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Remote Sensing Application in Carbon Sequestration

Ramya, A., Karthikeyan, G. and Dhevagi, P.*

Dept. of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu (641 003), India

Corresponding Author

Dhevagi, P.

e-mail: devagisivaraj@gmail.com

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E-mail: *bioticapublications@gmail.com*

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Abstract

Perennial vegetation is the most important element in the terrestrial carbon sequestration. Their key role in ecosystem dynamics is well known. However, it is paradoxical that the vegetation has undergone destruction and degradation in the modern times due to industrial and technological advancement achieved by the human society. This advancement has resulted in emission of carbon dioxide. Therefore there is an imperative need to address environmental issues related to them. Trees are important sink for atmospheric carbon *i.e*., carbon dioxide, since 50% of their standing biomass is carbon itself. Importance of forested area in carbon sequestration is already accepted and well documented. Ever green fruit trees, and needle leaf vegetation also have similar carbon sequestration ability as that of forest trees.

Introduction

The standing biomass in India is estimated to be 8,375 mt for the year 1986, of which the carbon storage would be 4,178 mt. The total carbon stored in forests, including soil is estimated to be 9,757 mt. On the other hand, carbon emission from fossil based energy production and consumption activities in India have been estimated at 152-205 mt per year. There are wide differences in the estimates made by different scientist and ecologists. The corresponding estimates from agricultural activities including fuel burning ranges from 43 mt to as high as 115 mt. The current rate of carbon emission from agricultural and forestry sectors are just about being balanced by the current rate of reforestation. This still leaves the entire fossil based emission unabated. About 6 m ha of pasture land can be brought under community forestry and about 9 m ha of cultivable waste lands under short timber plantations, 6 m ha of miscellaneous tree crop and other current fallows lands can be for long timber plantation, 12 m ha of partially degraded areas for natural regeneration and 6 m ha of fully degraded lands for enhanced regeneration. Such a mix of forestry options with land compatibility can enhance the sequestrations potential by 78 mt of additional carbon per year by 2020.

Studies on Remote Sensing Imagery in Vegetation Mapping

Assessing and monitoring the state of the earth surface is a key requirement for global climate change research. Classifying and mapping vegetation is an important technical task for managing natural resources as vegetation provides a base for all living beings and plays an essential role in influencing terrestrial carbon dioxide. In the field of vegetation mapping the most commonly applied sensors include Landsat (mainly TM and ETM+), SPOT, MODIS, NOAA-AVHRR, IKONOS and QuickBird (Figure 1). To estimate the above-ground biomass in tree biomes-temperate deciduous, temperate coniferous and boreal coniferous, LiDAR remote sensing is widely used. LiDAR remote sensing is designed to allow the signal to penetrate the canopy. LiDAR systems send out pulses of laser light and measure the signal return time to directly measure the height and vertical structures of forests. Estimating carbon stocks also done by a high resolution, helicopter-borne 3-dimensional (3-D) scanning LiDAR system.

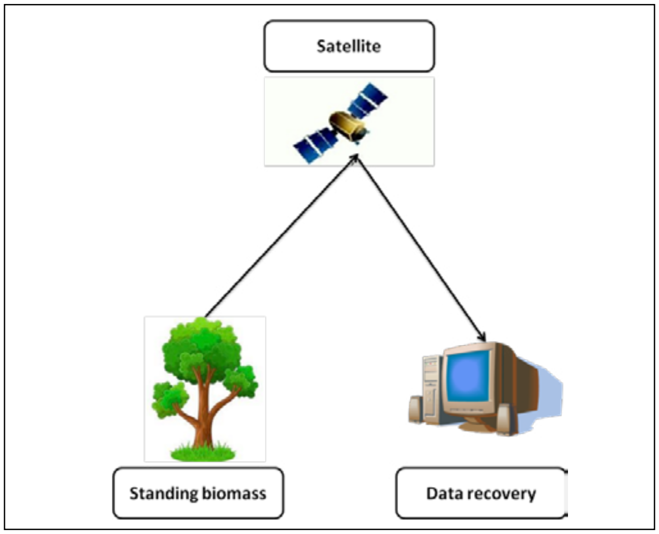

Figure 1: Remote sensing technology for vegetation monitoring

SPOT

The images acquired by SPOT Earth Observation Satellites are useful for studying, monitoring, forecasting and managing natural resources and human activities. SPOT imagery comes in a full range of resolutions from 1 km global scale (SPOT vegetation imagery) down to 2.5 m local scale. Two HRV (High Resolution Visible) imaging instruments on SPOT 1, 2 and 3 and the corresponding instruments of HRVIR (High Resolution Visible and Infrared) on SPOT 4 and HRG (High Resolution Geometry) on SPOT 5 scan in either panchromatic or multi spectral modes. In addition, SPOT 4 and 5 also have a second imaging instrument referred to as SPOT vegetation (VGT) instrument that collects data at a spatial resolution of 1 km and a temporal resolution of 1 day.

