CHAPTER-6

SUMMARY AND CONCLUSION

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6.1. Summary:

In this study the carbon dynamics of an unexplored semi evergreen forest of Northeast India are reported for a complete annual cycle from February, 2016 to January, 2017. The experimental site was located inside the world heritage site Kaziranga National Park, Assam, India. The CO_2 and energy fluxes were estimated by using the high frequency data generated from eddy covariance system. Seasonal and monthly variation of CO_2 concentration and CO_2 flux above the canopy were analyzed and the results are presented here. Attempts were also made to find out the factors which were responsible for the seasonal variation of CO_2 and other energy fluxes. The computed net CO_2 flux was partitioned in to its components gross primary production (GPP) and ecosystem respiration (Re). The impact of photosynthetically active radiation (PAR) on gross primary production was also investigated in this study. Efforts were also made to correlate the variations of ecosystem respiration with the soil carbon dynamics of the semi evergreen forest. The months of the year were arranged in to the following seasons for the seasonal interpretation of the results, winter (December-February), pre-monsoon (March-May), monsoon (June- September) and post monsoon (October - November). The summary of findings of each objective of the present thesis are elucidated below:

Objective 1:

In this study the diurnal variation of CO_2 concentration at different heights (eight measurement levels) of the tower are presented from the period February, 2016 to April, 2016. The recorded CO_2 concentration was invariably higher in the lower level of measurement compared to the upper levels. The study of diurnal variation of CO_2 concentration (monthly mean) in the month of February, 2016 showed a high peak of 621 µmol mol^{-1} at the measurement height of 2 meter on the tower. In all the eight levels of measurement the recorded CO_2 concentration was higher in the night time compared to day hours. During the night time the gradual decrease in average CO_2 concentration was recorded from 2 meter height to 36 meter due to CO_2 efflux effect. The recorded monthly average of CO_2 concentration for each month by the EC sensor on 37 meter height showed peak average concentration of 403.62 µmol mol^{-1} in the month of June, 2016 and minimum average CO_2 concentration of 380.16 µmol mol^{-1} in the month of April, 2016.

The general character of CO_2 concentration of the KNP forest ecosystem during the experimental period was found to vary from 380.16 µmol mol^{-1} to 403.62 µmol mol^{-1}.

The month wise analysis of diurnal variations in CO_2 flux (monthly mean) above the canopy showed distinct monthly variations in CO_2 flux. The diurnal variations of CO_2 flux (monthly average) showed a high negative value of 9.97 µmol m^{-2} s^{-1} in the month of June. The gradual increase in CO_2 uptake by the forest was observed from the winter season (February, 2016) to the beginning of monsoon season (June, 2016).

The CO_2 flux of the forest ecosystem recorded during our study reveals that the flux varied from -9.97 µmol m^{-2} s^{-1} to 7.74 µmol m^{-2} s^{-1}.

Objective 2:

The leaf area index (LAI) of the forest canopy was low in the winter and it increased gradually through pre-monsoon and attained an average value of 3.07 in the month of June, 2016. The gradual increase in LAI of the forest canopy resulted in increased CO_2 uptake by the forest through photosynthesis resulting in gradual decrease of atmospheric CO_2 concentration from February, 2016 to April, 2016. The average CO_2 concentration attained high peak in the month of June possibly due to the addition of extra CO_2 released from wet soil during the monsoon season after rainfall. The pattern of diurnal variation in latent heat (LE) and sensible heat flux (H) was similar to the variation in net radiation (Rn). During the day time the available energy was portioned more as latent heat flux than sensible heat flux except in the dry month of January. Diurnal variation of LE flux attained a peak of 394.91 W m^{-2} in the month of April at 1230 hours. Diurnal variation of sensible heat flux (H) showed its peak of 217.71 W m^{-2} in the month of January, 2017 at 1200 hours. The estimated annual mean evapotranspiration of the site was 2.8± 0.19 mm day^{-1}. The estimated energy balance closure of the site was 78 % which is well within acceptance limit of FLUXNET community. In our site, energy balance closure was found to increase with the increase in turbulence parameters (u* and Ϭw). At very high atmospheric turbulence (u* and σ_w > 0.8 m s^{-1}) the energy balance closure crossed 90 %. Good correlation (r^2=0.74) was observed between monthly average LAI and maximum negative CO_2 flux of the respective month. The carbon uptake was high at noon hours due to sufficient availability of PAR during that period of time. During mid-monsoon months (July and August) the day time CO_2 flux was reduced

