ABSTRACT

The large and dynamic soil organic carbon (C) pool plays an important role in regulating the global carbon budget. Global warming induced by changing climate may bring significant impacts on soil C cycling. The increasing temperature have direct influence on microbial degradation of soil organic matter (SOM), soil respiration and feedbacks of greenhouse gases to the atmosphere. Minor variation in soil respiration rate can have a significant impact on CO_2 concentrations in the atmosphere. Similarly, the sensitivity of soil CO_2 efflux to temperature results in positive feedback to atmospheric warming. The soil CO_2 efflux is regulated by an array of factors such as soil properties, climate and vegetation. Forests are the major terrestrial CO_2 reserves due to their innate ability to store carbon for extended periods. Soil CO_2 efflux has been studied in a variety of forest ecosystems across the globe. However, the forest ecosystem of Northeast India is idiosyncratic due to the subtropical climate of the region with typical monsoon, affluent biodiversity, topography and remoteness. Kaziranga National Park (KNP) of Northeast India was chosen as the representative site for the study because of its humongous forest cover and divergent vegetation patterns. Previous study using eddy covariance have identified Kaziranga National Park as a moderate sink of carbon. However, study on the role of soil properties in regulating the carbon dynamics of Kaziranga National Park is lacking. To address this major scientific gap on CO_2 efflux dynamics, the present study was undertaken with the following objectives:

1. To study the soil physico-chemical and biological characteristics of Kaziranga National Park (KNP) at seasonal scale.
2. To assess the soil mineralogy of KNP and their role on SOC stabilization and C sequestration.
3. To correlate the influence of soil properties in regulating CO_2 efflux from KNP.

Soil samples were collected from three representative ecosystems (grassland, forestland and wetland) of the park at two (0-15 cm and 15-30 cm) depths; except for the wetland ecosystem. Samples were collected for two consecutive years (2020-21 and 2021-22) during pre-monsoon (March to May), monsoon (June to September), and post-monsoon (October to November) season. Total 120 soil samples were collected using the grid sampling method covering a distance of ≈ 2.5 km. Following the collection, composite samples were prepared. After removing roots, detritus, small rocks, and particles larger

than 2 mm in size, the soil samples were sieved through a 2mm sieve. One portion of the sieved soil samples were air dried/oven dried and used for analyses of physicochemical parameters. The second portion of the soil samples were stored at 4°C in refrigerator to study the soil biological parameters. Soil CO_2 efflux was studied by alkali absorption method in the laboratory for a period of 90 days in the three seasons. Data presented are mean ± S.D. (n = 5). To process the data and to determine statistical difference between the treatment means, Duncan's multiple range test (DMRT) and analysis of variance (one-way ANOVA) were performed at $p \leq 0.05$. Statistical analyses were performed using SPSS 26 software package (SPSS Inc., Chicago, IL, USA), OriginPro 8.5 (OriginLab®, MA, USA) and R statistical software (R studio).

Maximum cumulative carbon mineralisation (after an incubation period of 90 days) was recorded in wetland ecosystem while the minimum was found in forestland ecosystem. Among the seasons, monsoon season recorded the highest cumulative carbon mineralisation whereas the lowest of the same was observed during pre-monsoon season. Higher value of cumulative carbon mineralisation was noted in the topsoil than the subsoil.

Soil physicochemical analysis revealed significant seasonal and ecosystem variation. Highest level of soil moisture, SOC, total N and soil available K was recorded in wetland ecosystem during monsoon season. Among the physical parameters, soil moisture revealed maximum influence in regulating the CO_2 efflux irrespective of the seasons and ecosystems. Whereas, soil texture revealed a minor role in controlling carbon mineralization. Soil chemical parameters such as SOC and total N were the key variables in controlling the carbon dynamics of the KNP. However, soil pH showed a negative association with carbon mineralisation in the studied ecosystems throughout the seasons.

Soil biological variables (MBC, soil enzymatic activities, relative abundance and diversity of bacteria) varied significantly with season. Monsoon season recorded the highest value of all the parameters. Likewise, wetland ecosystem recorded highest MBC and soil enzymatic activities. Both soil enzymatic activities and MBC documented significant correlation with carbon mineralisation. *Proteobacteria*, *Actinobacteria*, *Chloroflexi* and *Acidobacteria* were the predominant bacterial phyla. *Proteobacteria* and *Chloroflexi* revealed positive correlation with carbon mineralisation. Whereas, *Acidobacteria* and *Actinobacteria* documented a negative correlation for the same.

The mineralogical analysis of the soil samples inferred the presence of phyllosilicate minerals with the major phases being quartz, montmorillonite, vermiculite, augite, and dolomite. Presence of organic matter was also confirmed by FT-IR analysis. However, no significant influence of soil mineralogy in regulating carbon dynamics of KNP was noted.

Significant findings of this study are:

1. Seasonal variation in soil physicochemical and biological properties across the three ecosystems of the semi-evergreen forest was highest during the monsoon season and lowest during the pre-monsoon season.
2. Wetland ecosystem recorded the highest cumulative carbon mineralisation during monsoon season followed by grassland and forestland ecosystem.
3. Soil chemical and biological properties play pre-dominant role in regulating the CO_2 efflux of KNP.
4. Surface soil exhibited the greatest carbon mineralisation regardless of ecosystems and seasons as opposed to subsurface soil.