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Forest Carbon Pools and Global Carbon Cycle

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Abstract
Forest ecosystems store carbon in vegetation and soil, hence are critical in maintaining global carbon cycle. This review highlights the global carbon cycle, forest carbon pools majorly the aboveground biomass carbon and soil carbon, and carbon stocks in Indian forests. Increase in atmospheric CO2 highlights the significance of terrestrial carbon sinks. Biotic and abiotic factors including climate, vegetation, disturbances, and land-use potentially alter the carbon stocks in forest. Approaches like destructive sampling, field inventories, remote sensing, LiDAR and machine learning methods can effectively quantify biomass and carbon. Assessment of carbon pools in forest ecosystems will be helpful in framing sustainable forest management policies and climate-change mitigation.

Keywords: Global Carbon Cycle; Terrestrial Carbon Pool; Aboveground biomass; Soil Carbon

Introduction

Rising temperatures and global climate change are among the major climate challenges of 21st century. Global mean surface temperature reached approximately 1.55°C above the 1850–1900 baseline in 2024, while atmospheric CO_2 concentration increased from approximately 280 ppm in 1750 to 423.9 ± 0.2 ppm in 2024 (IPCC, 2023; WMO, 2025). This is primarily due to the greenhouse gases emissions from fossil fuels combustion, deforestation, land use and management changes. There are five global pools of carbon of which oceanic pool (38000 Pg) (Peta grams = 10 15 g) is the largest, followed by geological comprising fossil fuels (4130 Pg), soil (2500 Pg), atmosphere (760 Pg) and biotic (560 Pg) (Lal, 2008). The terrestrial C pool constitutes a pedological (soil) and biotic pool, estimated at approximately 2860 Pg.

The land use change by conversion of natural to managed ecosystems results in the depletion of terrestrial C pool. Approximately 1.0±0.8 Pg C net carbon is emitted to the atmosphere every year from land use changes (Le Quéré et al., 2015). Forests act as a carbon sink and store approximately 0.98 Pg carbon per year in terrestrial pools (Pan et al., 2024). However, the estimates of net release of carbon from world forests are highly uncertain with approximately 0.76 PgC per year primarily due to forest land conversions, with an overall net release of 0.2 Pg C per year (FAO, 2025a). Monitoring changes in carbon fluxes and pool sizes is essential for tracking human-induced climate change and predicting the future trajectories of the human-carbon-climate system (IPCC, 2023). For the development of viable strategies for mitigating climate change the understanding of global C cycle and its perturbation by anthropogenic activities is required.

Forest biomass and carbon pools

Globally, the forests ecosystems covering about 4.1 billion hectares and act as a major reserve of terrestrial C stock. Forest vegetation and soils contain about 714 Pg C, storing 313.08 Pg C in vegetation biomass and 329 Pg C in soil (FAO, 2025b). Forests play an important role in the global and regional C cycle as they actively exchange terrestrial C with the atmosphere by the processes of photosynthesis and respiration. Forests store large quantities of carbon in vegetation and soil and thus act as a source and sink of carbon depending upon the anthropogenic disturbances, management practices or successional stages (Masera et al., 2003). In a terrestrial ecosystem carbon is stored in five different pools i.e. above ground biomass (AGB), below ground biomass (BGB), litter biomass (LB), woody debris and soil organic matter (SOM) (Meena et al., 2019). The AGB carbon constitutes the maximum to the total ecosystem C stock and considered as the most important and visible C pool (Ma et al., 2024). Any change in land use has a direct impact on AGB.

The BGB is the biomass of all live roots and accounts for 20-26% of the total ecosystem biomass. The detritus pools constituting forest floor litter and dead wood contribute only a small fraction of C to the terrestrial pool and are therefore considered a minor carbon pool (IPCC, 2019).

Aboveground biomass

The above ground biomass is estimated by various traditional approaches. The earlier field measurements of vegetation biomass estimated aboveground biomass as a measure of biomass density (Brown and Lugo, 1982). Subsequently, spatial modelling using aerial surveys of the forest cover, spatial databases of forest and biomass productivity models helps to measure biomass over larger forest areas (Iverson et al., 1993). The use of forest inventories by applying volume equations, biomass expansion factors and density developed by sampling large areas has also been used for biomass estimation (Lal and Singh, 2000). The biomass density was calculated by extrapolating the values of biomass using destructive sampling. Recently, a better approach involving the integration of field measurements with remote sensing, airborne laser scanning (LiDAR), and machine learning models is a more reliable and accurate measure for biomass assessment (Ma et al., 2024; FAO, 2025b).

