OPEN ACCESS at journalijcir.com

Research Article ISSN: 2395 -5775

COMPARATIVE ANALYSIS OF MICROBIAL BIOMASS CARBON STOCK IN THE SOIL OF BAMBOO PLANTATION AND AGRICULTURAL SYSTEM IN TARAI REGION OF UTTARAKHAND, INDIA

Kavita Tariyal

Abstract

Assessment of carbon stocks in soil is a basic step in evaluating the carbon sequestration potential of an ecosystem. Soil microorganisms constitute a transformation matrix for all the organic materials in the soil and act as a labile reservoir for Carbon. Therefore Microbial Biomass Carbon (MBC) is considered of much importance in the labile pool of carbon in soils. Chloroform fumigation-incubation and chloroform fumigation-extraction approaches have significantly contributed to assess soil microbial biomass. The present study was conducted to compare the total biomass carbon stock between Bamboo plantations (*Bambusa balcooa* and *Bambusa nutans*) and agricultural systems (in agricultural fields C_{12} and D_7 having crop rotations) in the Tarai belt of Uttarakhand, India for two years. The major parameters of the study involved Soil microbial Biomass Carbon, Soil respiration and total MBC carbon stock. With this, the higher MBC stock (4.25 t ha^{-1}) was observed in the soil of bamboo plantation (*B. balcooa*) as compared to the agricultural soil (2.58 t ha^{-1}) of D_7. Thus the present study clearly demonstrates that besides being an economic strength bamboo plant have shown encouraging results in the field of MBC stock which is beneficial for soil health and environment, though agricultural soils can also contribute to much extent in the labile MBC stock if proper management practices are involved.

Key Words: Bamboo; Carbon sequestration potential; Chloroform fumigation-extraction; Crop rotation; Microbial Biomass Carbon; Soil respiration..

INTRODUCTION

The chloroform fumigation method for estimating the microbial biomass Carbon (C_{mic} or MBC) in soils was first proposed by Jenkinson (1966). This method is being used successfully to lyse microbial cells in soils for estimating the C_{mic} (Jenkinson and Powlson, 1976; Vance *et al.*, 1987) in microbial biomass (Klose *et al.*, 1999). The soil microbial biomass is the labile pool of organic matter (Jenkinson & Ladd, 1981) and is acts as both source and sink of plant nutrients (Singh *et al.*, 1989). It plays a vital role in nutrient cycling and its importance in soil fertility and nutrient concentration is well recognized. The studies on the measurement of microbial C in different natural and disturbed ecosystems have shown it to be important labile pool of C and mineral nutrients (Anderson & Domsch, 1980; Smith & Paul, 1990; Wardle, 1992) from which nutrients are liberated after the death of the microorganisms. Changes in the microbial population in response to variations in soil conditions (moisture, organic C, nutrients, temperature, pH) have serious implications for nutrient cycling, with microorganisms acting as a source and sink of nutrient. Climatic variability has influenced microbial populations and soil microbial biomass, which has been reported by various researchers (Diaz-Ravina *et al.*, 1993; Granatstein *et al.*, 1987; Lynch & Panting, 1980).

Seasonal changes in microbial biomass in grassland and agro ecosystem in tropical soils of India have been previously studied by Singh *et al.* (1989), Roy & Singh (1994). Measuring microbial biomass carbon offers a means of assessing the response of total microbial population changes in agricultural management (Voroney *et al.*, 1989; Sparling, 1992; Gupta *et al.*, 1994). Measurement of microbial biomass has been used in studies on carbon flow, nutrients cycling and plant productivity (Voroney *et al.*, 1989). The effects of microbial biomass in improving the soil fertility and primary production have been studied in organic matter decomposition

Department of Applied Sciences & Humanities, THDC Institute of Hydropower Engineering & Technology, Bhagirthipuram, Tehri Garhwal, Uttarakhand.
Correspondence and Reprint Requests: Kavita Tariyal
Received: July 25 , 2015 | **Accepted:** August 15, 2015 | **Published Online:** August28 , 2015

Conflict of interest: None declared | **Source of funding:** Nil

(Parkinson and Coleman, 1991). Microbial biomass may make contributions to nutrient availability to plant by being an important nutrient pool which is potentially available to plant, whereby microbial turnover acts as a dynamic source of soil available nutrients (Ladd and Foster, 1988).

One of the methods to assess the pace and progress of soil reclamation is through the monitoring of soil microbial biomass. It is considered as the most active fraction of soil organic matter (Jenkinson and Ladd, 1981) which acts as a source and sink of available nutrients (Smith and Paul, 1990; Diaz-Ravina *et al.*, 1993) and plays a critical role in nutrient conservation in tropical environments (Singh *et al.*, 1989). According to Powlson *et al.*, (1987), soil microbial biomass measurement can give an early indication of changes in total soil organic matter long

Table 1 Variation in Microbial Biomass Carbon (MBC) in the soils of different parts of India

