

The cultivation of cover crops throughout the year like forages is also reported to increase soil C stocks in no-till soils in many research papers. Most members of the grass family are excellent host for mycorrhizal fungi up to 100 times more efficient than other crops. Crops that increase soil C stocks are fundamental to the sustainability of agricultural production systems. This is possible with perennial forages. Bama (2014) reported the higher carbon sequestration potential of the Cumbu napier hybrid grass type. In this context to the study of carbon sequesteration potential of long time cultivating crops in the field and no-till situation. The data served as a base to determine carbon credit for forage crops which may offer benefits to the farmers besides sustaining soil fertility and environmental safety.

MATERIALS AND METHODS

To predict the carbon sequestration potential of various forage crops under different nutrient sources, an experiment was carried out during 2009-12. The important perennial forages like lucerne CO 1 (legume fodder), Cumbu napier CO(CN)4 (grass fodder) and sorghum CO(FS)29 (cereal fodder) and the nutrient sources viz., farm yard manure (FYM), poultry manure (PM), INM and inorganics were tried in this experiment. The FYM and poultry manure applied on N equivalent basis and for INM and inorganics treatments and all cultivation practices for Cumbu napier hybrid grass, lucerne and multicut fodder sorghum were followed as per crop production guide (CPG, 2013).

The initial soil was slightly alkaline in nature (8.0) and free from excessive salts (0.13 dS/m). It was medium in organic carbon (0.65%) and low in available N (168 kg/ha), medium in available P (16 kg/ha) and high in available K (507 kg/ha). Similarly, microbial populations viz., bacteria (41.1 CFU × 10^6 /g soil), fungal (13.5 CFU × 10^4/g soil) and actinomycetes (5.1 CFU × 10^3/g soil) were also determined. The green fodder yield of Cumbu napier was recorded initally on 85 days after planting and thereafter 45-50 days intervals. Totally seven cuts per year and 21 cuts for three years were completed. For lucerne, initial harvest was started at 70 days after sowing and thereafter at 25 days intervals. Totally, 12 harvests per year and for three years 36 harvests were completed. For multicut sorghum, initial harvest was started at 90 days after sowing, and thereafter at 60 days intervals and totally 15 harvests for three years. The dry fodder yield was recorded by keeping the samples in electric oven at 65ºC for moisture estimation. The general microflora of soil viz., bacteria, fungi and actinomycetes were estimated at the beginning of the experiment and after harvest of third year. The soil organic carbon was estimated by wet digestion method initially and after three year studies period. The below ground and above ground carbon was also calculated by multiplying dry matter with carbon content. The dry matter content and carbon content of plant biomass (Dry combustion method by Nelson and Sommers, *1982) were estimated in the laboratory. Depending upon the biomass yield, carbon content and dry matter yield, the CO_2 removal was calculated by multiplying carbon content with the factor 3.67.

RESULTS AND DISCUSSION

Carbon Dioxide Removal by the Above Ground Biomass

To calculate the CO_2 removal, the biomass yield is very important. The green fodder yield of the above ground portion was recorded for each harvest. The first year results showed that the Cumbu napier hybrid grass yielded higher biomass of 373 t/ha/year in the FYM appied plot followed by PM applied plots (350 t/ha/year). The INM practice (inorganics with 25 t FYM) recorded 325 t/ha followed by inorganics alone (275 t/ha). For second and third years also, FYM treatment performed better. But the yield level decreased over years in all the three fodder crops (Table 1). This may be due to reduction of soil fertility over the period of time. By comparing three crops, the Cumbu napier grass recorded higher biomass yield of 953 t/ha/3 years than lucerne (180 t/ha/3 years) and multicut fodder sorghum (429 t/ha/3 years) (Fig. 1). To work out the carbon removal, the biomass yield was converted into dry matter yield (Fig. 2). Fig 3 shows that carbon removal by the Cumbu napier hybrid grass was highest followed by multicut fodder sorghum and lucerne. The derived parameters of carbon dioxide removal were also worked out and the results showed that (Table 2), the Cumbu napier had the highest potential to remove carbon dioxide from the atmosphere at an average of 336.7 t/ha/3 years followed by multicut fodder sorghum (148.7 t/ha/3 years) and lucerne (86.4 t/ha/3 years). With respect to nutrients, the Cumbu napier responded to FYM application i. e. carbon dioxide removal by this crop was 381.3 t/ha/3 years, the

TABLE 1
Above ground biomass of various fodder crops as influenced by nutrient sources

