

Abiotic Factors Influences Soil Carbon Dioxide Flux in the Sub-Tropical Forests, Manipur, NE India



Biology

KEYWORDS : Seasonal variation, CO₂ flux, abiotic factors, Manipur, soil respiration.

M. Dineswori Devi

Ecology Laboratory, Centre of Advanced study in Life Sciences, Manipur University, Canchipur Imphal

P.S. Yadava

Ecology Laboratory, Centre of Advanced study in Life Sciences, Manipur University, Canchipur Imphal

ABSTRACT

Seasonal variations in the soil CO₂ flux were studied in two forest stands of sub-tropical forests in Senapati district of Manipur from April 2011- March 2012. The rate of soil CO₂ flux was measured using alkali absorption method.

The soil CO₂ flux ranged from 69.655 to 382.194 mgCO₂m⁻²hr⁻¹ and 72.297 to 392.985 mgCO₂m⁻²hr⁻¹ for forest stand I and II respectively in different months throughout the year. The soil CO₂ flux rate was recorded to be maximum during rainy season followed by summer season and winter season. The significant positive relation in soil CO₂ flux rate and abiotic factors i. e. soil moisture, soil temperature, relative humidity, mean air temperature and rainfall shows that soil CO₂ flux rates were highly influenced by abiotic factors in the sub-tropical forests of Manipur, N.E. India.

Introduction:

Atmospheric CO₂ concentration have been increasing in response to the disruption of the global carbon cycle by anthropogenic activities such as deforestation, agricultural practices and burning of fossil fuels. This results in large changes in the carbon pools. A forest in particular plays an important role in carbon cycle, as they contain respectively 80% and 40% the above ground and belowground global carbon stock (Dixon et al, 1994) [16]. Carbon dioxide is released from the soil through soil respiration which involves three biological process namely faunal respirations, microbial respiration and root respiration. Root respiration is one of the main fluxes in the global carbon cycle since soil is a major carbon reserve in the terrestrial ecosystems. Since soil respiration is directly related to both microbial and root activities, its temporal and spatial variations are largely controlled by environmental factors such as precipitation, soil moisture and temperature (Phongthep Hanpattanakit et al, 2009)[12]. The seasonal variability is mostly explained by soil temperature and soil water content. Seasonal changes in soil microclimate play a key role in defining seasonal differences in soil carbon dioxide emission within sites and climatic differences generate different soil respiration rates among distant sites (Raich and Potter, 1995)[13].

The soil CO₂ flux varied in different ecosystem depending upon the different environmental conditions. Many studies have been done to quantify soil carbon dioxide emission of different ecosystems and to understand the influences of abiotic variables on soil carbon dioxide emission [2],[3],[4],[5],[6]. So the objective of the present study is to investigate the monthly changes in the emission of CO₂ from the forest soil and effect of soil temperature, soil moisture and relatively humidity of air on CO₂ emission.

Materials and methods

Description of study sites

Two forests sites were earmarked for the present study. The forest stand I is situated at Sauntak Molnom at 25°03' N latitude and 93°55' E longitude at an altitude 988m above mean sea level in Senapati District at a distance of 36 Km from Imphal City. The forest stand II is located at 24°55' N latitude and 93°48'E longitude at an altitude of 1294 m above mean sea level at Konshram Konshakhul in Senapati district of Manipur at a distance of 32 Km from Imphal city. The climate of the area is monsoonic with warm moist summer and cool dry winter. The mean maximum temperature varied from 25.8°C (January) to 34.5°C (September) and mean minimum temperature ranged from 2.4°C (January) to 21.3°C (June). The mean annual rainfall is 1230.9 mm. The average relative humidity of air varied between 54%

(February) to 79% (August). The study was conducted during the 2011-2012. Soils of the study area were sandy loam in texture and reddish in colour in forests stand I and blackish brown in forest stand II. Forest stand I is dominated by *Quercus serrata* and *Schima wallichii* and is situated at the base of the hill. Forest stand II is dominated by *Ficus virens* and *Cinnamomum zeylanicum*.

Sampling and analysis

Soil pH was determined by (1:5; soil water suspension) by a PH meter (Systronics). Soil bulk density is weight of oven dry soil per unit volume which is usually expressed in gcm³. The soil texture was analysed by International pipette method of mechanical analysis (Gee and Bauder 1986). The soil organic carbon was estimated by Walkley- Black method[1]. Total soil nitrogen was measured using 2100 Kjeltex system and available soil phosphorus was determined following the method given by Bray and Kurtz (1945).

10 plots of 1mX1m size quadrat in each forest sites were laid down randomly and previously accumulated litter on the floor was cleared. Litterfall was collected at the end of every month with the help of a plastic bag. The litter was brought to the laboratory and oven-dried at 80°C for 48hrs and dry weight is measured.