S. No.	Study area	Type of site	Treatments	Average MBC (g kg^{-1})	Reference
1	Manipur, N-E India	Subtropical grassland ecosystem	Non-grazed Moderately grazed Heavily grazed	0.309 0.347 0.258	Devi *et al*, 2014
2	Arunachal Pradesh, India	Tropical wet-evergreen forest	Undisturbed forest Medium disturbed forest Highly disturbed forest	0.809 0.574 0.368	Barbhuiya *et al*, 2004
3	Tehri Garhwal, Uttarakhand, India	Different land use systems	Mixed forests Rice-Wheat cropping system Finger millet Maize wheat cropping system Cabbage Barren land	0.619 0.537 0.409 0.463 0.327 0.156	Arunkumar *et al*, 2013
4	Meghalaya, N-E India	Subtropical wet hill forest	Undisturbed	1.38	Arunachalam *et al*., 2000
5	Varanasi (Banaras) North India	Tropical dry land agro-ecosystem	Application of different tree leaves as fertilizer	0.291	Srivastava *et al*., 2014
6	Darjeeling Hill region, N-E India	Different tea gardens	-	0.835	Bishnu *et al*., 2009
7	Orissa, India	Natural tropical dry deciduous forest	Natural forest Regenerating forest With *Eucalyptus* plantation	0.902 0.567 0.246	Behera *et al*., 2003
8	Semi-Arid tropics of India	Agricultural fields with different crop and fertilizer management	Cotton - Green gram Maize-Chick pea Pigeonpea-Soybean-Chickpea Finger millet-maize-cowpea fodder Pearl millet-Sorghum Fallow-sorghum	0.325 0.185 0.168 0.281 0.204 0.144	Vineela *et al*., 2006
9	Assam, N-E India	Different land use systems	Groundnut Finger millet Castor-Sorghum Cultivated land Forest land Tea garden	0.138 0.144 0.113 0.154 0.207 0.145	Chattopadhyay *et al*., 2012
10	Assam, N-E India	Tropical Rainforests	Undisturbed Moderately disturbed Highly disturbed	1.14 0.452 0.246	Barbhuiya *et al*., 2008
11	Arunachal Pradesh, N-E India	Agricultural system having different crop plantations	Soybean AES (Agroecosystem) Millet AES Maize AES Vegetable AES	0.228 0.213 0.234 0.238	Bhuyan *et al*., 2013
12	Lucknow, Uttar Pradesh, India	Subtropical Agricultural Soils under Different Sugarcane Intercropping Systems	Sugarcane alone Wheat intercrop Maize intercrop Rajmash intercrop Green gram intercrop Cowpea intercrop Lentil intercrop Mustard intercrop Potato intercrop Sesbania intercrop	0.198 0.242 0.262 0.267 0.214 0.237 0.223 0.252 0.218 0.198	Suman *et al*., 2006
13	Jharkhand, India	Different types of soils	Soil of fresh mine spoil Soil of 6 yr old mine spoil degraded wasteland soil grassland soil pesticide treated soil agricultural soil forest soil	0.055 0.120 0.258 0.440 0.488 0.541 0.646	Kujur *et al*., 2012
14	Ludhiana, Punjab, India	Agricultural soil with different irrigation practices and amendments	Soil treated with Canal water (with organic amendments) Soil treated with sodic water(with organic amendments)	0.132 0.123	Kaur *et al*., 2008
15	Imphal, N-E India	Different land-uses in subtropical systems of north-east India	Grassland Agro ecosystem	0.297 0.254	Singh *et al*., 2006

before changes in total soil C and N can be reliably detected. However, the microbial biomass values are useful in the development and exercising of simulation models of labile carbon and nutrient turnover in a wide range of ecosystems.

Table 1 represents a review about various studies done on Microbial Biomass Carbon in the Indian soils depending upon different ecosystem types along with various experiments and amendments applied in the soil. It shows a variation in MBC content of different types of ecosystems.

Present study highlights the comparison between bamboo plantation and agricultural area having crop rotation practices in terms of soil Microbial Biomass Carbon. Although various researches have been done on bamboo with different parameters but present study differentiates itself from the others on the basis of Microbial Biomass Carbon content study on its soil.

MATERIALS AND METHODS

The details of the materials used and the methods followed in carrying out the field sampling and laboratory analysis studies have been described as follows:

Description of the Experimental Study Sites

The field study was conducted in two different sites of Tarai region of Uttarakhand namely Agroforestry Research Centre (AFRC), Haldi, Pantnagar; and Norman E. Borlaug Crop Research Centre, Pantnagar. Pantnagar is located at 29^0N Latitude, 79^03'E Longitude and at an altitude of 243.84 meters above the mean sea level. The area lies in Tarai belt of Shivalik range of the Himalayan foot hills. It falls in the sub-humid and sub-tropical climate zone.

Agroforestry Research Centre (AFRC) was chosen for the study on Bamboo plantations in which two species of bamboo were taken- *Bambusa balcooa* and *Bambusa nutans*. The year of plantation was March, 2006 (in case of *B. balcooa*); and March, 2007 (in case of *B. nutans*) in 4.0 ha (2.0 ha each) area. The experiment was designed as CRBD block planting at 5 × 5 meter spacing. Characteristics of both the species are given in Table 2. Second study site was Norman E. Borlaug Crop Research Centre, Pantnagar where two fields were chosen for carbon sequestration study, those were C_{12} and D_7. The total area chosen was 4.0 ha (2.0 ha each field). Each field was having crop rotations during the study. Crops grown in both the fields were totally 6 in number. These were: Wheat (*Triticum aestivum*), Lentil (*Lens culinaris*), Pigeon Pea (*Cajanus cajan*), Maize (*Zea mays*), Black Gram (*Phaseolus mungo*), and Green Gram (*Vigna radiata*). The further details are given in table 1.

