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Assessment of spatio-temporal changes in terrestrial carbon sequestration due to Kochi metro rail project in India

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ABSTRACT

Major infrastructure projects can cause sizeable reduction in the urban tree cover thereby affecting terrestrial carbon sequestration potential of cities. This study investigated the spatio-temporal changes occurred in terrestrial carbon sequestration due to the metro rail project at Kochi city in India during the years 2013 to 2015. Normalized Difference Vegetation Index (NDVI) estimated from IRS-P6 LISS IV satellite sensor data was used to detect the tree cover change and for the quantification of carbon stock. An urban carbon storage equation was used to estimate the carbon content from NDVI values. Stock difference approach was used to estimate the change in carbon sequestration due to the construction of metro rail. Results indicated reduction of 14.51 ha of tree cover area within a distance of 60 m from the center-line of metro rail during the study period. Study found that 2316 tCO2e was emitted as a result of cutting urban trees for the metro rail. Such an emission was overlooked while estimating the emission reduction due to the promotion of public transport. This study points to the need for estimating the impacts of major urban infrastructure projects to the global climate in addition to assessing their mostly localized environmental impacts.

1. Introduction

Recent report from the Intergovernmental Panel on Climate Change (IPCC) shows that urban areas are focal points of global energy use and greenhouse gas emissions (IPCC, 2014). Despite the importance of urban areas to climate change and the carbon cycle, there is limited understanding on how urban development processes affect the global carbon cycle and climate. Urban trees which falls under the category of “Trees outside Forests” (TOF) plays an important role in the carbon cycle by being a potential carbon sink (Singh and Chand, 2012). Carbon dioxide (CO_2) sequestration refers to the annual rate of storage of CO_2 in biomass over the course of one growing season. Sequestration depends on tree growth and mortality, which in turn depends on species composition and age structure of the urban forest (McPherson, 1998). The green spaces and tree cover which provide shade, digest the carbon, reduce heat island effect, control storm water runoff, bind the soil apart from various other environmental benefits are rarely valued or quantified over the process of development and densification (Chester et al., 2014). Carbon accounting is an important analytical task that provides baseline information to assist in establishing emissions targets, developing market-based carbon trading programs, and facilitating sustainable carbon management at the regional to international scales (Zhao et al., 2011).

Understanding the relationship between urbanization and urban carbon flows requires intellectual integration with research communities beyond the natural sciences (Romero-Lankao et al., 2014). There is a need to understand what infrastructure choices

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exist for cities to make the transition to sustainable growth trajectories (Camaren and Mark, 2011). Status of urban greenery in some of the Indian cities has been discussed by Chaudhry et al., 2011. Several previous studies have focused on the importance of carbon storage in urban green areas (Merry et al., 2013; Nowak et al., 2013; Pachaiyappan and Ushalaya, 2013; Ramachandra and Shwetmala, 2012; Nowak and Crane, 2002). Urban forests have the potential to sequester substantial amounts of carbon dioxide from the atmosphere and store it in as biomass. However, data on TOF is largely inadequate for any potential assessment of their influence on the carbon dioxide sequestration (FAO, 2010).

Assessing TOF is more challenging than assessing forests, especially due to the variability and heterogeneity of TOF systems, their sparse distribution and limited spatial footprint, and complex ownership and institutional arrangements. Promisingly, satellite remote sensing and Geographic Information Systems (GIS) techniques offers a facility to monitor and analyze vegetation cover over large areas on a routine basis (Roy et al., 2010; Ravindranath and Ostwald, 2008; Dahowski et al., 2001). Substantial body of literature is available on the application of remote sensing and GIS in carbon sequestration assessment (Asdrubali et al., 2013; Haghparast et al., 2013; Jain et al., 2013; Litynski et al., 2013; Singh and Chand, 2012; Helen, 2012; Bijalwan et al., 2010; Wu et al., 2008; Kale et al., 2002; James, 1999). Most of these studies utilized vegetation indices derived based on differential absorption, transmittance and reflectance in the red and near infrared regions of electromagnetic spectrum for the quantitative measurements of biomass or vegetation cover. The normalized difference index (NDVI) is one of such vegetation indices whose utility has been well demonstrated in previous studies (Huete and Liu, 1994; Leprieur et al., 2000). Normalized Difference Vegetation Index (NDVI) is sensitive to the presence of vegetation on the earth's land surface and can be used to address issues of vegetation type, amount and condition. NDVI values derived from satellite measurements could be useful in assessing carbon sequestration and storage potential of urban forests (Myeong et al., 2006).