as a result of low incoming PAR and high VPD. The diurnal variations in VPD recorded high values during the late afternoon hours with low negative CO_2 flux during that time indicating partial stomatal closure.

Objective 3:

The estimated net ecosystem exchange of CO_2 was partitioned in to its components GPP and Re. The estimated daily average GPP ranged between 1.58 g C m^{-2} day^{-1} and 15.86 g C m^{-1} day^{-1}. High LAI of the forest and abundant quantity of PAR in the month of May and June caused favorable condition for photosynthesis resulting in higher daily average GPP during these months. As a results of low LAI of the canopy in January the estimated daily average of GPP were low in January. The estimated annual GPP of the forest was 2660.07 g C m^{-2} yr^{-1} which is large compared to other Asian forest sites. The daily average value of ecosystem respiration ranged between 0.06 g C m^{-2} day^{-1} to 15.06 g C m^{-2} day^{-1}. From the month of February, 2016 to May, 2016 daily average of ecosystem respiration increased continuously parallely with increase in temperature and soil moisture. The daily values of ecosystem respiration decreased from the month of June to August due to reduction in soil respiration as a result of water stagnation. Estimated annual net ecosystem production of the forest (KNP) was 92.93± 1.7 g C m^{-2} yr^{-1}, which indicates that this semi evergreen forest (KNP) is acting as a moderate sink of carbon. The relationship between air temperature and ecosystem respiration was found to increase exponentially (r^2=0.54). The relationship between day time average of PAR vs GPP showed a good correlation (r^2=0.81) in the month of March. The estimated correlation coefficient in the months of February, April, May and June were 0.55, 0.72, 0.75 and 0.71 respectively. From the month of July, 2016 to January, 2017 the correlation between PAR and GPP was insignificant.

The results of least square fit between CO_2 flux and PAR showed good correlation (r^2=0.60) during the period March, 2016 to April, 2016. The correlation was also higher in the next two months May to June (r^2=0.75). During the middle of monsoon in July and August the correlation between the two parameters were not significant. In July there was fluctuation in incoming PAR and were low due to heavy cloud cover and the day time CO_2 flux was influenced by high VPD during August. Photosynthetically active radiation and CO_2 flux again showed a positive correlation (r^2=0.62) during the period from September, 2016 to November, 2016.

Objective 4:

The estimated soil organic carbon (SOC) of soil samples of KNP ranged between 1.31 to 1.71% in the upper depth and between 0.31- 0.79% in the lower depth. In the upper soil layer the seasonal average of estimated SOC showed highest value of 1.67 % in winter season and lowest 1.4 % in pre-monsoon season. The SOC at the lower depth recorded highest value of 0.74% in winter and lowest of 0.35 % in pre monsoon season. The BD of the top soil layer revealed maximum of 1.2 Mg m^{-3} in the monsoon season and lowest BD of 0.91 Mg m^{-3} during winter season. Highest respiration of 282.83 g C m^{-2} $month^{-1}$ and lowest of 77.99 g C m^{-2} $month^{-1}$ was recorded during pre-monsoon and winter season respectively. SOC and ecosystem respiration had shown a negative correlation (adj r^2=0.92, p=0.03, r^2=0.94). However, the correlation between bulk density and ecosystem respiration was positive (adj r^2=0.82, p=0.06, r^2=0.82). The correlation between seasonal average of ecosystem respiration and C/N ratio was found to be negative (adj r^2=0.97, p=0.0101). the amount of carbon stored in the soil was 0.137 Mg C ha^{-1} yr^{-1} over the complete annual cycle of study.

