Global Scientific JOURNALS

GSJ: Volume 8, Issue 5, May 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

Short Communication / Mini Review

Greenhouse gas fluxes and accounting vis-à-vis feedback to climate change in forest ecosystems

Suvadip Neogi
Independent Researcher, India

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 (CO_2), 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 (CH_4) and nitrous oxide (N_2O) including CO_2 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. CO_2, CH_4 and N_2O) 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 CO_2 [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 CO_2 fertilization effect) [5].

Net ecosystem CO_2 exchange, gross primary production and ecosystem respiration

The net ecosystem CO_2 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 CO_2 depends on the net exchange of CO_2 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. CO_2, CH_4 and N_2O) 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 CH_4 exchange (NEME) and net ecosystem N_2O 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 temperature [16]. 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 CO_2 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 CO_2 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, CO_2–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 CH_4 and CO_2 [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

1. Robertson A I, Alongi D M and Boto K G. 1992. Food chains and carbon fluxes, in tropical mangrove ecosystems. Coastal Estuarine Studies. 41, 293–326.
2. Pan, Y., Birdsey, R.A., Fang, J., Houghton, R., Kauppi, P.E., Kurz, W.A., Phillips, O.L.,Shvidenko, A., Lewis, S.L., Canadell, J.G., Ciais, P., Jackson, R.B., Pacala, S.W.,McGuire, A.D., Piao, S., Rautiainen, A., Sitch, S., Hayes, D., 2011. A large and persistent carbon sink in the world's forests. Science. 333, 988–993.
3. IPCC, 2019: Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley,

K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.
4. Daniel C Donato, Boone Kauffman J, Daniel Murdiyarso, Sofyan Kurnianto, Melanie Stidham and Markku Kanninen. 2011. Mangroves among the most carbon-rich forests in the tropics. Nature Geoscience. 4, 293–297.
5. Kondo, M., Ichii, K., Ueyama, M. 2015. Impact of anomalous climates on carbon allocation to biomass production of leaves, woody components, and fine roots in a cool-temperate deciduous forest. Agricultural and Forest Meteorology. 201, 38–50.
6. Lekphet S, Nitisoravut S and Adsavakulchai S. 2005. Estimating methane emissions from mangrove area in Ranong Province, Thailand. Songklanakarin Journal of Science and Technology. 27, 153–163.
7. Bhattacharyya, P., Neogi, S., Roy, K.S., Dash, P.K., Nayak, A.K., Mohapatra, T. 2014. Tropical low land rice ecosystem is a net carbon sink. Agriculture, Ecosystems and Environment. 189, 127-135.
8. Swain, C.K., Bhattacharyya, P., Singh, N.R., Neogi, S., Sahoo, R.K., Nayak, A.K., Zhang, G., Leclerc, M.Y. 2016. Net ecosystem methane and carbon dioxide exchange in relation to heat and carbon balance in lowland tropical rice. Ecological Engineering, 95, 364-374.
9. Smith, P., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E. A., Bolwig, S. 2014. Agriculture, Forestry and Other Land Use (AFOLU). In Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 811-922). Cambridge University Press.
10. Zhang, Y.P., Sha, L.Q., Yu, G.R., Song, Q.H., Tang, J.W., Yang, X.D., Wang, Y.S., Zheng, Z., Zhao, S.J., Yang, Z. 2006. Annual variation of carbon flux and impact factors in the tropical seasonal rain forest of Xishuangbanna, SW China. Science in China Series D-Earth Sciences. 49, 150-162.
11. Yu, G.R., Zhu, X.J., Fu, Y.L., He, H.L., Wang, Q.F., Wen, X.F., Li, X.R., Zhang, L.M., Zhang, L., Su, W. 2013. Spatial patterns and climate drivers of carbon fluxes in terrestrial ecosystems of China. Global Change Biology. 19, 798-810.
12. Yan, J.H., Zhang, Y.P., Yu, G.R., Zhou, G.Y., Zhang, L.M., Li, K., Tan, Z.L., Sha, L.Q. 2013. Seasonal and inter-annual variations in net ecosystem exchange of two old-growth forests in southern China. Agricultural and Forest Meteorology. 182, 257-265.
13. Zhu, X.J., Yu, G.R., He, H.L., Wang, Q.F., Chen, Z., Gao, Y.N., Zhang, Y.P., Zhang, J.H., Yan, J.H., Wang, H.M. 2014. Geographical statistical assessments of carbon fluxes in terrestrial ecosystems of China: Results from upscaling network observations. Global and Planetary Change. 118, 52-61.
14. Zhu, X.J., Yu, G.R., Wang, Q.F., Gao, Y.N., He, H.L., Zheng, H., Chen, Z., Shi, P.L., Zhao, L., Li, Y.N. 2016. Approaches of climate factors affecting the spatial variation of annual gross primary productivity among terrestrial ecosystems in China. Ecological Indicators. 62, 174-181.
15. Kondo, M., Saitoh, T.M., Sato, H., Ichii, K. 2017. Comprehensive synthesis of spatial variability in carbon flux across monsoon Asian forests. Agricultural and Forest Meteorology. 232, 623-634.
16. Malhi, Y., Meir, P., Brown, S. 2002. Forests, carbon and global climate. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. 360, 1567-1591.
17. Jones, M.B., Donnelly, A. 2004. Carbon sequestration in temperate grassland ecosystems and the influence of management, climate and elevated CO2. New Phytologist. 164, 423-439.
18. Dennison, M.S., Berry, J.F. 1989. Wetlands. Guide to Science, Law, and Technology Wetlands. Noyes Publications, Park Ridge, NJ, USA, p. 439.
19. Mahmood, R. 2005. Land use change in the Ogallala aquifer region of the Great Plains and its impacts on the long-term temperature. In: 15th Conference on Applied Climatology, Savannah, GA, USA.
20. Law, B. E., E. Falge, L. Gu, D. D. Baldocchi, P. Bakwin, P. Berbigier, K. Davis, A. J. Dolman, M. Falk, J. D. Fuentes, A. Goldstein, A. Granier, A. Grelle, D. Hollinger, I. A. Janssen, P. Jarvis, N. O. Jensen, G. Katul, Y. Mahli, G. Matteucci, T. Meyers, R. Nonson, W. Munger, W. Oechel, R. Olson,