Table 2 Characteristics of the study sites

Sl. no.	System	Area (ha)	Tree Density (Stem ha^{-1})	Age (Year)	Bulk density of soil (g cm^{-3})	Water holding capacity (%)
1	*B. balcooa* (Plantation)	2.0	400	5	1.52	85.05
2.	*B. nutans* (Plantation)	2.0	400	4	1.48	81.41
3.	C_{12} (Agricultural site)	2.0	-	-	1.39	60.66
4.	D_7 (Agricultural site)	2.0	-	-	1.38	62.08

Estimation of soil microbial biomass carbon (MBC)

Soil microbial biomass carbon was estimated by Chloroform–Fumigation K_2SO_4-Extraction Method (Vance *et al.*, 1987). This procedure compares the amount of total organic carbon (TOC) in a chloroform-fumigated soil sample to that in a nonfumigated soil sample to determine soil microbial biomass. In the chloroform-fumigated sample, TOC will be higher because the sample contains the cell contents of lysed microbial cells. Hence the difference in extracted TOC between fumigated and nonfumigated samples will provide a measure of microbial biomass (Vance *et al.*, 1987; Coleman *et al.*, 2004).

Fumigations were carried out for a period of 2 days in vacuum desiccators with alcohol-free chloroform. Soil samples were extracted with 0.5 K_2SO_4 and the filtrate was analyzed for TOC. Analysis results were adjusted to a TOC/g dry soil value. Soil samples were refrigerated until the fumigation and K_2SO_4 extractions are performed. The concentration of organic C in the extract was determined with a Total Organic Carbon analyzer (Shimadzu Model TOC-5050) after acidification with one drop of 2 M HCl to remove any dissolved carbonate. Microbial biomass C was calculated as follows (Vance *et al.*, 1987; Coleman *et al.*, 2004):

$C_{mic} = EC/k_{EC}$,

Where EC = (Total organic carbon extracted from fumigated soil)-(Total organic carbon extracted from non-fumigated soil), and

$k_{EC} = 0.45$, a proportionality factor for converting the EC value to C_{mic} (Wu *et al.*, 1990; Klose *et al.*, 1999).

Soil respiration activity

The soil respiration rates were calculated by alkali absorption method using 13 cm diameter and 23 cm tall aluminum cylinders inserted 10 cm deep into the soil (Coleman *et al.*, 2004). The surface area enclosed by each cylinder was 132.8 cm^2. Cylinders 13 cm tall and of same diameter as the experimental ones and capped at both the ends were used for control. A beaker containing 20 ml of 1 M NaOH is placed over each cylinder enclosed surface. All green herbaceous vegetation was clipped and litter was removed, before measuring the soil respiration rates for 24 hours. After that the NaOH was taken back to the laboratory and 20 ml of saturated solution of $BaCl_2$ was added to it and titrated with 1N HCl using phenolphthalein indicator. Titrate till pink color disappears. The experiment was performed at monthly interval for two years. The respiration study was performed under the soils of (i) *B. Balcooa* (ii) *B. nutans* (iii) D_7 and (iv) C_{12}. Each measurement was done for five replicates.

Calculation

CO_2 evolution rates are calculated as follows:

$CO_2 – C$ (mg) = (B-X) M×E

Where B = HCl (ml) needed to titrate the NaOH solution from the blank

X= HCl (ml) needed to titrate the NaOH solution in the experimental jars, exposed to the soil atmosphere;

M= 1.0 (HCl molarity); and E= equivalent weight (22 for CO_2, and 6 for C).

The data are thus expressed as milligrams of CO_2 or CO_2-C per square meter per day (Coleman *et al.*, 2004).

Microbial Biomass Carbon Stock

Microbial Biomass Carbon Stock was computed by multiplying the microbial biomass carbon (g kg^{-1}) with bulk density (g cm^{-3}) and depth (cm) and is expressed in ton ha^{-1} (Joao Carlos *et al.*, 2001).

All the data collected for different experiments and field samples during the study were compiled and processed for statistical treatment. The data were analyzed for the mean and standard error. Analysis of Variance (ANOVA) was used to test the significance of difference between treatment means.

RESULTS AND DISCUSSIONS

Soil Microbial Biomass Carbon (MBC)

The data for soil microbial biomass carbon (MBC) (g kg^{-1}) for the four study sites at the depth of 0-15 cm and 15-30 cm is presented in the figure 1 for the first and second year of study period. The MBC at the first study site *i.e. B. balcooa* plantation ranged from 0.030 to 0.279 g kg^{-1} during the whole study period. The minimum MBC content of 0.031 and 0.030 g kg^{-1} was observed in the month of January 2010 in the depths of 0-15 cm and 15-30 cm respectively. Maximum MBC content of 0.279 g kg^{-1} was observed in July 2011 at the depth of 0-15 cm and 0.160 g kg^{-1} was observed during June 2011 at the depth of 15-30 cm. The MBC content in the *B. nutans* plantation site showed the maximum and minimum in the months similar to *B. balcooa* plantation. However the values of MBC were lower at *B. nutans* site as compared to *B. balcooa*. The MBC ranged from 0.027 g kg^{-1} to 0.232 g kg^{-1} during the whole study period. The minimum MBC content of 0.040 and 0.027 g kg^{-1} was observed in the month of January 2010 in the depths of 0-15 cm and 15-30 cm respectively. Maximum MBC content of 0.232 g kg^{-1} was observed in June 2011 at the depth of 0-15 cm and 0.149 g kg^{-1} was observed during June 2010 at the depth of 15-30 cm.