Treatment	Cumbu Napier green fodder yield (t/ha)				Lucerne green fodder yield (t/ha)				Fodder sorghum green fodder yield (t/ha)			
	I	II	III	Total	I	II	III	Total	I	II	III	Total
S_1–FYM	373	365	341	1080	56.2	55.4	54.4	166	164	155	131	451
S_2–PM	350	342	314	1006	62.1	61.2	58.2	182	179	175	147	503
S_3–INM	325	314	282	922	63.7	63.4	61.7	189	151	147	105	404
S_4–Inorganics	275	269	256	802	62.3	62.0	58.3	183	135	126	96	358

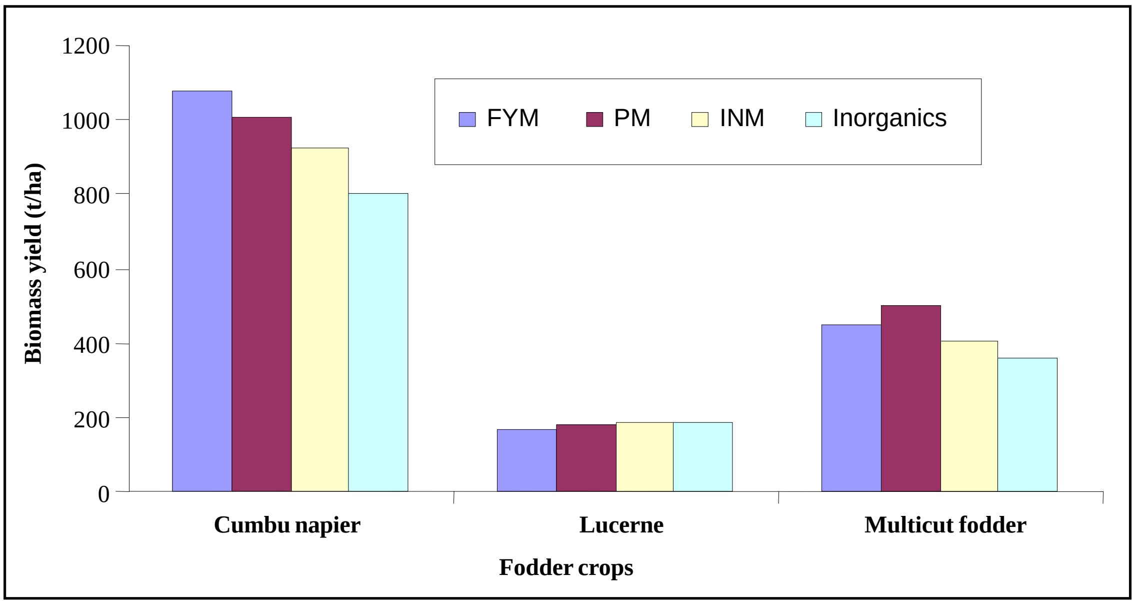

Fig. 1. Influence of nutrient sources on biomass yield of various fodder crops (sum of 3 years).

