Abstract
Forest ecosystems are complex ecosystems with various species of trees, shrubs, animals, and microbial lives. Forest ecosystems play a key role in climate change mitigation by absorbing large amounts of atmospheric carbon dioxide (CO₂), one of the major greenhouse gases (GHGs) responsible for global warming and subsequent climate change. Because of the accumulation of gaseous carbon (C) over considerable long time, these areas are amongst potent terrestrial C pools on Earth. Due to their substantial contribution to the global C balance, forests are an integral part of the C cycle and forest ecosystems worldwide are gaining more and more importance with regard to climate change research. But their role as net source/sink of other major GHGs viz. methane (CH₄) and nitrous oxide (N₂O) including CO₂ is yet to be well defined, which itself is a researchable issue under changing climatic scenario. Due to the complex associations of several environmental factors over forests, GHGs fluxes have been uncertain. Moreover, the characterization of ecosystem level C, nitrogen (N) biogeochemistry, nutrient (element) cycling, water and energy flux dynamics, their spatio-temporal variability and quantification of net C sequestration potential is still limited in different forest ecologies worldwide with relation to biometric components and bio-physical variables under changing climatic scenario and anomalous climate events. Moreover, land use may impact watershed hydrology and regional climate by altering the land-atmosphere exchanges of trace gases, energy and water cycling. Thus the investigation of the processes and the mechanisms involved in gaseous C and N exchanges (viz. CO₂, CH₄ and N₂O) between terrestrial ecosystems and the atmosphere and their driving/governing factors are essential in context of global warming and changed climate. The Impact of GHGs on climatic conditions and the influence of such climatic change on (forest) productivity is reality, although there is a need to assess the extent of such influences. The holistic studies of GHG fluxes, their quantification from different forest ecologies, major controlling factors for such fluxes and their mitigation are still limited in forest ecosystems.

Keywords: Forest ecosystems; Greenhouse gas; Carbon and nitrogen flux; Water and energy budget; Global warming; Climate change

Introduction
Forest ecosystems, one of the most productive terrestrial ecosystems and natural renewable sources, are considered to be potential sources of organic matter [1]. Forest ecosystems play a key role in climate change mitigation by absorbing large amounts of atmospheric CO₂ [2,3]. Because of the accumulation of C
over considerable long time, these areas are among the largest terrestrial C pools on Earth [4]. Moreover, C inputs to the soil are largely determined by the land use, with forest systems tending to have the largest input of C to the soil. Due to their substantial contribution to the global C balance, forests are an integral part of the C cycle and climate change research [5]. They are complex ecosystems with various species of trees, shrubs, animals, and microbial lives [6]. Due to the complex associations of several environmental factors over forests, GHGs fluxes have been uncertain. Moreover, the characterization of ecosystem level C, N, water and energy flux dynamics, their spatio-temporal variability and quantification of net C sequestration potential is still limited in forest ecology in different climatic zones with relation to biometric components and bio-physical-anthropogenic variables (viz. phenology, leaf area index, biomass, average stand age, fluctuation in temperature and shift in radiation patterns including photosynthetic photon flux density, temporal variation in moisture availability, change in canopy structure and variation in light intensity, altered pattern of evapotranspiration, N deposition under changing climatic scenario and climate events (viz. Asian monsoon effects, anomalous El Nino southern oscillation, elevated temperature and CO2 fertilization effect) [5].