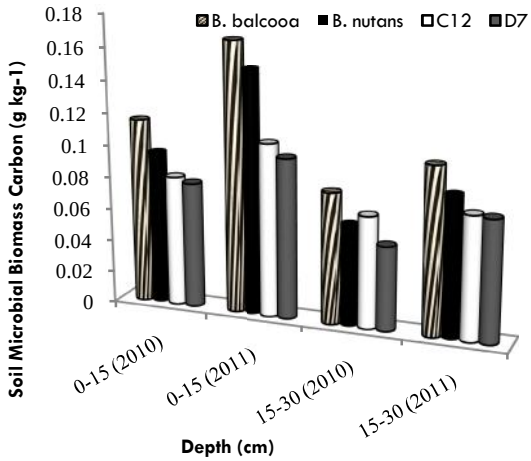

Figure 1 Change in Soil Microbial Biomass Carbon (g kg^{-1}) in all study sites with depth and time

For the agricultural sites of C_{12} and D_7 the minimum values for MBC content were observed in the first year of study period and maximum in the second year in both the layers. In case of C_{12}, minimum value of MBC at 0-15 cm was observed in the month of March 2010 and it was 0.056 g kg^{-1}, and at 15-30 cm the value was 0.034 g kg^{-1} in the months of July

and November 2009. A maximum value of MBC at 0-15 cm was observed in the month of June 2011 and it was 0.149 g kg^{-1}, and at 15-30 cm the value was 0.148 g kg^{-1} in the month of June 2010. In case of D_7, minimum value of MBC at 0-15 cm was 0.054 g kg^{-1} in the month of August 2009 and at 15-30 cm, the value was 0.029 g kg^{-1} in the month of September 2009. Maximum value of MBC (at 0-15 cm) was 0.145 g kg^{-1} in the month of January 2010 whereas at 15-30 cm, the maximum value was 0.099 g kg^{-1} in the month of July 2011.

Overall the soil MBC content decreased with the increasing depth of the soil at all the five study sites and in every month during the study period of two years. According to Dilly *et al.* (2003) and Benbi *et al.* (2004), the amount of C in the soil microbial biomass mostly accounts for 1%-5% of the total soil carbon, and its turnover time is less than one year, so present study gave similar results. Wang *et al.* (2004) investigated the levels of MBC in the soil profiles of five different vegetation systems including bare area, Bamboo, Chinese fir, Citrus Orchard and Rice field. The MBC level in surface soil for the Bamboo system was higher than those in the other systems. In almost all study sites MBC level was higher during rainy season (Killham 1994; Jiang-shan 2005). The MBC content was not differed significantly ($P<0.05$) among all the study sites. Though it differed significantly between months ($P<0.05$) throughout the study and interaction between sites and months was also found significant ($P<0.05$) throughout the study yet rest of interactions (site and depth, depths and months, sites, depths and months) were not differed significantly.

Soil respiration due to microbial activity

The soil respiration was studied as the parameter to observe the activity of soil microbes at different study sites. Soil respiration was measured in terms of mg CO_2 evolved m^{-2} hr^{-1} in the surface layer (0-15 cm) and subsurface layer (15-30 cm) in every month at each study site during the two years of study. The values for soil respiration in the study sites for both the years of study are presented in figure 2. At *B. balcooa* plantation site soil respiration values ranged from 821.59 to 1511.55 mg CO_2 m^{-2} hr^{-1} during the whole study period to two year. The minimum soil respiration activity observed was 1210.62 and 821.59 mg CO_2 m^{-2} hr^{-1} in the month of December 2009 for the surface layer and subsurface layer, respectively. However the activity found to be increased in the next year of the study due to increased amount of leaf litter and improvement in soil organic carbon content. Maximum values for soil respiration was observed to be 1511.55 mg CO_2 m^{-2} hr^{-1} at 0-15 cm depth in the month of July 2011 and 1091.24 mg CO_2 m^{-2} hr^{-1} in the month of August 2010 for the depth of 15-30 cm.

For another Bamboo plantation of *B. nutans* the value for soil respiration activity of soil micro fauna ranged from 769.56 to 1512.84 mg CO_2 m^{-2} hr^{-1} during the whole study period. The minimum values were observed in the month of January 2010, 1192.56 and 769.65 mg CO_2 m^{-2} hr^{-1} for the surface and subsurface layers respectively. Maximum values for soil respiration was observed to be 1512.84 mg CO_2 m^{-2} hr^{-1} at 0-15 cm depth in the month of August 2010 and 1022.82 mg CO_2 m^{-2} hr^{-1} in the month of September 2010 for the depth of 15-30 cm. Deka and Mishra (1982); Upadhyay (2007); Singh (1984) and Upadhyay *et al.* (2004) observed similar seasonal fluctuation trend of soil respiration activity of soil in the bamboo plantation sites. Higher temperature and moisture supports the microbial activity in the rainy season. At the C_{12} study site soil respiration varied from 621.59 to 1335.64 mg CO_2 m^{-2} hr^{-1} during the whole study period.

