Digital earth for manipulating urban greens towards achieving a low carbon urban society

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Abstract. Urban greens are integral components of urban ecosystem, contributing towards quality of life and sustainable urban development. Urban greens can help in creating Low Carbon Society (LCS) by playing an integral role through sequestering carbon. India is undergoing significant change in the process and pace of its urbanization. As the growing population becomes more urban, the importance of the way urban areas are developed and managed will be a central point of intervention for addressing climate change and maintaining low carbon trajectories in Indian cities.

While the Government of India has been addressing climate change issues through National Climate Action Plan to achieve sustainable development, there remain major gaps in the climate resilient, low carbon approaches to urban development. There is evidence that urban green spaces can mitigate the impacts of climate change through absorption of pollutants, including greenhouse gases. Hence, green areas play a critical role as carbon sinks and help in achieving low carbon society.

Considering the vast gamut of spatial data used as an input for planning and climate change analysis, the use of geo-information technology is essential. Government initiatives as NSDI and National GIS having sub-components as National Urban Information System and ENV-GIS, as contributors to Digital Earth, focus on use of GIS and related technology for planning, management and development of urban areas with thrust on environment and climate change monitoring to achieve sustainable development. Geospatial technology use has been mainly for creation of base maps and change analysis, which needs to be taken to the next level of its use as a decision-making tool.

This paper attempts to provide a framework for monitoring carbon sinks in urban areas by allowing users to inventorize large, complex spatial datasets. The outcome of such initiative not only integrates geospatial technologies in climate change studies but will bridge the existing information gap and enable in deriving the results about existing carbon sequestration in urban areas for India specific conditions. Furthermore, the results will contribute to a knowledge base, which can be used for planning by city officials and decision makers to build low carbon society as well as by climate change experts.

1. Introduction

Rapid urbanization taking place in Indian cities is putting tremendous stress on natural ecosystems and degrading the environmental quality. India is undergoing significant change in the process and pace of its urbanization. Census of India for 2011, states that number of urban centers have increased by 2,774 since last census (2001) to 7,935 in 2011. As the growing population becomes more urban, the importance of the way urban areas are developed and managed will be a central point of intervention for addressing climate change and maintaining low carbon trajectories in Indian cities. In last two decades, Level of
Urbanization increased from 27.81% in 2001 Census to 31.16% in 2011 Census. Over the last two and half decades spatial growth of cities has often been three-times faster than the growth of population [1]. Urbanization alters the Carbon cycle, and because of the large amount of land covered by urban areas. Despite extensive evidence of the critical role played by urban trees in city environments, urban planners and architects have often undervalued the role played by trees [2].

2. Low Carbon society and Carbon sequestration
Urban greens are integral component of urban ecosystem, contributing towards quality of life and sustainable urban development. Trees in urban systems provide a variety of ecosystems services including biodiversity conservation, removal of atmospheric pollutants, oxygen generation, noise reduction, mitigation of urban heat island effects, microclimate regulation, stabilization of soil, ground water recharge, prevention of soil erosion, and carbon sequestration [3].

Although the main climatic benefits of urban green space is cooling and shading, vegetation particularly trees, counter poor air quality by absorbing greenhouse gases such as carbon dioxide and other air pollutants. Trees take in carbon dioxide during photosynthesis and store carbon. This natural process can be especially effective in reducing affects of pollution by strategically locating different types of trees close to pollution sources. Currently terrestrial carbon uptake offsets roughly one third of global anthropogenic CO2 emissions [4]. Urban greens play an integral role by sequestering carbon for achieving low carbon society as green spaces within cities can act as 'carbon sinks'. Hence the open green spaces become increasingly important when viewed against the backdrop of a changing climate.

The term “urban green spaces” is used in this article as a comprehensive term, comprising all urban parks, forests and related vegetation that add value to the inhabitants in an urban area. The term “urban trees” includes trees growing both within the built environment as well as road-side avenues and public places in urban systems.

International minimum standard suggested by World Health Organization (WHO) and adopted by the publications of United Nations Food and Agriculture Organization (FAO) is a minimum availability of 9 m² green open space per city dweller [5]. The urban green differs in extent across the India. The metropolitan cities are most stressed out in terms of per capita green. A study of 15 metropolitan cities and their per capita green yield the following result.

A city’s carbon performance can be significantly affected by the amount of carbon sequestration within the cities as the amount of carbon sequestered is directly proportional to the quantity and quality of carbon sinks.

3. Current Initiatives by India for terrestrial carbon sequestration
The Government of India addresses climate change issues through National Action Plan on Climate Change (NAPCC) to achieve sustainable development. It must be noted that India does not have a mandate to achieve Greenhouse House Gas (GHG) reduction targets; however as an environmentally conscious nation, initiatives have been taken voluntarily. Under the NAPCC initiative, out of eight Missions the more relevant ones for the greening and urban areas are National Mission for a Green India and National Mission on Sustainable Habitat.

National Mission for Green India specifically addresses the urban areas by laying stress on enhancing green cover in urban and peri-urban areas by 0.20 million hectares in total. The Mission aims at enhancing ecosystem services such as carbon sinks. It builds on the Prime Minister’s Green India campaign for afforestation of 6 million hectares and the national target of increasing land area under forest cover from 23% to 33% [6].

The National Mission on Sustainable Habitat while addressing mitigation and adaptation techniques for urban areas reiterates ‘increasing tree cover - by mandatorily setting aside spaces for plantation at plot level. A new legal category of temporary protected forest can be created to enable afforestation of vacant public lands and enable their protection under the Indian Forest Act and Forest Conservation Act until
such time that they are required for recognized public use. They would enhance groundwater recharge and also provide economic benefits’ [7].