**Net ecosystem CO2 exchange, gross primary production and ecosystem respiration**

The net ecosystem CO2 exchange (NEE) between the biosphere and the atmosphere is the balance between the fluxes associated with photosynthetic assimilation by the foliage (gross primary production, GPP) and respiratory effluxes (RE) from autotrophs and heterotrophs (microbial and soil fauna) [7]. The NEE provides information about the length of the active season and the strength of the component processes (i.e. photosynthesis of above-ground vegetation and autotrophic and heterotrophic respiration) [8]. Carbon dioxide flux measurements of terrestrial vegetation in relation to photosynthesis and respiration are vital for understanding the physiological behaviour of vegetation and predicting future climate change. The change in atmospheric CO2 depends on the net exchange of CO2 within the C pools involved in the C cycle processes and to understand the variability within C cycles, fluxes such as autotrophic respiration (AR), litterfall, heterotrophic respiration (HR) and soil respiration (SR) need to be analyzed comprehensively in conjunction with net ecosystem production (NEP), GPP, and RE [2,5,7,9]. The NEE between forest ecosystems and the atmosphere is controlled by several biological and physical processes. The characteristics of NEE over forest (vegetation) canopy have a relationship with several ecosystem parameters and environmental variables (viz. latent heat, air temperature, vapour pressure deficit, canopy irradiance, heat stress, stomatal response, high evaporative demand, circadian rhythm, growth stages / age of vegetation stand, leaf area index, biomass, etc.). The amplitude of the diurnal, seasonal, annual and interannual variation in NEE increases as leaf area index / crop phenology at different vegetation stand ages advances and reaches its peak. The diurnal pattern of NEE and C uptake is dependent on sunlight. This is due to leaf gas exchange and pattern of light interception by the canopy. The shifts in NEE is also dependent on physical environmental conditions and is particularly sensitive to climate change [5,7,8,10,11,12,13,14,15]. Thus the investigation of the processes and the mechanisms involved in gaseous C and N exchanges (viz. CO2, CH4 and N2O) between terrestrial ecosystems and the atmosphere are essential in the context of global warming and changing climatic scenario. However, the real time data of net ecosystem CH4 exchange (NEME) and net ecosystem N2O exchange (NENE) between forest vegetation and atmosphere is still limiting, which is worth researchable issue. The balance between production and decomposition determines whether a system is a sink or a source of atmospheric C [7].

**Net primary production, net ecosystem production and net biome production**

Rate of C input to the soil in forest ecosystems is related to the productivity of the vegetation growing on that soil, measured by net primary production, NPP. The NPP varies with climate, land cover, species composition and soil type. Even, NPP shows seasonal variation due to its dependence on light and
Over longer time periods, a proportion of NPP enters the soil as organic matter (OM) either via plant leachates, root exudates, or by decomposition of litter and fragmented plant structures [17], and it is converted back to atmosphere in form of CO₂ via soil (heterotrophic) respiration processes. The remaining C is termed as NEP. However, many other processes viz. harvest, fire and insect damage also remove C, which when combined with the heterotrophic processes counterbalance the terrestrial CO₂ input from gross primary production (GPP). Any residual C is termed net biome production (NBP) and can be negative or positive depending on whether the terrestrial ecosystem is a source or sink for C [17].

### Water and energy fluxes

The energy exchange is regarded as a vital process in terrestrial forest ecosystems because it affects variables such as temperature, plant growth and productivity [18]. The main components of surface energy balance are the net radiation, the heat stored in soil, the sensible heat flux, and the latent heat flux. Forest land use and management may impact watershed hydrology and regional climate by altering the land-atmosphere exchanges of trace gases, energy and water [19].

### Net ecosystem C balance (NECB)

It is a key issue to understand the response of terrestrial ecosystems to environmental change on various time scales [20]. In the context of our understanding on the processes and components of net ecosystem C balance (NECB) in forest ecosystem, it is essential to determine whether the system is behaving as net C sink (net C accumulation in the system) or source (net C depletion or loss from the system) [21,22]. In such systems, C may be added through activities like rhizodeposition, CO₂–C fixation in terms of net ecosystem production (NEP), decayed roots and litters from the decomposing material and C become lost to the atmosphere through vegetation deforestation and gaseous C emission in the form of CH₄ and CO₂ [9,15,23,24,25].

### Conclusion

A range of soil, climatic variables and varied forest types and usages of forested lands in different climatic zones influence the gaseous C and N fluxes. The Impact of GHGs on climatic conditions and the influence of such climatic change on forest productivity is now reality, although there is a need to assess the extent of such influences. There is paucity of studies of GHG fluxes, quantification followed by subsequent validation and upscaling from different forest ecologies and their behaviour (net GHGs source or sink) in terms of ecological sustainability under changing climatic condition which demands holistic research. The potential enhancement of net C storage capacity in forest soil-vegetation matrix could contribute positively to abate and mitigate gaseous C emissions to atmosphere and the attendant climate change.

### References

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