Minimum soil respiration was observed in the month of February 2010, 931.53 for surface layer and 621.59 mg CO_2 m^{-2} hr^{-1} for subsurface layer. Maximum values for soil respiration was observed to be 1335.64 mg CO_2 m^{-2} hr^{-1} at 0-15 cm depth in the month of August 2010 and 985.85 mg CO_2 m^{-2} hr^{-1} in the month of July 2011 for the depth of 15-30 cm. The temperature and soil moisture were found to be the main factors influencing soil respiration of the site. The study site D_7 showed the variation of soil respiration similar to above three study sites. The values varied from 544.89 and 1285.35 mg CO_2 m^{-2} hr^{-1} during two years of study. The minimum soil respiration value for 0-15 cm depth was 838.35 mg CO_2 m^{-2} hr^{-1} in the month of February 2010, and for 15-30 cm was 544.89 mg CO_2 m^{-2} hr^{-1} in the month of December 2009. Maximum values for soil respiration was observed to be 1285.85 mg CO_2 m^{-2} hr^{-1} at 0-15 cm depth in the month of August 2010 and 991.36 mg CO_2 m^{-2} hr^{-1} in the month of June 2011 for the depth of 15-30 cm.

Overall level of soil respiration was increased in all study sites during second year. Among all study sites *B. balcooa* showed highest soil respiration activity in second year at surface layer whereas lowest rate was seen in D_7 at subsurface layer. Overall the subsurface layer showed lesser soil respiration activity as compared to the surface layer in all the study sites in each month (Shrestha *et al*, 2008). Labile carbon compounds in the litter are utilized by

the microbes and resulted into release of CO_2 as soil respiration activity (Brady, 1990). The surface layer of the study sites are richer in carbon and nitrogen content in comparison to the subsurface layer thus higher values of soil respiration were observed in the surface layer in all the sites. Franzluebbers *et al.* (2001) in a laboratory incubation experiment observed linear correlation in soil respiration and content of soil organic carbon.

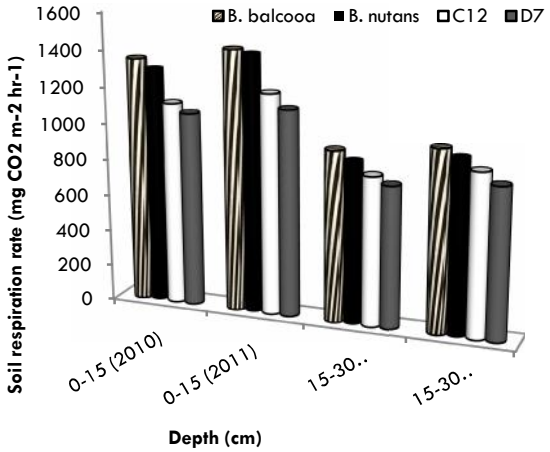

Figure 2 Change in Soil respiration in all study sites with depth and time

The soil respiration activity differed significantly ($P<0.05$) among all the study sites, at both depths and between all the months. Interactions between site and depth, depth and site, site and month, and between site depth and month were found highly significant ($P<0.05$) during study. Highest values of soil respiration activity of microbes and soil carbon content were observed at the *B. balcooa* site thus the rate of litter mineralization and release of carbon from the site was highest in this plantation site, but the difference in soil respiration activity between both the bamboo plantation sites was too small.

Clipping and shading experiments in grass land in US Great Plains decreased soil respiration by nearly 70% within one week (Craine *et al.*, 1999; Wan and Luo, 2003), indicating a direct and dynamic link between soil respiration and substrate supply from the above ground photosynthesis. Thus site with

Table 3 Soil Microbial biomass carbon (MBC) stock (t ha^{-1}) in Bamboo plantations and agricultural system

Study sites	2010		2011		2010	2011
	0 -15 cm	15-30 cm	0-15 cm	15-30 cm	Mean	Mean
B. balcooa	2.64	3.72	3.81	4.69	3.18	4.25
B. nutans	2.13	2.81	3.36	3.85	2.47	3.60
C_{12}	1.69	2.89	2.23	3.19	2.29	2.71
D_7	1.61	2.13	2.05	3.11	1.87	2.58

respiration activity (Shrestha *et al*, 2008). The soil respiration is also found as a linear function of primary productivity of the ecosystem (Janssens *et al.*, 2001; Reichstein *et al.*, 2003). In the present study the primary productivity of the herbaceous vegetation was highest in bamboo plantation site thus signifies highest soil respiration activity.

Comparison between Bamboo Plantation System and Agricultural System in Terms of Soil Microbial Biomass Carbon (MBC) Stock

The soil Microbial Biomass carbon (MBC) stock in bamboo plantation system and agricultural system at the depth of 0-15 cm and 15-30 cm is shown in table 3. The soil MBC stock was more in subsurface soil as compared to the surface soil. The mean values of MBC stock increased with time for all the study sites. In the first year maximum MBC stock in the surface layer was observed in *B. balcooa* (2.64 t ha^{-1}) followed by *B. nutans* (2.13 t ha^{-1}), C_{12} (1.69 t ha^{-1}) and D_7 (1.61 t ha-1, while in the subsurface layer maximum MBC stocks was observed in *B. balcooa* (3.72 t ha^{-1}) followed by C_{12} (2.89 t ha^{-1}), *B. nutans* (2.81 t ha^{-1}) and D_7 (2.13 t ha^{-1}).