The biomass and carbon stocks in Indian forests have been estimated using field inventories, remote-sensing and destructive sampling. Early estimates by Tiwari and Singh (1987) in the forest areas of the Himalayan forests of Uttar Pradesh based on aerial photographs and ground survey data, were 137 to 245 Mg ha^{-1} of aboveground biomass. Haripriya (2000) estimated the biomass growing in different forests of India by using forest inventories for volume and estimated 14 to 210 Mg ha^{-1}, with a mean of 67.4 Mg ha^{-1} and 34 Mg ha^{-1} of aboveground biomass and carbon, respectively. Chhabra et al. (2002) estimated the total aboveground and belowground biomass for the year 1992-93 as 6865.1 and 1818.7 Mt (Mt = 10 12 g), respectively. Sheikh et al. (2011) estimated the C stock in India forest biomass during the years 2003, 2005 and 2007 which ranged from 3325 to 3161 Mt, respectively and reported a continuous decrease in the carbon stock in India's forest biomass since 2003, despite a slight increase in forest cover. Forest Survey of India (FSI) made the first attempt in Indian forests to estimate the woody growing stock in 1995 using data of forest cover and forest inventory and thematic maps. FSI estimates forest cover, biomass and carbon across country and various states carbon and monitor the changes over the period. The significant role of forest and tree cover as a terrestrial carbon sink has been recognized in national inventories on greenhouse gases and has recently highlighted that land-use conversions reduce carbon capture from the atmosphere (MoEFCC, 2024). The understory and forest litter contribution to the total ecosystem biomass and carbon is comparatively small as compared to aboveground biomass, although it is a significant pool. Various factors including forest type, stand age, anthropogenic disturbances, and climate change, influence the understory biomass.

Soil carbon

Soil or pedological carbon pools are the second largest and play a critical role in the global climate system (Caddeo et al., 2019). Soils are crucial to the global carbon cycle by serving as a connection between the atmosphere, plants, and oceans. Even slight variations in soil carbon might have a significant effect on atmospheric CO_2. Soils have the potential to store carbon for a very long time, and may either be a sink for CO_2 through carbon sequestration in soil organic matter (Brevik, 2012). Worldwide soil stores approximately 1200 to 1600 Pg up to 1 m depth, with 695 to 930 Pg as soil inorganic carbon (Sahoo et al., 2019).

Forests store vast amounts of carbon in their soil and vegetation, contributing significantly to the global carbon cycle (Joshi and Garkoti, 2025). More than half of the forest soil organic carbon stocks can come from soil that is less than 30 cm deep. Understanding the dynamics of soil carbon is crucial to maintain a balance and prevent the release of carbon into the environment, potentially leading to climate change. The main source for long-term atmospheric carbon storage is the soil carbon pool. The soil provides a medium for short- to long-term carbon storage since it contains more carbon than the atmosphere and all terrestrial vegetation combined. With the repercussions of global climate change, it is critical to appreciate the various mechanisms that lead to the cache of carbon in soils (Mason et al., 2023).

Conclusion

Forests play a critical role in maintaining the global carbon cycle and maintaining terrestrial carbon stocks by storing carbon in vegetation and soil carbon pools. The aboveground biomass is a widely measurable pool and is an indicator for forest carbon storage. Belowground and soil carbon pools are potential carbon pools but are less studied. Recent technologies combining the field studies with remote sensing and machine learning tools have the potential to measure carbon stocks more accurately. Assessment of carbon pools, together with disturbance and land-use information, is therefore essential for accurately quantifying carbon storage, understanding carbon dynamics and developing effective forest-management and climate-change mitigation strategies.