K. Pilegaard, K. T. Paw U, H. Thorgeirsson, R. Valentini, S. Verma, T. Vesala, K. Wilson and S. Wofsy. 2002. Environmental controls over carbon dioxide and water vapor exchange of vegetation. Agricultural and Forest Meteorology. 113, 97-120.

21. Neogi, S., Bhattacharyya, P., Roy, K.S., Panda, B.B., Nayak, A.K., Rao, K.S., Manna, M.C. 2014. Soil respiration, labile carbon pools and enzyme activities as affected by tillage practices in a tropical rice-maize-cowpea cropping system. Environmental Monitoring and Assessment. 186, 4223-4236.
22. Neogi, S., Dash, P.K., Padhy, S.R., Bhattacharyya, P. 2020. Rice Cultivation and Greenhouse Gas Fluxes: Monitoring, Quantification, Adaptation and Mitigation. Modern Concepts and Developments in Agronomy. 5(4). MCDA.000620.2020. DOI: 10.31031/MCDA.2020.05.000620.
23. Smith, P., Nabuurs, G., Janssens, I.A. et al. 2008. Sectoral approaches to improve regional carbon budgets. Climatic Change 88, 209–249. https://doi.org/10.1007/s10584-007-9378-5.
24. Bhattacharyya, P., Karthikeyan, S., Manna, M.C., Bajpai, R.K., Pal, S.S., Srinivas, D., Rao, K.S. and Mohapatra, T .2013a. Soil organic carbon dynamics vis-à-vis anticipatory climatic changes and crop adaptation strategis. CRRI, Cuttack, pp 65.
25. Bhattacharyya, P., Neogi, S., Roy, K.S., Dash, P.K., Tripathi, R., Rao, K.S. 2013b. Net ecosystem CO2 exchange and carbon cycling in tropical lowland flooded rice ecosystem. Nutrient Cycling in Agroecosystems. 95, 133-144.