In the second year of study maximum MBC stock in the surface layer was observed in *B. balcooa* (3.81 t ha^{-1}) followed by *B. nutans* (3.36 t ha^{-1}), C_{12} (2.23 t ha^{-1}) and D_7 (2.05 t ha^{-1}). Similarly in the subsurface layer maximum MBC stocks was observed in *B. balcooa* (4.69 t ha^{-1}) followed by *B. nutans* (3.85 t ha^{-1}), C_{12} (3.19 t ha^{-1}) and D_7 (3.11 t ha^{-1}).The mean MBC stock followed the order of *B. balcooa* > *B. nutans* > C_{12} > D_7 in the first year and same order in second year of the study. Since plant species differ in quality of leaf litter (e.g. C/N ratio), soil microbes associated with different plant species often have variable amounts of microbial biomass (Bauhus *et al*, 1998; Liu *et al*, 2001; Jiang-shan *et al*, 2005). Microbial biomass and activities are closely related to labile organic C in soil. soil microbial biomass and activity respond sensitively to changes in organic C levels or quality resulting from agronomic practices and other disturbances (Powlson *et al.*, 1987; Lundquist *et al.*, 1999; Tu *et al.*, 2006). The soil having rich organic matter have high microbial biomass (Jiang-shan *et al*, 2005).

CONCLUSION

Bamboo plantation due to rapid growth, multiplicity and having huge biomass is gaining wide popularity and attention across the globe. This 'green gold' is quite economic and efficient to fulfill several needs of the people of any status whether it is poor man or a millionaire. Therefore its use as a carbon sequestering substrate is a good option as it has multiple benefits

for the world and its people. The soil microbial population and soil respiration are found to be increased with the time and showed lower values in the subsurface layer. Soil microbial biomass carbon represented a very important part in the carbon stock of the soil of all study sites. Although its value did not vary significantly among the study sites but yet it helped to understand the dynamics of carbon in the soil and soil health as the soil having more organic matter showed more microbial biomass carbon and with increasing depth it declined may be due to scarcity of organic matter.

On the basis of the results obtained in the present investigation it may be concluded that choice of species for plantation influences carbon storage, CO_2 mitigation potential and soil properties of the plantation ecosystem. Although present study was mainly focused towards a comparative assessment of MBC stocks of bamboo plantation and agricultural system but it also throws light on the capacity of carbon sequestration in each site individually too. It must be noticed here that bamboo, being an economic plus point provides a huge hope for carbon market as it has tremendous capacity to sequester carbon due to fast growth and high primary productivity, but we cannot ignore the role of agriculture in this respect due to its rich soil MBC stock. Agriculture may not compete with forestry or agroforestry system based on its high carbon sequestration capacity but it can enroll itself significantly in this field if some better management practices can be involved. If the straw part of the crops gets fully incorporated into the soil as mulch, it can significantly contribute to the carbon stock of the system. The MBC in the entire soil microbial population treated as an entity. The soil MBC is a source of nutrients and changes in the MBC can be used to predict the effects of ecosystem perturbations. This is why microbial indicators have been used as reliable tools to characterize soil quality with respect to land use and soil management.

References

1. Anderson, J.P.E. and K.H. Domsch. 1980. Quantities of plant nutrients in the microbial biomass of selected soils. *Soil Science*. 130: 211-216.
2. Arunachalam, A., and Arunachalam, K. 2000. Influence of gap size and soil properties on microbial biomass in a subtropical humid forest of north-east India. *Plant and Soil* 223: 185–193.
3. Arunkumar, K., Singh, R.D., Patra, A.K., Sahu, S.K. 2013. Probing of microbial community structure, dehydrogenase and soil carbon in-relation to different land uses in soils of Ranichauri (Garhwal Himalayas). *Int.J.Curr.Microbiol.App.Sci.* 2(11): 325-338.
4. Barbhuiya, A.R., Arunachalam, A., Pandey, H.N., Arunachalam, K., Khan, M.L., Nath, P.C. 2004. Dynamics of soil microbial biomass C, N and P in disturbed and undisturbed stands of a tropical wet-evergreen forest. *European Journal of Soil Biology*. 40:113–121.
5. Barbhuiya, A.R., Arunachalam, A., Pandey, H.N., Khan, M.L., Arunachalam, K. 2008. Effects of disturbance on fine roots and soil microbial biomass C, N and P in a tropical rainforest ecosystem of Northeast India. *Current Science*, 94(5): 572-574.
6. Bauhus, J., Pare, D., Cote, L. 1998. Effects of tree species, stand age and soil type on soil microbial biomass and its activity in a southern boreal forest [J]. *Soil Biol. Biochem*.30: 1077-1089.
7. Behera, N., and Sahani, U. 2003. Soil microbial biomass and activity in response to *Eucalyptus* plantation and natural regeneration on tropical soil. *Forest Ecology and Management*, 173:1-11.
8. Benbi, D.K., and Nieder, R. 2004. Handbook of processes and modeling in the soil-plant system. *The Haworth Press Inc, New York*. ISBN 81-7649-833-5. pp- 762.
9. Bhuyan, S.I., Tripathi, O.P., and Khan, M.L. 2013. Seasonal changes in soil microbial biomass under different agro-ecosystems of Arunachal Pradesh, North East India. *The Journal of Agricultural Sciences,* 8(3):142-152.
10. Bishnu, A., Saha, T.M, Ghosh, P.B., Mazumdar, D., Chakraborty, A., Chakrabarti, K. 2009. Effect of Pesticide Residues on Microbiological and Biochemical Soil Indicators in Tea Gardens of Darjeeling Hills, India. *World Journal of Agricultural Sciences*. 5 (6): 690-697.
11. Brady, N.C. 1990. "The Nature and properties of soils". Macmillan, New York. 621 pp.
12. Chattopadhyay, T., Reza, S.K., Nath, D.J., Baruah, U., and Sarkar, D. 2012. Effect of land use on soil microbial biomass carbon and nitrogen content in the soils of Jorhat district, Assam. *Agropedology*, 22(2):119-122.
13. Coleman, D.C., Crossley, D.A., Hendrix,P.F. 2004. Fundamentals of soil ecology. 2nd Edition. *Elsevier Acadmic Press*. pp-325.
14. Coleman, M.D., Isebrands, J.G., Tolsted, D.N., Tolbert, V.R. 2004. Comparing soil carbon of short rotation poplar plantations with agricultural crops and woodlots in North Central