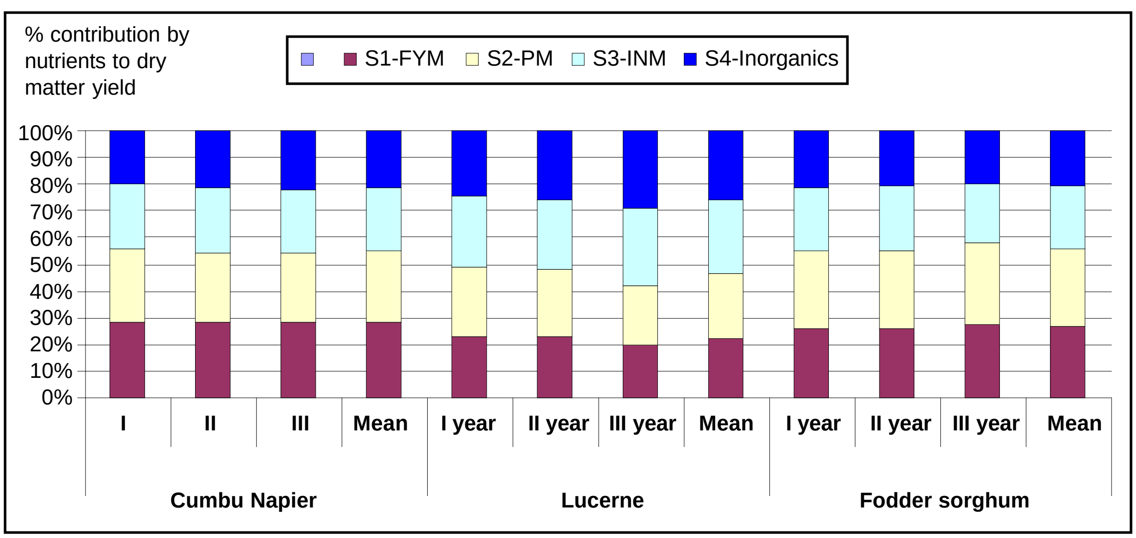

Fig. 2. Influence of nutrient sources on dry matter yield of various perennial fodder crops over years.

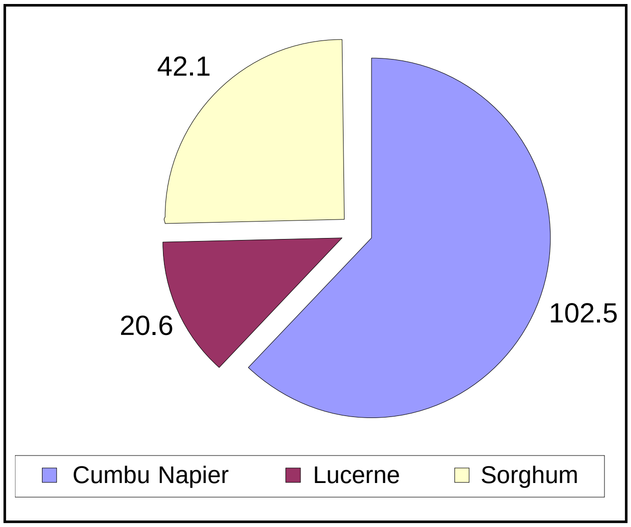

Fig. 3. Influence of nutrient sources on carbon removal (t/ha) by above ground biomass by various fodder crops.

TABLE 2
Carbon dioxide removal (t/ha/3 years) by the above ground biomass of various fodder crops

Treatment	Carbon di-oxide removal by above ground biomass (For three years)			
	Cumbu Napier	Lucerne	Sorghum	Mean of all crops
S_1–FYM	381.3	76.7	156.5	204.8
S_2–PM	355.4	85.5	174.5	205.1
S_3–INM	326.4	93.9	139.7	186.7
S_4–Inorganics	283.7	89.6	123.9	165.7
Total	336.7	86.4	148.7	-

lucerne responded to integrated nutrient management practices (93.9 t/ha/3 years) and the multicut fodder sorghum responded to poultry manure application (174.5 t/ha/3 years) (Table 2). Primarily, plants possessing C_4 photosynthetic pathway were capable of fixing 60 to 80 mg of $CO_2/dm^2/h$, while C_3 plants produced 15 to 30 $CO_2/dm^2/h$ (Cooper and Tainton, 1968). The data suggest that the C_4 plant species are ideal candidates for C sequestration process in agricultural production system. Among the field crops, forages are high biomass producing plants and can survive under limited moisture conditions. Sundaram *et al.* (2014) found that hybrid napier promised to be a potential fodder for carbon sequestration in agricultural ecosystem. They also demonstrated that agricultural practices impacted the soil carbon storage and again it varied with the climatic condition. Similar results were also reported by Sivakumar *et al.* (2014). The above ground biomass had a high influence on the amount of carbon sequestration which enters the soil usually in the form of senescent leaves and post-harvest remnants (Walker and Borek, 2008). Firdaus *et al.* (2010) also quantified the biomass in terms of dry matter production and annual litter fall by *Jatropha curcas* and its contribution to increased soil carbon.

Carbon Dioxide Removal by the Below Ground Portion of the Cumbu Napier Grass

CO(CN)4

The quantity of carbon removed by the below ground portion of the various fodder crops was calculated as that of above ground portion. The results revealed that (Table 3) irrespectice of nutrient sources, the Cumbu napier hybrid grass recorded higher root biomass of 4.72 t/ha after completing three years of experimentation followed by lucerne 2.76 t/ha and

TABLE 3
Below ground biomass (t/ha) of various fodder crops as influenced by nutrient sources