It needs to be highlighted that a void in the planning of the urban areas exists in terms of environmental resilience and particularly with respect to achievement of low carbon scenarios which can be attributed largely to the lack of database. In India for planning urban areas, Urban Development Plan Formulation and Implementation Guidelines are referred to. The Guidelines detail the suggested planning system, planning process, plan approval system, contents of various plans, fiscal, land and manpower resource mobilization, and legislative support needed to achieve effective planning. Apart from lack of database, the focus on planning from environmental perspective needs to be accentuated. The Guidelines only restrict to recommending the area under recreation or green as 15-20% of the total urban area, whereas the emphasis needs to be much more than just the quantum of area under greens.

In India, except for a few cities, urban forests are not well-studied. There are, however, some studies (cited in [2]) on Bangalore ([8-9], [10-11] on urban forest of Vishakapatnam City), Chandigarh ([12-15]) and Delhi [15]. Some studies such as biodiversity and carbon storage are also available for Bhopal [16], Delhi [17], Jaipur [18-19], Mumbai [20] and Pune [21]. A few studies are also available for specific locations within the urban ecosystems, such as NEERI Campus, Nagpur [22] and Indian Institute of Science Campus, Bangalore [23].

Creation of detailed information has been done for the first time for all the urban areas in the state of Gujarat in 2011 with the objective of estimation of number of trees and status of tree cover in the urban areas; to gather baseline information to monitor trend of tree cover; to find out the preferences of tree species; to assess changes in tree cover in future; to assess carbon store and also scope of carbon sequestration, and to develop plans for improving tree cover in the cities and towns.[24]

![Figure 1](source)

**Figure 1.** Estimates on per capita green space in different (million plus) cities of India.
(Source: Computed by Authors based on various data sources).

4. Geospatial information a vital tool
As spatial planners, a link is needed to be created between low carbon society and carbon sequestration potential and this realization is rapidly growing. Across the world and in India Urban land cover/use mapping has received an increasing amount of attention from urban planners and geospatial professionals. A numbers of significant studies have been making extensive use of satellite remote sensing technology and geographic information systems in mapping urban land use/land cover and change analysis.
However, the studies are broadly limited to analysis of the change over two or three periods of time, which needs to be taken to next level of using the information generated to enable decision-making. A low carbon society is not possible without enhancing the carbon sequestration potential and digital technology has a very critical role to play due to the need of huge amount of data required to create a baseline, which can be furthered as an input for decision-making.

Prerequisite for informed decision-making for carbon sequestration potential at urban level needs to include detailed inventory including species composition and distribution of the existing tree cover according to different categories, technological intervention for speed, accuracy and handling data, and categories for carbon sinks within green areas based on types, density, distribution, pattern and intensity.

The modern technology of remote sensing which includes both aerial as well as satellite based systems, allow the collection of physical data, with speed and on repetitive basis, and together with GIS helps us to analyze the data spatially. Complexity of degrading urban environment necessitates use of geospatial technology to resolve urban environmental decisions. However, there is no India specific standardized information system available to quantify the carbon sequestered. Hence, a framework is proposed for integrating technology into the mainframe of climate change planning of urban areas.

5. Suggested Framework
The use of geospatial technology for finding out carbon sequestration potential is already being highlighted by researchers and scientists. Remote sensing images GIS and related geospatial techniques can be used in the estimation of urban greens –

- using remote sensing images and GIS for mapping of the area under greens
- using the ground validation techniques for capturing the detailed information
- using GIS integration, analysis and decision-making

Geospatial technology can be effectively used for creating data on urban forest and tree cover and composition and management and can be used for ecosystem services and monitoring as well. Broadly under the urban forest and tree cover, coverage, location and distribution, potential plantation space including its location and distribution can be determined. This information will be based on the data collated using GIS and remote sensing on aspects as tree density, number of trees, species composition, diameter and size, species diversity, canopy cover and ground cover. Using this base data, over time change in tree cover, species composition and change can be determined. Gradually the data can be fine tuned for analysis as air pollution removal, carbon storage and sequestration, rainfall interception and further scientific analysis.

The advantage of satellite image interpretation in terms of accuracy, timeliness and cost is indisputable in comparison to conventional methods. Using geospatial technologies urban authorities can play a proactive and coordinating role in enhancing urban carbon sinks within cities and leading to low carbon society.

The suggested framework can be well integrated within the existing and to be created geospatial systems as National Urban Information Systems (NUIS) and ENV-GIS of National GIS (NGIS). NUIS is Government of India’s initiatives at building a comprehensive database of the urban areas of the country for the purpose of planning and management of the urban areas and NGIS is a GIS based decision-support system built of GIS infrastructure for all the sectors of the government machinery. If the framework for achieving carbon sequestration is integrated in the NUIS and NGIS setups, the realization of low carbon cities will get well integrated within the planning paradigm.

6. Conclusion
Geospatial technology is capable of extracting urban land cover information with robust results. Satellite remote sensing with repetitive and synoptic viewing capabilities, as well as multispectral capabilities, is a powerful tool for mapping and monitoring the ecological changes in the urban areas. Current use of geospatial techniques for green areas is restricted to state and district level and to change analysis.
However rapid development in city poses several challenges including problems associated with urbanization for urban managers and policy makers especially in terms of urban greens. Meeting the challenges requires access to timely and reliable information. Increasing green cover consciously and monitoring them with the help of geospatial techniques is a win-win situation as green areas have multiple benefits including addressing climate change concerns.

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