United States. *Environmental Management*, 33(Supplement 1): S299-S308.
15. Craine, F.M., Wedin, D.A. and Chapin, F.S. 1999. Predominance of ecophysiological controls on soil CO_2 flux in a Minnestoa grassland. *Plant and Soil*. 207: 77-86.
16. Deka, H.K., Mishra, R.R. 1982. Decomposition of bamboo (Dendrocalamus hamiltonii Nees.) leaflitter in relation to age of jhum fallows in Northeast India. *Plant and Soil*. 68(2):151-159.
17. Devi, T.I., Yadava, P.S., Garkoti, S,C. 2014. Cattle grazing influences soil microbial biomass in sub-tropical grassland ecosystems at Nambol, Manipur, northeast India. *Tropical Ecology*. 55(2): 195-206.
18. Diaz-Ravina, M., M.J. Acea & T. Carballas. 1993. Seasonal fluctuation in microbial populations and available nutrients in forest soils. *Biology and Fertility of Soils*. 16: 205-210.
19. Dilly, O., Blume, H.P., Sehy, U. 2003. Variation of stabilized, microbial and biologically active carbon and nitrogen in soil under contrasting land use and agricultural management practices [J]. *Chemosphere*. 52: 557-569.
20. Franzluebbers, A.J., Haney, R.L., Honey, R.L., Honeycutt, C.W., Arshad, M.A., Scholberg, H.H. and Hons, F.M. 2001. Climatic influences on active fractions of soil organic matter. *Soil Biology and Biochem*. 33(7-8): 1103-1111.
21. Granatstein, D.M., D.F. Bezdicek, V.L. Cochran, L.F. Elliott & J. Hammel. 1987. Long-term tillage and rotation effects on soil microbial biomass carbon and nitrogen. *Biology and Fertility of Soils*. 5:265-270.
22. Gupta, V.V.S.R., Roper M.M., Kirkegaard J.A. and Angus J.F. 1994. Changes in microbial biomass and organic matter levels during the first year of modified tillage and stubble management practices on a red earth. *Austr. J. Soil. Res*. 34: 1339–1354.
23. Janssens, I.A., Lankreijer, H., Matteucci, G., Kowalski, A.S., Buchmann, N., Epron, D., Pilegaard, K., Kutsch, W., Longdoz, B., Grunwald, T. et al. 2001. Productivity overshadows temperature in determining soil and ecosystem respiration across European forests. *Global Change Biology*. 7(3): 269-278.
24. Jenkinson, D.S. & J.N. Ladd. 1981. Microbial biomass in soil : Measurement and turnover. pp. 415-417. In: E.A. Paul & J.N. Ladd (eds.) *Soil Biochemistry*. Mercel Dekker, New York.
25. Jenkinson, D.S., 1966. Studies on the decomposition of plant material in soil. II. Partial sterilization of soil and the soil biomass. *Journal of Soil Science*. 17:280-302.
26. Jenkinson, D.S., Powlson, D.S., 1976. The effect of biocidal treatments on metabolism in soil: V. A method for measuring soil biomass. *Soil Biology & Biochemistry*. 8:205-213.
27. Jiang-shan, Z., Jian-fen, G., Guang-shui, C. and Wei, Q. 2005. Soil microbial biomass and its controls. *Journal of Forestry Research*. 16 (4): 327-330.
28. Joao Carlos de, M.S., Carlos, C.C., Warren, A.D., Rattan, L., Solismar, P., Venske, F., Marisa, C.P. and Brigitte, E.F. 2001. Organic matter dynamics and carbon sequestration rates for a tillage chronosequence in a Brazilian Oxisol. *Soil Sci. Soc. Amer. J.* 65(5): 1486-1499.
29. Kaur, J., Choudhary, O.P., and Singh, B. 2008. Microbial biomass carbon and some soil properties as influenced by long-term sodic-water irrigation, gypsum, and organic amendments. *Australian Journal of Soil Research*, 46:141–151.
30. Killham, K. 1994. Soil Ecology [M]. Cambridge: Cambridge University Press.
31. Klose, S., Tabatabai, M.A. 1999. Urease activity of microbial biomass in soils. *Soil Biology and Biochemistry*. 31:205-211.
32. Kujur, M., and Patel, A.K. 2012. Quantifying the contribution of different soil properties on microbial biomass carbon, nitrogen and phosphorous in dry tropical ecosystem. *International Journal of Environmental Sciences*. 2(3):2272-2284.
33. Ladd, J.N. and Foster, R.C. 1988. Role of soil microflora in nitrogen turnover. In: Wilson J.R. (ed.), Advances in Nitrogen Cycling in Agricultural Ecosystems. *CAB International, Wallingford, UK*.
34. Liu, J., Yu, Z., and Li, H. 2001. A primary study on biornass of soil microbes in Pinus tabulae formis and Quercus aliena van acuteserata stands [J]. *Shanxi Forest Science and Technology*. 2: 7-10.
35. Lundquist, E.J., Scow, K.M., Jackson, L.E., Uesugi, S.L., Johnson, C.R., 1999. Rapid response of soil microbial communities from conventional, low input, and organic farming systems to a wet/dry cycle. *Soil Biol. Biochem*. 31:1661–1675.
36. Lynch, J.M. & L.M. Panting. 1980. Cultivation and the soil biomass. *Soil Biology and Biochemistry*. 12: 29-33.
37. Parkinson, D. and Coleman, D.C. 1991. Methods of assessing soil microbial populations, activities, and biomass. *Agric. Ecosyst. Environ*. 34: 3–33.
38. Powlson, D.S., Brookes, P.C., Christensen, B.T., 1987. Measurement of soil microbial biomass

provides an early indication of changes in the total soil organic matter due to straw incorporation. *Soil Biol. Biochem*. 19:159–164.

