ABSTRACT

The increase in global temperature by anthropogenic forcing primarily due to the increase in atmospheric CO_2 concentration is a major threat to the earth and environment. The most common anthropogenic sources of CO_2 are burning of fossil fuel and changes in land use or land cover pattern. Approximately less than half of the total CO_2 remains in the atmosphere out of the total CO_2 emitted from different sources. The rest of the CO_2 gets absorbed by some unquantified sinks like forest and ocean. Forests are considered as major terrestrial reserves of CO_2 due to its inherent capacity of storing carbon for a long period of time. Forest ecosystems are reported to contain large amount of carbon. Although, the tropical forests are known as significant carbon sinks but there are lots of uncertainty about its variation with respect to space and time. Earlier studies also elucidated some tropical forests as net source of carbon to the atmosphere. Therefore, it is essential to understand the carbon cycles of the forests of different regions to overcome from the prevailing uncertainty in global carbon cycle. The adequate information on the carbon dynamics of south East Asian forests would add value to the global carbon budget since reports of forest carbon balance covering different parts of this region are not adequate. India is one of the largest countries in south East Asia and mosaic of ecosystems starting from evergreen conifers to different types of deciduous forest exists inside the Indian subcontinent. Although the forests of India are thought to be good sink of carbon but there is a need of real time field data to understand the variation of sink strengths of different forests ecosystems. The forests of Northeast India are very unique due to the subtropical climate of the region with typical monsoon, richness in biodiversity, physiography and remoteness. Soil organic carbon (SOC) is the largest terrestrial reservoir of carbon and forest has the capacity to store higher amount of SOC than other terrestrial ecosystems. To study the carbon dynamics of forests of Northeast India we have chosen Kaziranga National Park (KNP) as representative due to its large forest cover and existence of diverse vegetation patterns inside it. For CO_2 flux studies the eddy covariance technique (EC) is globally used and accepted due to the accuracy and advantages of this technique. Considering the above views and to address the major scientific gap of the forest carbon cycle, an eddy covariance flux tower was installed inside the KNP and results of a complete annual cycle (from February, 2016 to January, 2017) are presented here. Following objectives were selected for the present study (1) To study the seasonal and annual variation of CO_2

flux and changes in atmospheric CO_2 concentration. (2) Investigation and analysis of the factors regulating the seasonal and diurnal variations of CO_2 concentrations and fluxes. (3) To study the effect of photosynthetically active radiation (PAR) on ecosystem gross primary productivity and net ecosystem exchange (4) To study the relationship of annual and seasonal variation of CO_2 flux with soil carbon dynamics.

The change of canopy architecture of the forest was monitored by biweekly measurement of leaf area index. The canopy of the semi evergreen forest showed distinct seasonal changes with high LAI of 3.07 in the beginning of monsoon season (June).The monthly average of CO_2 concentration above the canopy showed its peak in the month of June and the lowest CO_2 concentration was recorded in April. Gradual decrease in night time CO_2 concentration from lower height to top of the canopy was observed during the period of study. Study of diurnal variations of CO_2 flux (monthly mean) showed high negative flux of 9.97 µmol m^{-2} s^{-1} in the month of June which was the beginning of Indian summer monsoon. Lower day time negative flux values during the winter months indicated lower uptake of CO_2 by the canopy during winter season.

The available net radiation (Rn) was partitioned in to its principal components latent heat flux (LE) and sensible heat flux (H) throughout the study period. Throughout the study period, energy was portioned more as latent heat than sensible heat due to favourable conditions for high evapotranspiration in the forest, however reversal was observed in the month of January due to very low leaf area index as well as dry soil conditions of the forest. The estimated average annual evapotranspiration of the forest using LE flux data was 2.8± 0.19 mm day^{-1} .The quality check of eddy covariance measurement was done by estimating the energy balance closure of the site. The estimated energy balance closure using half hourly data was 78 %, which was well within the range of other available FLUXNET reports. Energy balance closure of the site was found to be a function of atmospheric turbulence.