6.2. Conclusion

In this study, the variations of monthly and seasonal CO_2 concentration, CO_2 flux above the canopy and surface energy fluxes are reported for the first time from a semi evergreen forest of Northeast India. The CO_2 flux above the canopy and atmospheric CO_2 concentration showed distinct seasonal and monthly variation. The energy balance closure of the site was 78% which is fairly good and indicated accuracy and acceptable quality of the used flux data. The turbulence in the atmosphere was found to have a major role in the variation of energy balance closure. Energy balance closure was highest during the neutral conditions of the atmosphere. The monthly variation of CO_2 flux was primarily modulated by the change in leaf area index of the semi evergreen forest canopy. The diurnal variation of CO_2 flux was a function of incident photosynthetically active radiation. The correlation between incident PAR and CO_2 flux was highest in the pre monsoon to monsoon transition phase (May and June). The poor correlation between PAR and CO_2 flux in July and August was caused by cloudy sky and high VPD respectively. The diurnal variation of CO_2 flux (monthly average) showed peak negative CO_2 flux of 9.97μmol m^{-2} s^{-1} in the month of June. The CO_2 flux above the canopy was also regulated by the parameter VPD, the higher VPD values in the forest during the late

afternoon hours was responsible for partial stomatal closure of leaves and thus lowering the CO_2 uptake by the canopy. The diurnal variation of LE flux attained peak of 394.91 W m^{-2} in the month of April, 2016 at 1230 hours. Domination of latent heat flux over the sensible heat flux was observed in the forest except the month of January and the mean annual evapotranspiration of the forest was estimated as 2.8 mm day^{-1}. Remarkable monthly variation of ecosystem respiration was seen in the KNP ecosystem which in turn influenced the monthly as well as the annual net ecosystem productivity (NEP) of the semi evergreen forest. The gross primary productivity (GPP) of the KNP forest was primarily due to the function of LAI and incoming PAR. The water logged condition of the site during the monsoon season played a critical role over the GPP and Re of the forest. Using eddy covariance technique, estimated annual GPP and Re of the forest was 2660.07 g C m^{-2} yr^{-1} and 2567.13 g C m^{-2} yr^{-1} respectively. The estimated annual NEP of 92.93 g C m^{-2} yr^{-1} of the KNP forest indicated that the ecosystem is sequestering carbon as a moderate sink. Carbon fixation potential of the forest was highest in the month of June, coinciding with the beginning of Indian summer monsoon. Leaf litter decomposition in the soil is considered to be responsible for variation in soil organic carbon. The role of soil temperature in controlling the seasonal variation of ecosystem respiration was not very clear inside the KNP forest. Seasonal variation in bulk density (BD) of soil and ecosystem respiration showed positive correlation with marginal level of significance (adj r^2=0.82, p=0.06, r^2=0.82). The role of moisture and SOC content of soil was important in the regulation of seasonal behavior of ecosystem respiration. C/N ratio played a vital role in controlling the seasonal behavior of CO_2 efflux which in turn effected the ecosystem respiration. During the period of study, the amount of carbon stored in the soil of KNP was 0.137 Mg C ha^{-1} yr^{-1}, this indicated that the soil of KNP could act as an effective sink of carbon in coming years.

6.3. Take home messages:

Take home messages from the present study are as follows:

1. Variation in leaf area index of the semi evergreen forest was the most important and significant driver of monthly variation of above canopy CO_2 flux.
2. The available energy in the forest was partitioned more as latent heat flux than sensible heat flux.
3. On annual scale, the forest ecosystem of KNP acted as a moderate carbon sink with estimated annual NEP of 92.93 g C m^{-2} yr^{-1}.
4. During the period of study the amount of carbon stored by the forest soil was 0.137 Mg C ha^{-1} yr^{-1}, which is the indicator of potential sink strength of KNP soil.