Treatment	Dry weight of below ground biomass (end of three years)			Carbon-di-oxide removal by below ground biomass (total of three years)			
	Cumbu Napier	Lucerne	Sorghum	Cumbu Napier	Lucerne	Sorghum	Mean
S_1–FYM	4.88	2.50	1.03	7.98	3.81	1.56	4.45
S_2–PM	4.80	2.80	1.05	7.86	4.27	1.60	4.58
S_3–INM	4.63	2.88	0.98	7.57	4.39	1.49	4.47
S_4–Inorganics	4.58	2.85	0.95	7.49	4.35	1.45	4.44
Mean	4.72	2.76	1.00	7.73	4.21	1.53	4.49

multicut fodder sorghum (1.00 t/ha). The carbon removal by the various fodder crops of below ground biomass i.e root biomass results showed that (Fig. 4) the Cumbu napier had the highest potential to store below ground carbon by the biomass followed by lucerne and multicut fodder sorghum. Gale and Cambardella (2000) reported in cash and cover crops the role of shoots and roots as sources of soil organic carbon. Santos *et al.* (2011) reported that forages or legume cover crops contributed to carbon sequestration in no-till tropical ferrosals and most of this contribution was from roots and stored in the mineral associated fraction. Bama (2014) reported that the Cumbu napier grass had the potential of removing more biomass carbon from the atmosphere.

The fodder quality is also influenced by the nutrient sources in all the fodder crop (Table 4), but pattern was different in different crops.

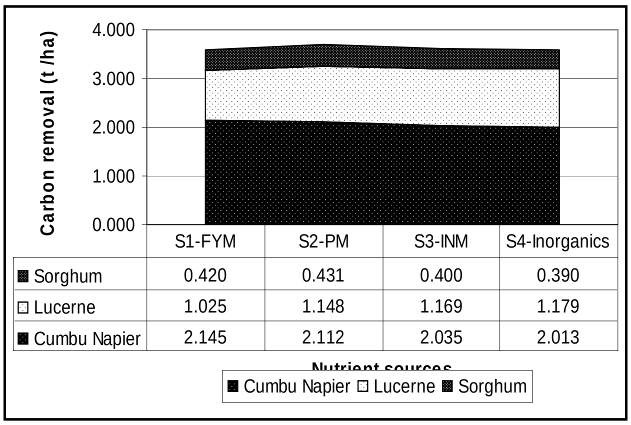

Fig. 4. Quantification of carbon removal (t/ha) by the below ground root portion by the various fodder crops.

Carbon Storage in the Soil

The soil organic carbon was estimated in the different fodder crops grown soil under various nutrient sources. Among the various fodder crops, the Cumbu napier grass grown soil recorded higher SOC of 0.92 per cent from the initial level of 0.65 per cent followed by multicut fodder sorghum (0.87%) and lucerne (0.75%) (Fig. 5). Irrespective of crops, FYM applied plots, recorded higher SOC of 1.05 per cent followed by PM (0.88%), INM (0.77%) and inorganics (0.69%). In all the plots, the SOC level was increased might be due to the addition of stubbles, root hairs and residues by the fodder crops as well as undisturbed condition for long time (Table 5). The per cent increase of soil organic carbon over initial period was 41.5 for Cumbu napier, 33.8 for sorghum and 15.8 for lucerne crop. Forages accumulated more carbon in soils compared to grain crops due to a higher root biomass production. There was a drastic improvement in the organic carbon status of the soil by the application of organic manures. The FYM applied on N equivalent basis recorded higher organic carbon content of 1.28 and 1.12 per cent followed by poultry manure applied treatment recorded 0.91 and 0.99 per cent, respectively, in the Cumbu napier hybrid grass, and multicut fodder sorghum from the initial carbon status of 0.62 per cent. In the lucerne, the INM treatment soil recorded higher SOC of 0.80 per

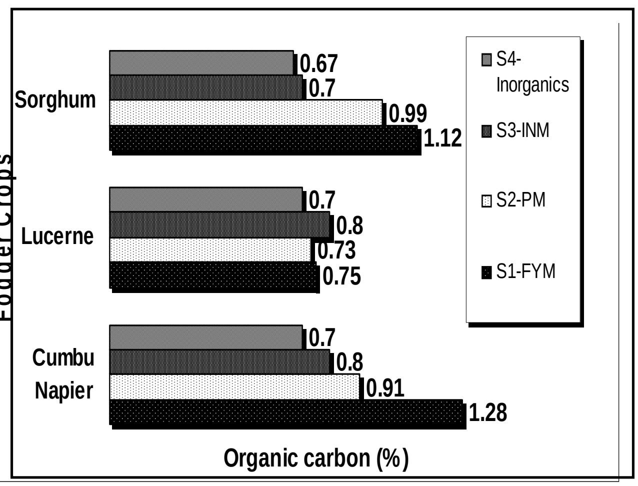

Fig. 5. Impact of various fodder crops on soil organic carbon status.