The monthly variation in CO_2 concentration above the canopy was regulated by the change in canopy architecture and soil moisture. The CO_2 flux above the canopy showed clear seasonal and monthly variation during the period of study. Estimated highest negative CO_2 flux in the month of June is well supported by high LAI in the same month. The gradual increase in CO_2 uptake from winter to the beginning of the monsoon season smoothly followed the continuous canopy development trend. The diurnal variation of CO_2 flux above the canopy was regulated by the variation of incoming photosynthetically active radiation. The correlation results between CO_2 flux and PAR indicted good correlation between the parameters except the mid-monsoon months (July-August). During the mid-monsoon season, the recorded CO_2 flux above the canopy was affected by fluctuations of incoming PAR possibly due to the cloudy sky and high vapour pressure deficit. Vapour pressure deficit (VPD) has played its role by regulating the stomatal openings of the leaves. At very high values of VPD, stomates were partially closed and thus decreased the CO_2 flux in late afternoon hours.

The net CO_2 flux of KNP was partitioned in to the major components gross primary production (GPP) and ecosystem respiration (Re). During the complete cycle of study, highest GPP (daily average) of 15.86 g C m^{-1} day^{-1} was observed during last part of April and minimum GPP (daily average) of 1.58 g C m^{-2} day^{-1} was recorded in the month of January, 2017. In the ecosystem (KNP), variations in GPP were mainly regulated by LAI and PAR. The relationship between daily average PAR and GPP showed highest correlation (r^2=0.81) in the month of March, 2016 among the parameters. However, the monthly analysis showed insignificant relationship between PAR and GPP from July, 2016 to January, 2017. The estimated annual GPP of the forest during the annual cycle of study was 2660.07 g C m^{-2} yr^{-1}. The daily ecosystem respiration of the forest was found to be in between 0.06 g C m^{-2} day^{-1} to 15.06 g C m^{-2} day^{-1}. The estimated annual ecosystem respiration of the forest was 2567.13 g C m^{-2} yr^{-1}. Water logged condition of the site during monsoon played a significant role in controlling the month wise variation of ecosystem respiration. Highest daily average net ecosystem productivity (NEP) of 5.03 g C m^{-2} day^{-1} was observed in the beginning of May. Monthly sums of GPP, Re and NEP indicated that the forest was a source of carbon in the months of February and March. From the month of April to June, monthly sums of GPP of the forest were higher than Re and the ecosystem acted as a carbon sink. Dominance of GPP over Re were seen from the month of July to September. Thus, ecosystem respiration of this semi evergreen forest played a significant role in carbon cycle of the KNP forest. Annual estimated NEP of 92.93± 1.7 g C m^{-2} yr^{-1} reveals that this semi evergreen forest is a moderate sink of carbon on annual basis.

In this study, the seasonal variations of different soil parameters were studied and results were correlated with the variations of CO_2 flux above the canopy. The soil organic carbon (SOC) content was found to be higher in the top soil than the soil of lower depth due to higher litter decomposition in the top soil. The SOC content in top soil was low in pre monsoon season due to loss of CO_2 from wet soil during this season. In winter season the measured SOC values were very high as a result of higher litter decomposition. The bulk density of top soil was low compared to the soils of lower depth. The relationship between SOC and bulk density of the top soil showed negative correlation with marginal level of significance. The seasonal average of ecosystem respiration was correlated with seasonal averages of SOC and BD. Negative correlation between SOC and ecosystem respiration (adj r^2=0.92, p=0.03, r^2=0.94) was observed in the forest ecosystem. The correlation between C/N ratio and ecosystem respiration was found to be negative (adj r^2=0.97, p=0.01). In the beginning of measurement during winter season the estimated organic carbon content of the soil was 22.7955 Mg ha^{-1}, which increased to 22.932 Mg ha^{-1} towards the end of the year in the post monsoon season. Therefore, an amount of 0.137 Mg C ha^{-1} yr^{-1} was stored in soil, which indicated the carbon sequestering ability of the forest soil of KNP.

The most significant findings of this study are:

1. Diurnal variation of monthly mean of CO_2 flux over the semi evergreen forest showed maximum negative CO_2 flux of 9.97μmol m^{-2} s^{-1} above the canopy during the month of June.
2. Change in canopy architecture of the forest is the important driver of seasonal and monthly variation of CO_2 flux.
3. Energy was partitioned more as latent heat than sensible heat in the forest. The mean annual evapotranspiration of the KNP forest was 2.8± 0.19 mm day^{-1}.
4. The world heritage site KNP acted as moderate carbon sink with annual NEP of 92.93 g C m^{-2} yr^{-1}.
5. Soil C/N ratio and soil moisture are the major drivers of seasonal and annual variation of net CO_2 flux. During our study cycle 0.137 Mg C ha^{-1} yr^{-1} of carbon was stored in the soil, which indicates the potential sink strength of KNP soil.