Soil CO₂ emission was measured by alkali absorption method (Anderson 1982). An open ended aluminium cylinder (25cm tall and 13cm diameter) was inserted into the soil up to 15 cm depth. Six identical cylinders were used in each of the forest sites. Fifty ml of 0.25N NaOH solution in each cylinder was maintained for 24 hours and all green vegetation inside the cylinder was removed. After 24 hours the alkali was titrated with 0.25N HCl solution using Phenolphthalein as an indicator. CO₂ absorbed from the soil was calculated using the formula proposed by Anderson and Ingram (1993):

$$V \times N \times 22 = \text{CO}_2 \text{ mg}$$

where V= volume of HCl, N=Normality of HCl.

Results

The soil was sandy loam in which 68.83% is sand, 18.66% silt and 12.26% clay in forest stand I and in forest stand II 72.73% is sand, 16.66% silt and 10.66% clay. Soil moisture varied from 19.88% to 46.76% and 17.98% to 36.89% in forest stand I & II respectively. Soil temperature varied from 13.36°C to 22.68°C in stand I and 11.34°C to 21.36°C in stand II. Soil pH ranged from

4.35 to 4.71 and 5.17 to 5.57 in forest stand I and II respectively. (Table 1)

Table 1: Abiotic variables of soils in forest stand I and stand II.

| Abiotic variables | Stand-I | Stand-II |
|----------------------------------|------------|------------|
| Soil temperature(°C) | 18.92 | 17.59 |
| Soil Moisture (%) | 31.58 | 28.515 |
| Soil texture | Sandy loam | Sandy loam |
| Sand (%) | 68.83 | 72.73 |
| Silt (%) | 18.66 | 16.66 |
| Clay (%) | 12.26 | 10.66 |
| Bulk Density(gcm ⁻³) | 1.279 | 1.33 |
| Soil PH | | |
| Organic Carbon (%) | 4.35-4.71 | 5.17-5.57 |
| Total Nitrogen (%) | 1.43 | 1.55 |
| Available Nitrogen (%) | 0.277 | 0.305 |
| Phosphorus (%) | 0.03 | 0.051 |
| C/N Ratio | 5.31 | 5.13 |

Litter fall rate varies from 23.58gm² (July) to 138gm² (February) and 28.7gm² (August) to 137.08gm² (February) in site I and II respectively for different tree species. The total litter fall rate was recorded to be 7.89t ha⁻¹ yr⁻¹ for site I and 7.49t ha⁻¹ yr⁻¹ for site II. (Fig. 1)The litter fall rate is maximum in the month of February in both the forest stand. Then the rate of litter fall decrease consistently upto July in stand I leading to minimum litter fall and then increases thereafter. In forest stand II the minimum litter fall was observed in the month of August which thereafter increases until maximum. The difference in the two stands may be due to difference in species composition.

The soil CO₂ flux ranged from 67.69 to 382.35 mg CO₂ m⁻² hr⁻¹ and 74.60 to 394.88 mg CO₂ m⁻² hr⁻¹ forest stand I and II respectively. Maximum CO₂ flux rate were recorded in the month of August in both the forest stands which then decreased consistently till January and thereafter increased (Fig 2). Seasonally, the mean CO₂ flux rate was recorded maximum during rainy season followed by summer season and winter season. The soil CO₂ flux rate correlated positively and significantly with abiotic factors viz., soil moisture, soil temperature, relative humidity, mean air temperature and rainfall in both the forest stands I and II (Table3). The variability in soil CO₂ flux was recorded to be 88.1% and 82.0% due to soil temperature and soil moisture respectively in forest stand I and 88.3% and 72.4% due to soil moisture and soils temperature respectively in forest stand II.

The relationship between rate of soil CO₂ flux (mg CO₂ m⁻² hr⁻¹) and soil properties, i.e. soil temperature (X₁), soil moisture (X₂) and soil organic carbon (X₃) has been analysed by multiple regression in both the study sites and is summarized as follows:

Site-I

$$Y = -655.568 + 11.29X_1 + 2.804X_2 + 402.179X_3,$$

$$(r_1 = 0.93; r_2 = 0.90; r_3 = 0.52) \text{ at } P < 0.05.$$

Site-II

$$Y = -794.313 + 3.892X_1 + 3.116X_2 + 532.890X_3,$$

$$(r_1 = 0.85; r_2 = 0.93; r_3 = 0.51) \text{ at } P < 0.05.$$

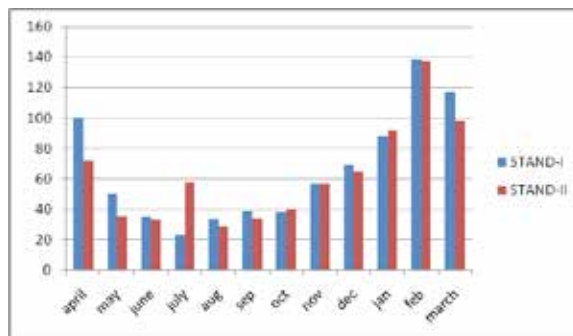


Fig. 1 Monthly variation of litter fall rate in Forest stand-I and Forest stand-II