TABLE 4

Fodder quality as influenced by nutrient sources on various fodder crops

Treatment	Crude fibre (%)			Crude fat (%)		
	Cumbu Napier	Lucerne	Sorghum	Cumbu Napier	Lucerne	Sorghum
S_1–FYM	31.9	21.9	25.1	2.3	3.7	3.1
S_2–PM	31.5	22.0	24.3	2.2	3.8	3.0
S_3–INM	32.1	21.7	24.2	2.1	3.5	2.9
S_4–Inorganics	32.5	23.1	24.0	2.1	3.6	2.8

TABLE 5
Soil organic carbon (0-15 cm) as influenced by various fodder crops grown under different nutrient sources

Treatment	SOC (%)			
	Cumbu Napier grown soil	Lucerne grown soil	Sorghum grown soil	Mean
S_1–FYM	1.28	0.75	1.12	1.05
S_2–PM	0.91	0.73	0.99	0.88
S_3–INM	0.80	0.80	0.70	0.77
S_4–Inorganics	0.70	0.70	0.67	0.69
Mean	0.92	0.75	0.87	1.05
C. D. (P=0.05)	0.10	0.09	0.11	-

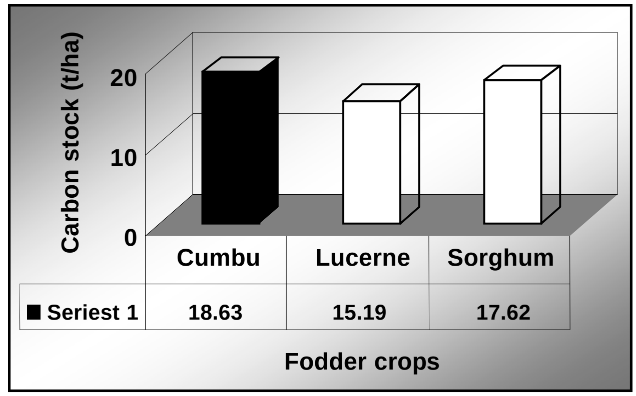

Fig. 6. Soil carbon stock in the various fodder crops grown soil.

cent than FYM (0.75%) and poultry manure (0.73%). This may be due to nitrogen fixation by legumes. Lower N requirement needed by legume was applied through low quantity of manures (Table 5). Choice of forage had a large impact on the amount of carbon that can be sequestered into the soil and perennial C_4 forages had potential to sequester larger amounts of carbon into the soil than other temperate perennial and annual forages (Neal *et al.,* 2013).

Soil Carbon Stock

To quantify the soil organic matter (SOC) stock in the soil, the carbon percentage was converted to t/ha by multiplying SOC (%) with bulk density (Mg/m^3) and soil depth (cm) (Lal, 2004). Among the different forages, grass type fodder Cumbu napier hybrid cultivated soil stored more carbon of 18.63 t/ha compared with multicut fodder (17.62 t/ha) and lucerne (15.19 t/ha) cultivated soil (Fig. 6). Also irrespective of crops, FYM applied treatment improved carbon stock to the tune of 21.26 t/ha followed by poultry manure (17.82 t/ha) and INM (15.59 t/ha) (Table 6). By increasing one tonne of root carbon in the soil, the food production can be improved by 30-50 million tonnes (Swaminathan, 2012). Anderson and Coleman (1985) stated that by altering management practices on marginal lands, carbon sequestration could be increased. They also reported the factors affecting carbon retention in soils included some important factors such as reducing tillage by including perennial forages in the crop rotation, increasing the use of fertilizer to enhance plant and root production and optimal forage varieties selected for yield and root mass production. Nishanth *et al.* (2013) reported that hedge lucerne and hybrid napier crops could be effectively used to enhance and store carbon in the southern district of Tamil Nadu, India.

