Monitoring the Indian tropical carbon flux – need for a holistic approach

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Several studies on the functions and nature of ecosystems, particularly in the tropical rainforest, highlighting rich diversity with high deforestation rates have been found in the global carbon literature. The tropical forests of India and its vulnerable carbon stocks have been inadequately studied. Out of the total land-use change derived global estimated net carbon flux during 1850 and 2000; nearly half were produced from the tropical forests. However, towards the end of the 20th century, the global total carbon flux average decreased to approximately 1.5 Pg C yr^{-1}; the main cause being deforestation within these tropical zones[1]. Tropical forests act as dynamic reservoirs of carbon through sequestration and are thought to reduce global warming through mitigation strategies[2]. On the other hand, carbon dioxide is released into the atmosphere through deforestation and forest degradation. Here, the aim of this article is to highlight the integrated approach of monitoring the terrestrial carbon stock in the Indian scenario.

In the past, various studies have highlighted a net positive sink approximately 1.09–5 Tg C yr^{-1} against small emissions of 0.4–5.65 Tg C yr^{-1} within the Indian forest carbon flux through the sample plot forest inventory and methodologies utilizing the Inter-governmental Panel on Climate Change (IPCC) norms[3–5]. The lesser carbon emissions in India have been highlighted using the district level analysis according to the National Communication (NATCOM)[6]. Intervention through massive plantations within and outside the forests has been the trigger behind these efforts in increasing forest productivity. Correspondingly, a reduction in the rate of deforestation in the 20th century has been another factor, leading to the temporary curbing of increase in atmospheric carbon emission[5,7] since the endorsement of the Forest Conservation Act, 1980. On the other hand, the estimated carbon emissions approximately 0.4 Tg C yr^{-1} from the Indian forests were due to the degradation of the existing forest through overexploitation, loss of natural regeneration, low growing stock, shifting cultivation, fire and overgrazing activities. However, the large differences in the range of the net carbon flux from the Indian forests were due to the estimations utilizing different methodologies with various sources of data and different carbon pools for different years.

Ongoing international research within the tropical zone such as in Barro Colorado Island (Panama), the La Selva Biological Reserve (Costa Rica)[8], Amazonia Basin (RAINFOR)[9] and in the African Tropical Forest (AfriTRON)[10] during the past decades through large plots network encouraged Indian ecologists to set up a 50 ha permanent monitoring plot within the deciduous forests of Mudumalai, southern India in the 1980s[8]. Through this plot, structure (dominant species) and dynamics (patterns of species dispersion, regeneration and mortality) of vegetation have been examined in detail. Monitoring of the RAINFOR and AfriTRON networks have reported increased tree growth rates at stand-level; highlighting more vegetation productivity and a recorded carbon sink effect through the recent re-evaluation of global carbon flux[11]. A common theme of all these studies is the increased resource availability[12] in terms of increased CO_2 levels[13], rise in surface temperature and higher shortwave radiation[14] as the main potential driving factors. In this context, such information on the different mechanisms (responsible drivers) underlying the increase/decrease of forest growth/productivity using plot monitoring in Indian forests have not been studied adequately till date.

Satellite remote sensing data have been used for detecting the changes in tropical forest through spectral characteristics in terms of forest structure, dynamics and productivity (e.g., advanced very high resolution radiometer (AVHRR), moderate resolution imaging spectroradiometer (MODIS)). However, it was noted that increased atmospheric CO_2 fertilization and reduction in vapour pressure deficit (increased water availability to plants) have increased productivity in Indian tropical forests[15]. In addition, several static biogeographical models have been developed in the past to study the global climate – vegetation patterns using palaeoecological data[16]. Regional Climate Models HadRM3 version with BIOME4 in SRES scenarios: A2 (740 ppm CO_2) and B2 (575 ppm CO_2) have predicted large scale alterations of different vegetation types such as a reduction of tropical xerophytic shrubland and expansion of tropical evergreen forest and tropical savanna due to increased rainfall pattern and moderate temperature rise by 2085 (ref. 17). An overall increase in forest productivity was predicted with higher rate amongst the warmer vegetation types mainly due to the CO_2 fertilization effect through light-use, water-use and nutrient-use efficiency concepts. However, inability to simulate the transient phase vegetation responses associated with the Static Models, the Dynamic Global Vegetation Model (DGVM) came into being (e.g. TRIFFID, CLIMBER, LPJ and SHEFFIELD). Using DGVM hybrid-V4.1, through the IS92a Business-As-Usual, the large tropical C_4 grasslands were simulated to be lost to scrub or superceded by C_3 grassland in the 21st century in response to temperature rise, increasing CO_2 and rainfall in the Sahel, India and Australia[18]. As a result, an increase in soil carbon was predicted in northeastern India[19]. Therefore, increased soil and vegetation carbon storage within the Indian tropical forest has been realized.