SPOT images, particularly SPOT VGT, are very useful for observing and analyzing the evolution of land surfaces and understanding land changes over large areas. Because of the multiple sensor instruments and the revisit frequencies, SPOT satellites are capable of obtaining an image of any place on earth every day and having an advantage of mapping vegetation at flexible scales (regional, national, continental or global). SPOT VGT imagery is very useful to detect large-scale dynamics of environmental changes due to the wide swath and sensitivity of the images to vegetation growth. In addition, SPOT imagery is also effective in monitoring the distribution and growth of particular plants.

MODIS

MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument on board of the terra (EOS AM) and aqua (EOS PM) satellites. Terra MODIS and aqua MODIS together are able to view the entire earth's surface every 1-2 days. The gathered images from MODIS, including 36 spectral bands with spatial resolutions ranging from 250 m to 1 km, are mainly applied to map vegetation dynamics and processes at a large scale. The ETM+ data provided multi spectral data at 30 m spatial resolution is used to map forest types and non-forest vegetation area. The contribution of the forest to carbon sequestration by applying remotely sensed images. Bayesian network is more sensitive to the variation in Leaf area index (LAI) derived from MODIS than to the variation of LAI 3-PG values.

Studies on Vegetation Indices

Vegetation Indices (VIs) are the quantitative measure of biomass or vegetation vigor, usually formed by a combination of several spectral bands, whose values are added, divided or multiplied in order to yield a single value that indicates the amount or vigor of vegetation. A number of vegetation indices have been developed for broad-waveband optical sensors over the last few decades, and can be generalized into three categories:

- Vegetation indices that use only red and NIR spectral bands, including NDVI.
- Vegetation indices that use blue, red and NIR spectral bands.
- Vegetation indices that use NIR and SWIR spectral bands.

Use of MODIS for GPP Estimation and Carbon Sequestration Studies

Satellite remote sensing which estimates gross primary production (GPP) enables evaluation of scientific questions related to environmental degradation and the impacts of pollution and climate change on the global carbon cycle. Estimation of GPP using the moderate resolution imaging spectroradiometer (MODIS) sensor, integrate climate and demonstrated utility at regional, continental and global scales. The MODIS sensor provides near daily coverage of the globe at 1 km resolution in 36 spectral bands using state of the art geolocation, atmospheric correction and cloud screening techniques.

Using the MODIS instrument, foliage characteristic can be determined using visible and near infrared spectral wave length and this is combined with global meteorology and a set of biomass specific parameters, simulates vegetation growth under a range of conditions, and allows the prediction of GPP. A key parameter in the MODIS GPP algorithm is the radiation conversion efficiency max, which varies with different vegetation types and is constrained by sub-optimal temperature and vapor pressure, the variations that limit plant photosynthesis. The MODIS algorithm however does not incorporate other factors, which expressed at local and regional scales can limit plant growth, such as nutrient availability, soil type, and soil water availability (Sakthivel *et al*., 2010).

Satellite remote sensing in combination with spatially distributed carbon cycle model shows promise for monitoring of land-base carbon flux at high spatial (30 mt) and temporal (3-5 years) resolutions. Ground based scaling of GPP has the potential to improve the parameterization of the light use efficiency in satellite based GPP monitoring algorithms. It estimated GPP, using satellite derived enhanced vegetation index (EVI), land surface water index (LSWI), air temperature and photo synthetically active radiation (PAR). Multi-year data analysis have shown that EVI had a stronger linear relationship with GPP that did the normalized difference vegetation index (NDVI).

Forest carbon stock mainly includes vegetation carbon stock, soil carbon stock, litter carbon stock and animal carbon stock. VCSt (vegetation carbon stock) is the carbon content that above-ground vegetation holds. SCS (soil carbon stock) refers to carbon content that soil organic matter (*e.g.*, soil humus) holds. By integrating forest inventory data and soil inventory data into GIS, vegetation photosynthesis method combined with forest biomass method and stem volume method were employed to quantify the VCSi and VCSt, and soil type method was applied to calculate the SCS.

VCSi mainly involves forest CO_2 fixation. In forest ecosystem, plants transform solar energy into biotic energy through photosynthesis, fixing CO_2 and releasing O_2, and mitigating greenhouse gases increase, and it plays an irreplaceable role in maintaining the CO_2/O_2 balance. Based on the forest inventory data, in this study we adopted the photosynthesis method associated with vegetation NPP. NPP, a key component of the terrestrial carbon cycle, represents the net carbon accumulation by the stand and accounts most of the annual carbon fluxes between the atmosphere and biosphere (Anthea *et al*., 2017).

Conclusion

The Remote Sensing and GIS Techniques like Image Classification Techniques, Vegetation Index models and Estimation of above Ground Biomass methods are used for estimating the Carbon Sequestration. Land Use and Land cover Mapping was used for comparison and estimation of carbon sequestration either increased or decreased. Spectrally-based Normalized Difference Vegetation Index (NDVI) and other vegetation indices, derived from RS platforms, are common indicators used to monitor biophysical conditions and vegetation cover. These indices are solely designed to optimize the spectral signatures of vegetation and to minimize the influence of soil reflectance and atmospheric attenuation. Hence, remote sensing and NDVI measurements has potential role in estimating CO_2 sequestration in a particular area.

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