TABLE 6
Soil carbon stock (t/ha) as influenced by various fodder crops under different nutrient sources

Treatment	Soil carbon stock (t/ha)			
	Cumbu Napier	Lucerne	Sorghum	Mean
S_1–FYM	25.92	15.19	22.68	21.26
S_2–PM	18.43	14.78	20.05	17.82
S_3–INM	16.20	16.20	14.18	15.59
S_4–Inorganics	14.18	14.18	13.57	13.97
Mean	18.63	15.19	17.62	21.26

Soil Physical Properties

Soil physical properties viz., bulk density and porosity are the important quality deciding factors for soil quality. Application of different source organic manures and fertilizers indicated that FYM applied plot recorded higher pore space percentage of 53.5 which is on par with poultry manure (PM) applied plot of 50.1 per cent followed by INM plot (48.4%) (Table 7) and inorganic (46.5%). Same trend of results was observed in fodder sorghum also. In the lucerne crop, the treatments showed non-significant response to the physical properties. Irrespective of the treatments, Cumbu napier hybrid recorded higher pore space percentage of 49.6 than lucerne (46.66%) and multicut fodder sorghum (48.9%) (Figs. 7 and 8).

Soil Microbial Properties

The data pertaining to bacteria, fungi and actinomycetes counts in soil as influenced by the

TABLE 7
Soil physical properties of various fodder crops grown soil as influenced by nutrient sources

Treatment	Cumbu Napier		Lucerne		Fodder sorghum	
	Pore space (%)	Bulk density (Mg/M^3)	Pore space (%)	Bulk density (Mg/M^3)	Pore space (%)	Bulk density (Mg/M^3)
S_1–FYM	53.5	1.28	46.55	1.38	52.5	1.27
S_2–PM	50.1	1.33	46.40	1.37	49.5	1.31
S_3–INM	48.4	1.37	47.12	1.34	46.9	1.36
S_4–Inorg	46.5	1.39	46.55	1.39	46.5	1.39
Mean	49.6	1.34	46.66	1.37	48.9	1.33
C. D. (P=0.05)	4.5	0.12	NS	NS	4.6	0.11

NS–Not Significant.

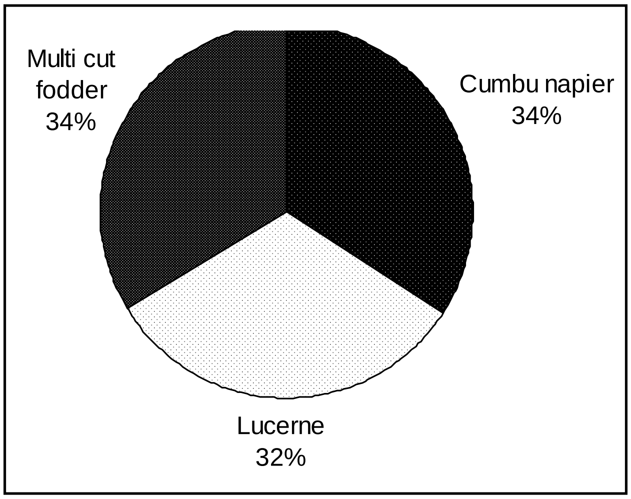

Fig. 7. Pore space of various fodder crops grown soil.

application of different sources of organic manures and fertilizers (Table 8) revealed that the population of bacteria in soil after the harvest of crop was increased irrespective of sources of nutrients. In the Cumbu napier hybrid grass, the highest population of bacteria was recorded with FYM applied plot (65.1×10^6 cfu/g) followed by PM applied plot of 58.2×10^6 cfu/g and INM (55.2×10^6 cfu/g). The lowest population of bacteria (43.7×10^6 cfu/g) was recorded in the inorganics plot. The highest fungal population was observed in FYM (35.1×10^4 cfu/g) followed by PM plot (30.3×10^4 cfu/g). The PM and INM recorded comparable bacterial and fungal population. The comparable actinomycetes population also in FYM plot (19.3×10^3 cfu/g) and in PM plot (19.1×10^3 cfu/g) was followed by INM (15.2×10^3 cfu/g). This is in corroboration with the findings of Okur *et al.* (2009) that the amounts of soil organic C and soil microbial biomass C (SMBC) were significantly higher in the plots amended with organic materials, as compared to those of the conventional plots that received only inorganic fertilizers.