References

Brevik EC (2012) Soils and climate change: Gas fluxes and soil processes. Soil Horizons 53:12–23. https://doi.org/10.2136/sh12-04-0012

Brown S and Lugo AE (1982) The storage and production of organic matter in tropical forests and their role in the global carbon cycle. Biotropica 14(3):161–187. https://doi.org/10.2307/2388024

Caddeo A, Marras S, Sallustio L, Spano D and Sirca C (2019) Soil organic carbon in Italian forests and agroecosystems: Estimating current stock and future changes with a spatial modelling approach. Agricultural and Forest Meteorology 278:107654. https://doi.org/10.1016/j.agrformet.2019.107654

Chhabra A, Palria S and Dadhwal VK (2002) Growing stock-based forest biomass estimate for India. Biomass and Bioenergy 22(3):187–194. https://doi.org/10.1016/S0961-9534(01)00068-X

FAO (2025a) Forest emissions and removals: Global, regional and country trends. Food and Agriculture Organization of the United Nations.

FAO (2025b) Global Forest Resources Assessment 2025. Food and Agriculture Organization of the United Nations, Rome. https://doi.org/10.4060/cd6709en

Haripriya GS (2000) Estimates of biomass in Indian forests. Biomass and Bioenergy 19(4):245–258. https://doi.org/10.1016/S0961-9534(00)00040-4

IPCC (2019) Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use. Intergovernmental Panel on Climate Change.

IPCC (2023) Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Iverson LR, Brown S, Prasad A, Liu D and Grainger A (1993) Carbon sequestration in tropical Asia: An assessment of technically suitable forest lands using geographic information systems analysis. Climate Research 3:23–38. https://doi.org/10.3354/cr003023

Joshi RK and Garkoti SC (2025) Ecosystem carbon storage, allocation and carbon credit values of major forest types in the central Himalaya. Carbon Research 4:7. https://doi.org/10.1007/s44246-024-00159-4

Lal M and Singh R (2000) Carbon sequestration potential of Indian forests. Environmental Monitoring and Assessment 60:315–327. https://doi.org/10.1023/A:1006139418804

Lal R (2008) Sequestration of atmospheric CO_2 in global carbon pools. Energy and Environmental Science 1:86–100. https://doi.org/10.1039/B809492F

Le Quéré C, Moriarty R, Andrew RM, Canadell JG, Sitch S, Korsbakken JI, Friedlingstein P, Peters GP, Andres RJ, Boden TA, Houghton RA, House JI, Keeling RF, Tans P, Arneth A, Bakker DCE, Barbero L, Bopp L, Chang J, Chevallier F, et al. (2015) Global Carbon Budget 2015. Earth System Science Data 7(2):349–396. https://doi.org/10.5194/essd-7-349-2015

Ma T, Zhang C, Ji L, Zuo Z, Mukete B, Hu Y, Li X and Xiao X (2024) Development of forest aboveground biomass estimation, its problems and future solutions: A review. Ecological Indicators 159:111653. https://doi.org/10.1016/j.ecolind.2024.111653

Mason ARG, Salomon MJ, Lowe AJ and Cavagnaro TR (2023) Microbial solutions to soil carbon sequestration. Journal of Cleaner Production 417:137993. https://doi.org/10.1016/j.jclepro.2023.137993

Meena A, Bidalia A, Hanief M, Dinakaran J and Rao KS (2019) Assessment of above- and belowground carbon pools in a semi-arid forest ecosystem of Delhi, India. Ecological Processes 8:8. https://doi.org/10.1186/s13717-019-0163-y

MoEFCC (2024) India: Fourth Biennial Update Report to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change, Government of India, New Delhi. https://unfccc.int/documents/645149

Pan Y, Birdsey RA, Phillips OL, et al. (2024) The enduring world forest carbon sink. Nature 631:563–569. https://doi.org/10.1038/s41586-024-07602-x

Sahoo UK, Singh SL, Kenye A and Gogoi A (2019) Active and passive soil organic carbon pools as affected by different land use types in Mizoram, Northeast India. PLOS ONE 14(7):e0219969. https://doi.org/10.1371/journal.pone.0219969

Sheikh MA, Kumar M, Bussmann RW and Todaria NP (2011) Forest carbon stocks and fluxes in physiographic zones of India. Carbon Balance and Management 6:15. https://doi.org/10.1186/1750-0680-6-15

Tiwari AK and Singh JS (1987) Analysis of forest land-use and vegetation in a part of Central Himalaya, using aerial photographs. Environmental Conservation 14(3):233–244. https://doi.org/10.1017/S0376892900016441

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