39. Reichstein, M., Rey, A., Freibauer, A., Tenhunen, J., Valentini, R., Banza, J., Casals, P., Cheng, Y., Grunzwieg, J.M., Irvine, J. 2003. Modeling temporal and large- scale spatial variability of soil respiration from soil water availability, temperature and vegetation productivity indices. *Global biogeochemical cycles*. 17(4): 1104.
40. Roy, S. and Singh, J.S. 1994. Consequences of habitat heterogeneity for availability of nutrients in a dry tropical forest. *Journal of Ecology*. 82: 503- 509.
41. Shrestha, B. M. and Singh, B. R. 2008. Soil and vegetation carbon pools in a mountainous watershed of Nepal. *Nutr Cycl Agroecosyst*. 81:179–191.
42. Singh, J. 1984. Effect of temperature, rainfall and soil moisture on soil moisture on soil respiration and litter decomposition in a sub tropical humid forest ecosystem. *Acta Bot. Indica*. 12 (2):167-173.
43. Singh, J.S., A.S. Raghubanshi, R.S. Singh & S.C. Srivastava. 1989. Microbial biomass act as a source of plant nutrients in dry tropical forest and savanna. *Nature*. 338: 499-500.
44. Singh, L.I., and Yadava, P.S. 2006. Spatial distribution of microbial biomass in relation to land-use in subtropical systems of north-east India. *Tropical Ecology* 47(1): 63-70.
45. Smith, J.L., Paul, E.A., 1990. The significance of microbial biomass estimations. In: Bollag, J.M., Stozky, G. (Eds.), *Soil Biochemistry*. Marcel Decker, New York, pp. 357–396.
46. Sparling G.P. 1992. Ratio of microbial biomass carbon to soil organic carbon as a sensitive indicator of changes in soil organic matter. *Austr. J. Soil Res*. 30: 195–207.
47. Srivastava, R., and Singh, K.P. 2014. Variation in wheat yield, microbial biomass and N-availability in tropical dry land agroecosystem: Impact of application of different tree leaves. *Int.J.Curr.Microbiol.App.Sci*. 3(4): 830-842.
48. Suman, A., Lal, M., Singh, A.K., and Gaur, A. 2006. Microbial Biomass Turnover in Indian Subtropical Soils under Different Sugarcane Intercropping Systems. *Agron. J*. 98:698-704.
49. Tu, C., Louws, F.J., Creamer, N.G., Mueller, J.P., Brownie, C., Fager, K., Bell, M., Hu, S.J., 2006. Responses of soil microbial biomass and N availability to transition strategies from conventional to organic farming systems. *Agric. Ecosyst. Environ*. 113:206–215.
50. Upadhyay, A. 2007. An integrated study on carbon sequestration, litter decomposition, soil and plant community dynamics in Tarai forest plantations of Uttarakhand. *Ph.D. thesis. Department of Environmental Sciences, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India*.
51. Upadhyay, K., Arunachalam, A. and Arunachalam, K. 2004. Effect of bamboo foliage on soil respiration, microbial biomass and N mineralization. *J. of Bamboo and Rattan*. 3(2): 169-183.
52. Vance, E.D., Brookes, P.C., Jenkinson, D.S.1987. An extraction method for measuring soil microbial biomass C. *Soil Biol. Biochem*. 19:703-707.
53. Vineela, C., Wani, S.P., and Padmja, B. 2006. Microbial Status of Different Systems in the Semi-Arid Tropics. *Global Theme on Agroecosystems* Report no . 25 Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 32 pp.
54. Voroney, R.P., Paul, E.A. and Anderson, D.W. 1989. Decomposition of wheat straw and stabilization of microbial products. *Can. J. Soil Sci*. 69: 63–73.
55. Wan, S. and Luo, Y. 2003. Substrate regulation of soil respiration in a tallgrass prairie: Results of a clipping and shading experiment. *Global biogeochemical cycles*. 17:1054.
56. Wang, E.E., Cben, Y.X., Tian, G.M.2004. Microbial biomass carbon, nitrogen and phosphorus in the soil profiles of different vegetation covers established for soil rehabilitation in a red soil region of southeastern China [I]. *Nutrient Cycling in Agroeeosystems*. 68: 181-189.
57. Wardle, D.A. 1992. A comparative assessment of factors which influence microbial biomass carbon and nitrogen levels in soils. *Biological Review*. 7: 321-358.
58. Wu, J., Joergensen, R.G., Pommerening, B., Chaussod, R., Brookes, P.C., 1990. Measurement of soil microbial biomass C by fumigation extraction : an autoclaved procedure. *Soil Biology & Biochemistry*. 22:1167-1169.

****