In the lucerne crop, the highest population of bacteria was recorded with INM applied plot (44.3×10^6 cfu/g) followed by FYM applied plot (36.1×10^6 cfu/g) and PM (35.2×10^6 cfu/g). The lowest population of bacteria (32.2×10^6 cfu/g) was recorded in the inorganics plot. The highest fungal population was observed in INM (25.1×10^4 cfu/g) which was followed by FYM plot (21.2

TABLE 8
Effect of source of nutrients on microbial population of various fodder crops grown soil

Treatment	Cumbu Napier			Lucerne			Fodder sorghum		
	Bact (cfu*106)	Fungi (cfu*104)	Act (cfu*103)	Bact (cfu*106)	Fungi (cfu*104)	Act (cfu*103)	Bact (cfu*106)	Fungi (cfu*104)	Act (cfu*103)
S_1–FYM	65.1	35.1	19.3	36.1	21.2	8.7	55.2	29.2	18.3
S_2–PM	58.2	30.3	19.1	35.2	20.4	7.5	61.2	31.8	19.2
S_3–INM	55.2	27.3	15.2	44.3	25.1	9.8	47.3	24.3	14.1
S_4–Inorganics	43.7	23.2	13.1	32.2	19.2	7.2	40.2	17.3	12.2
Mean	55.6	29.0	16.7	37.0	21.5	8.3	51.0	25.7	16.0
C. D. (P=0.05)	5.8	3.2	1.8	3.8	2.3	0.7	5.6	2.2	1.7

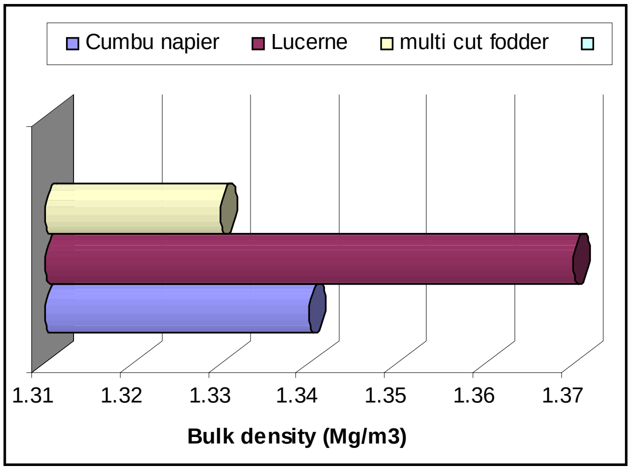

Fig. 8. Bulk density of various fodder crops grown soil.

$\times 10^4$ cfu/g). The PM and INM recorded comparable bacterial and fungal population. The same trend of results was recorded with actinomycetes population. A cover of mixed legumes established in an apple orchard increased soil organic C and soil biological activity for trees over a two-year period (Hoagland *et al.*, 2008).

In the multicut fodder sorghum, the highest population of bacteria was recorded with PM applied plot (61.2×10^6 cfu/g) followed by FYM applied plot of 55.2×10^6 cfu/g and PM (47.3×10^6 cfu/g). The lowest population of bacteria (40.2×10^6 cfu/g) was recorded in the inorganics plot. The highest fungal population was observed in PM (31.8×10^4 cfu/g) which was followed by FYM plot (29.2×10^4 cfu/g). The lowest population was observed in inorganics plot (17.3×10^4 cfu/g). The same trend of observations was made in actinomycetes. A similar report of organics on perennial suggested that cover crops integrated in almond orchards of perennial crop improved soil quality relative to clean tillage by increasing soil organic C, soil aggregate stability and microbial activity (Ramos *et al.*, 2010).

CONCLUSION

In conclusion, forages particularly grass type fodder contributes to carbon sequestration and most part of the long time carbon storage from roots i. e. below ground portion. This type of fodder crop can saturate carbon level quickly wherever the climate change mitigation is essential. 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 improved the soil carbon stock than poultry manure and integrated nutrient management. In general, forages can be recommended to sequester more carbon into the soil and prevent environmental degradation. Carbon gains are rapidly lost if the land is returned to annual crop production. The value of forages and their role in land use decisions to address environmental issues will remain an important challenge for agriculture. The challenge is to institute a mechanism, such as a carbon credit programme.

REFERENCES

Anderson, D. W., and D. C. Coleman.1985 : The dynamics of organic matter in grassland soils. *J. Soil and Water Conserv*., **40** : 211-216. In : *Change and Forestry,* Watson, R. T., Noble, I. R. and Bolin, B. (eds.).

Bama, S. K. 2014 : Prediction of carbon sequestration potential of forage system. *J. Ecobiol.*, **33** : 169-175.

Cooper, J. P., and Tainton, N. M. 1968 : Light and temperature requirement for growth of tropical and temperate grasses. *Herb. Abstr.,* **38** : 167-176.

CPG. 2013 : *Crop Production Guide.* Tamil Nadu Agricultural University, Dept. of Agriculture, Govt. of Tamil Nadu. Retrieved from : *http://www.tnau.ac.in/tech/cgagri.pdf.*

Firdaus, M. S., A. H. M. Hanif, A. S. Safiee, and M. R. Ismail. 2010 : Carbon sequestration potential in soil and biomass of *Jatropha curcas.* 19th World Congress of Soil Science, 1-6 August., Brisbane, Australia.