Infrastructure projects are a major cause for sizeable reduction of urban trees. The impacts of such developments on the carbon cycle are prominent, as the carbon which would otherwise have sequestered by the biomass is now available in the atmosphere. Reduction of urban trees would therefore tantamount to carbon emissions due to infrastructure development and could offset the carbon benefits due to implementation of such a project. The present work analyzed such a scenario for a metro rail project at Kochi city in India. With the implementation of Kochi metro rail project in the city by 2018, it is expected that number of commuters would shift from road transport to metro. This shift is anticipated to reduce the number of kilometers travelled by road and the corresponding fuel consumption, leading to reduction in the associated emissions (CDM Smith, 2013). Present study investigated the spatio-temporal changes occurred in urban tree cover due to the metro rail project in Kochi city in India during the years 2013 to 2015 using IRS-P6 LISS IV (Linear Imaging and Self-Scanning Sensor) data. The NDVI derived from satellite data was used to estimate the difference in carbon stock due to the reduction in tree cover as per IPCC guidelines. The methodology adopted and streamlined in this study is a model for estimating climatic impacts of large scale infrastructure projects. This study is important since state level climate change action plans are being prepared in India (Sahu et al., 2015).

2. Study area

The present study focused on a metro rail corridor in Kochi city, one of the most important port cities situated in Ernakulam district of Kerala, the south-western state of India. In recent years, the city has witnessed heavy investments, thus making it one of the fastest growing second-tier metro cities in India. Kochi city is situated along the Arabian Sea and Vembanad Estuary, which is the largest Ramsar site of southern peninsular India (MoEF, 2007). It lies between 76°9′25″–76°24′28″ E longitudes and 9°47′26″–10°10′38″ N latitudes. The average altitude towards the eastern fringes is about 7.5 m above mean sea level and towards the west the altitude is less than 1 m on an average. Kochi has a wet humid monsoon type of climate. The annual rainfall ranges from 3233 to 3456 mm at different places of the district, most of which falls in months from June to September during southwest and northeast monsoon seasons (Thomas, 2005). The months from February to May are the hottest (summer season in Kerala). December to January months are the coldest. Kochi's maximum temperatures range from 28.9 °C to 32.7 °C and minimum temperatures range from 22.1 °C to 25.4 °C (KMRL, 2014b).

Kochi city is the nerve center of a large urban agglomeration viz., Greater Cochin Development Authority (GCDA) area consisting of Aluva, Kalammassery, Thrippunithura, Maradu, Perumbavoor and Thrikkakara municipalities as well as several panchayats centered around the Kochi Corporation. This region encompasses the majority of the urbanized area, covering 732 km^2 and has a population of 2.12 million (Census, 2011).

The city has undergone tremendous changes both in emission scenario and land use pattern due to urbanization in the recent decade. The total extent of study area was approximately 60 km^2 covering the Kochi metro rail project infrastructure (Fig. 1). The Kochi metro rail project is a major infrastructure development project aimed at resolving the problems due to inadequate transport facilities within the city Kochi metro rail project corridor extends to a length of 27.6 km with 24 stations and a maintenance yard. The major tree species of study area are coconut, teak, golden flamboyant, rain tree, mango and jack tree. Mangalavanam bird sanctuary is located only 1.2 km distance from the metro line and is well known for its rich biological diversity.

3. Materials and methods

3.1. Data

This study used a set of cloud-free IRS-P6 LISS IV (Linear Imaging and Self-Scanning Sensor) image acquired on 26 February 2013 and 16 February 2015 (Table 1). Since both images have been acquired during the summer season in Kerala (Feb–May), they