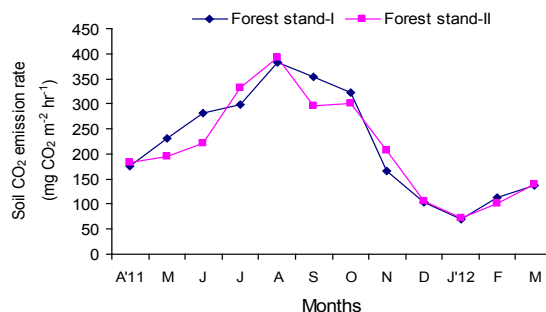


Fig.2. Monthly variation of soil CO₂ emission rate (mg CO₂ m⁻² hr⁻¹) in Forest stand-I and Forest stand-II

Table 2: Seasonal variation in soil CO₂ emission rate (mg CO₂ m⁻² hr⁻¹) in Forest stand-I and Forest stand-II

| Season | Stand I | Stand II |
|---------------------------|---------|----------|
| Summer (March – May) | 180.58 | 173.5 |
| Rainy (June – October) | 392.9 | 313.32 |
| Winter(November-February) | 112.96 | 121.32 |
| Mean Annual | 220.26 | 214.37 |

Table 3: Correlation coefficient (r) for the relationship of soil CO₂ emission rate with the abiotic variables measured in the two forest stands

| Parameters | Stand I | Stand II |
|---------------------------|---------|----------|
| Soil moisture (%) | 0.829 | 0.871 |
| Soil Temperature (°C) | 0.938 | 0.850 |
| Relative Humidity (%) | 0.828 | 0.798 |
| Mean Air Temperature (°C) | 0.880 | 0.825 |
| Rainfall | 0.647 | 0.586 |

NS- not significant; P<0.05

Discussion

The study shows that there is significant positive relationship between soil CO₂ flux rates and abiotic variables. Soil moisture, soil temperature and soil organic carbon has strong influence on the release of CO₂ into the atmosphere from the soil in both the ecosystems. Similar findings have also been reported in different ecosystems by several workers.[2],[3],[6],[7],[10].

The soil CO₂ flux shows negative relationship with the litter fall in different months in both the forest stands. There is a significant high litter fall during the dry and cool winter season as compared to the rainy season. But on the contrary soil CO₂ emission is minimum during winter and maximum during rainy season. Thus this shows that monthly plant litter fall does not show any effect on soil CO₂ emission.

The rate of soil CO₂ flux was recorded to be maximum in the month of August in both the forest stands as the micro flora and micro fauna becomes active due to availability of higher soil moisture coupled with soil temperature. The decomposition of plant litter enhanced during this period thereby increasing the rate of soil CO₂ flux. The rate of soil CO₂ flux was recorded to be minimum in the month of January in both the forests stands which may be due to low moisture content of soil and temperature thereby inhibiting the microbial activity and decomposition (Devi and Yadava, 2006)[4]. Thus leading to low carbon dioxide emission. Thereafter there is a consistent increase in the soil CO₂ flux till August which may be due to high temperature and soil moisture with the onset of summer season. The difference in the rate of soil CO₂ flux in the two forest stands may be due to the difference in the diversity of micro flora, micro fauna and tree species. The mean soil CO₂ emission rate was found to be higher in the forest stand I as compared to forest stand II which may be due to higher soil moisture and higher soil temperature thereby enhancing the rate of higher microbial activity. A maximum rate of soil CO₂ flux in either spring or early summer season has been reported by several workers (Davidson et al, 2002[2], Laishram et al, 2002[9], Rastogi et al, 2002[15]). On the contradictory to their finding, we found a maximum rate of soil respiration in rainy season. Similar trend has also been reported by Devi, N.B. and Yadava, P.S. 2008 in a Subtropical Mixed Oak Forest of Manipur, North-eastern India [3]. Several reports on high soil respiration rate in wet season are also exist (Kursar 1989, in a lowland moist forest panama[8]; Rajvansi and Gupta 1986 in Tropical Dalbergia sissoo forest[14]; Savage and Davidson 2001 in Harvard forest[18]; Saraswathi et al, 2008, in a semi-arid soil of India[17] which are in conformity with our observations. An increase in soil respiration rate immediately after the rain-

fall events have also been reported (Holt et al, 1990[5] and Law et al, 2001[11]. In both the forest stands a high correlation shows that soil CO₂ emission is positively affected by soil moisture, soil temperature, relative humidity, mean air temperature and rainfall. However soil temperature and air temperature have strong influence on soil CO₂ flux in comparison to other factors i.e., by soil moisture, relative humidity, and rainfall in forest stand I. In forest stand II soil moisture and air temperature have strong influence on soil CO₂ flux as compared to other factors.

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