Gale, W. J., and C. A. Cambardella. 2000 : Carbon dynamics of surface residue- and root-derived organic matter under simulated no-till. *Soil Sci. Soc. Am. J.*, **64** : 190-195.

Hoagland, L., L. Carpenter-Boggs, D. Granatstein, M. Mazzola, J. Smith, F. Peryea, and J. P. Reganold. 2008 : Orchard floor management effects on nitrogen fertility and soil biological activity in a newly established organic apple orchard. *Biol. Fert. Soils*, **45** : 11-18.

Intergovernmental Panel on Climate Change. 2000 : Climate Change Panel on Climate Change. *Special Report.* Cambridge University Press, UK. pp. 167-176, Ravindranath, N. H., Verardo, D. J. and Dokken, D. J. (eds.), Intergovernmental sequestration in the agricultural soils of Europe. *Geoderma.* pp. 122-123.

IPCC. 2001 : Intergovernmental Panel on Climate Change. *Third Assessment Report.* Cambridge University Press, Cambridge, UK. http://www.ipcc.ch.

Lal, R. 2004 : Soil carbon sequestration to mitigate climate change. *Geoderma*, **123** : 1-22.

Neal, J. S., S. M. Eldridge, W. J. Fulkerson, R. Lawrie, and I.

M. Barchia. 2013 : Differences in soil carbon sequestration and soil nitrogen among forages used by the dairy industry. *Soil Biol. & Biochem.*, **57** : 542-548.

Nelson, D. W., and L. E. Sommers. 1982 : Total carbon, organic carbon, and organic matter. p. 539-580. In : *Methods of Soil Analysis, Part 2 2nd edn.*, A. L. Page *et al.* (eds.). *Agron. Monogr. 9.* ASA and SSSA, Madison, WI.

Nishanth, B., J. S. I. Rajkumar, S. Meenakshi Sundaram, T. Sivakumar, V. M. Sankaran, and Tamil Vanan Thanga. 2013 : Sequestration of atmospheric carbon through forage crops cultivated in Ramayanpatti, Tirunelveli district, Tamil Nadu, India. *Res. J. Agric. and Forestry Sci.*, **1** : 11-14.

Okur, N., A. Altindisli, M. Cengel1, G. Gocmez, and H. H. Kayikcioglu1. 2009 : Microbial biomass and enzyme activity in vineyard soils under organic and conventional farming systems. *Turk J. Agric. For.* **33** : 413-423.

Ramos, M. E., E. Benitez, P. A. Garcia, and A. B. Robles. 2010 : Cover crops under different managements. Soil vs. frequent tillage in almond orchards in semi-arid conditions : Effects on soil quality. *Appl. Soil Ecol.* **44** : 6-14.

Santos, N. Z., J. Dieckow, C. Bayer, R. Molin, N. Favaretto, V. Pauletti, and J. T. Piva. 2011 : Forages, cover crops and relared shoot and root addition in no till rotations to C sequestration in a sub-tropical ferrolsol. *Soil & Tillage Res.* **111** : 208-218.

Sivakumar, T., S. Meenakshi Sundaram, V. M. Sankaran, and J. S. I. Rajkumar. 2014 : Sequestering of atmospheric carbon through fodder cultivation–A measure for mitigating global warming. International Conference on Food, Agriculture and Biology FAB–2014), June 11-12, Kuala Lumpur (Malaysia).

Smith, P., O. Andren, T. Karlsson, P. Pera¨la¨, K. Regina, M. Rounsevells, and Van wesemael, B. 2005 : Carbon sequestration potential in European croplands and temperate grasses. *Herb. Abstr.* 38. *Soil Sci. Soc. Am. J.*, **73** : 1699-1706.

Sundaram, M. S., T. Sivakumar, V. M. Sankaran, J. S. I. Rajkumar and B. Nishanth. 2014 : Farming forage crops for improving soil organic carbon stocks in agricultural lands, 2012. *Int. J. Res. Biol. Sci.*, **2** : 116-119.

Swaminathan, M. S. 2012 : Study climate change impact on food production. *The Hindu*, Dated 16.02.2012.

Walker, M. B., and R. Borek, 2008 : Evaluation of carbon sequestration in energetic crops. *Intl. Agrophysics*, **22** : 185-190.