The advent of the recent issue of the 'tipping point' of the major earth systems including the tropical ecosystems towards the end of the 21st century have highlighted tipping elements notably 'Amazonia dieback effect' and 'greening of Sahara'[20]. Related to this, disturbance in the regular trend of the Indian summer monsoon has been predicted, thus implying more frequent droughts in the near future. Due to this fluctuation, the major forest types of India are predicted to undergo a major change notably dieback of tropical evergreen forest, loss of biodiversity and the extension of the tropical xerophytic vegetation.

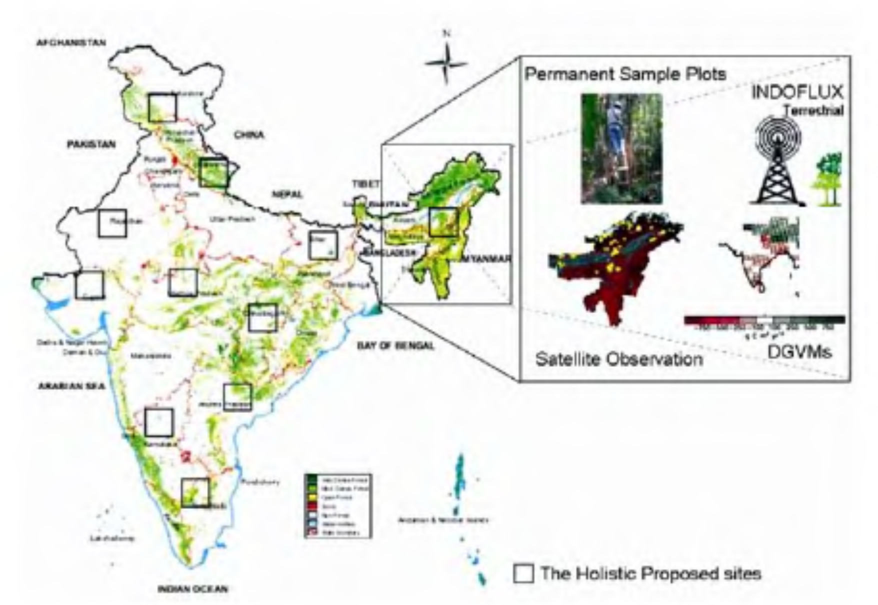

Figure 1. The holistic approach (Forest cover, source: SFR[22]).

Thus, there is a growing realization for the need and importance of the Indian forests in view of the regional–global scenario in a changing environment (increased warming and carbon emissions) initiative through various interventions and methods of capturing the up-to-date information on the forest carbon flux. Replication of the permanent monitoring plot of Mudumalai should be encouraged extensively in synchrony with the INDOFLUX[21] plan covering the different climatic, vegetation and land-use areas of India, viz. temperate conifer-broad leaved forests and tropical moist deciduous forests (northeastern and northwestern India) to temperate mixed forest (northwestern Himalaya) down the tropical dry deciduous forest (Terai belt and Central India) reaching the tropical evergreen forests (Western Ghats), where existing national parks and sanctuaries are the promising sites. This network will provide a strong foundation for studying the Indian tropical carbon flux utilizing plant physiological experiments and long-term monitoring of the species composition, growth, regeneration and mortality of the existing forests. Use of the earth observation resources through ISRO such as IRS-series and WiFs in conjunction with dynamic global vegetation models would highlight the status of different mechanisms of tropical carbon in the Indian context. Additionally, monitoring of the CO_2 movement within land–atmosphere interface using micrometeorological techniques such as the upcoming INDOFLUX would provide an opportunity for cross validation of the dynamics of the carbon flux. Thus, this is such an opportunity for the wider Indian community including scientists, policymakers and advocacy groups to highlight the dynamics of the Indian tropical forests and such a proposed holistic approach (Figure 1) could accurately harness the carbon dynamics of the Indian sub-continent in varying timescales.

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ACKNOWLEDGEMENTS. I thank Dilip Mutum (Warwick Business School, University of Warwick) for fruitful discussions and critical comments. The research was financially facilitated by an Erasmus Mundus (EC) fellowship.

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