Spatial Model for Estimation of Carbon Stock and Carbon di Oxide Sequestration by Indian Forest through Landsat Imageries

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Abstract— This study discusses about the spatial modelling to assess the total carbon stock and amount of Carbon-di-Oxide sequestrated by forest cover from atmosphere. The software ArcGIS were used to create a spatial model based on modelbuilder utility. The existing regression model and formulas were employed such as above ground biomass, tasselled cap transformation, brightness index, wetness index, below ground biomass, total accumulated biomass, total carbon stock and total carbon di oxide sequestered. These were integrated in model builder utility. Then output toolbox were utilised for further carbon footprint studies.

Key words: Remote Sensing, Landsat, Forest Carbon Stock, ArcGIS, Geoprocessing, Toolbox

I. INTRODUCTION

Since the remote sensing technologies played a major role in wide variety of applications that leverages the efficiency of earth inventory and among one of them is forest studies. The Landsat images are having long records of captured images from 1973(USGS) with difference in spectral, spatial, radiometric and temporal resolutions. Remote sensing images are that captures reflectance and radiance from the earth surface and that were stored as digital numbers. These digitals numbers were calibrated with field data and regression models were calculated (P.S. Roy, 1996). Forest carbon stock was calculated using forest biomass (Westlake, 1963).

The review of literature showed that several methods were developed by different authors for estimating biomass of a trees such as (Brown S et al., 1989) given field based biomass estimation using only the diameter of the trees, (Chaiyo et al., 2011) used tree height and diameter to determine the biomass. (P.S. Roy, 1996) used remote sensing images with integration of field data and developed an allometric models for Indian heterogeneous forests. Carbon stock can be assessed through biomass through which 47 per cent carbon present in the dry biomass reported by (Westlake 1963). ArcGIS is a commercial and leading software in geospatial industry, the main feature includes rich set of scripts, tools, toolset, stability, interoperability and user friendly. This software helps the earth scientists to develop their own tools such as by using python, visual basic and C# languages. So, by using this programming concept the formulas were incorporated and used for further researches.

II. METHODOLOGY AND FORMULAS

A. *Field based Estimation of Biomass*

For attaining tree by tree based estimating of Above Ground Biomass the equation (1) is selected (Chaiyo et al., 2011) which consists for two parameter such as Tree Height and Diameter, Suppose if the Height information not available then equation (2) will be selected (Brown et al., 1989)

Above Ground Biomass (AGB) = 0.0396 x D^2 x H^0.932 - - (1)

Above Ground Biomass (AGB) = 34.4703 – 8.0671D + 0.6589D^2 - - - (2)

Where, ABG measured in Kilograms, 'D' is diameter at breast height in centimetres and 'H' is the height of tree in meters.

B. *Satellite Based Estimation of AGB*

Remote Sensing imageries, especially Landsat image series played a major role in land inventories and among one of them is forest resource monitoring. (P.S. Roy et., al 1996) developed an empherical equation (3) with high correlation coefficient of R^2 = 0.66. This model directly fits to Indian vegetation condition. So, this method is adopted for the study,

ABG (Kg per hectare) = Log_{10} (Y) - - - - - - - - - - (3)

Where Y = 3.7163 – 0.01078*(Brightness Index) + 0.007065*(Wetness Index)

C. *Calculation of Brightness Index (BI) and Wetness Index (WI)*

Process of estimating of Brightness Index and Wetness Index is called Tasselled Cap Transformation (TCT). Where multiple bands were compressed based on the spectral fit and results to meaningful Information. Initially (Crist, E.P 1984) developed TCT for Landsat TM, Later on (Chenquan H , 2002) developed TCT for Landsat ETM+ and recently (M.H.A Baig, 2014) developed TCT for Landsat 8 OLI Series, The coefficient were given in Table 1

		Band 1	**Band 2**	**Band 3**	**Band 4**	**Band 5**	**Band 7**
Landsat 5 TM	**Brightness**	0.3037	0.2793	0.4743	0.5585	0.5082	0.1863
	Wetness	0.1509	0.1973	0.3279	0.3406	-0.7112	-0.4572
Landsat 7 ETM+	**Brightness**	0.3561	0.3972	0.3904	0.6966	0.2286	0.1596
	Wetness	0.2626	0.2141	0.0926	0.0656	-0.7629	-0.5388
		Band 2	**Band 3**	**Band 4**	**Band 5**	**Band 6**	**Band 7**
Landsat 8 OLI	**Brightness**	0.3029	0.2786	0.4733	0.5599	0.508	0.1872
	Wetness	0.1511	0.1973	0.3283	0.3407	-0.7117	-0.4559

Table 1: Tasseled Cap Transformation Coefficients for Landsat bands
Source: Crist E.P (1984), Chenquan H (2002) and M.H.A Baig (2014)

$$TCT(\text{Brightness or Wetness}) = \sum(\text{Band}_{ith} * \text{Coefficient of Band}_{ith}) \text{ - - - - - - - (4)}$$

D. Estimation of Below Ground Biomass (BGB)

To estimate Below Ground Biomass, equation (5) is selected (MacDicken et al., 1997), which if the AGB is 100 per cent then the BGB would be 15 per cent. So, the Satellite Derived AGB is multiplied by 0.15.

BGB in Kg per hectare = 0.15 * AGB - - - - - - - (5)

E. Calculation of Total Accumulated Biomass (TAB)

Total accumulated biomass was found by adding above ground biomass and below ground biomass as shown in equation (6).

TAB in Kg per hectare = AGB + BGB - - - - - - - - (6)

F. Computation of Total Carbon Stock (TCS)

Westlake (1963) was reported that there is 47 per cent carbon present in the dry biomass and Takimoto et. al (2008) demonstrated 50 per cent of Carbon were present in dry biomass. So, study followed Westlake, and Total Carbon stock is obtained by equation (7).

TCS in (Kg Carbon per hectare) = 0.47 * TAB - - (7)

G. Determination of Amount of CO2 Sequestration (ACS)

Using chemical equations for converting carbon di oxide to carbon, the amount of carbon di oxide sequestrated were calculated using equation (8)

CO_2 Sequestration = 3.67 * TCS - - - - - - - - - - (8)

III. RESULTS

The result was shown in fig: 2, Executed Spatial Model showing window to assess carbon stock and carbon sequestration using Landsat 8. This study also created Geoprocessing toolbox for Landsat 5 and Landsat 7 imageries

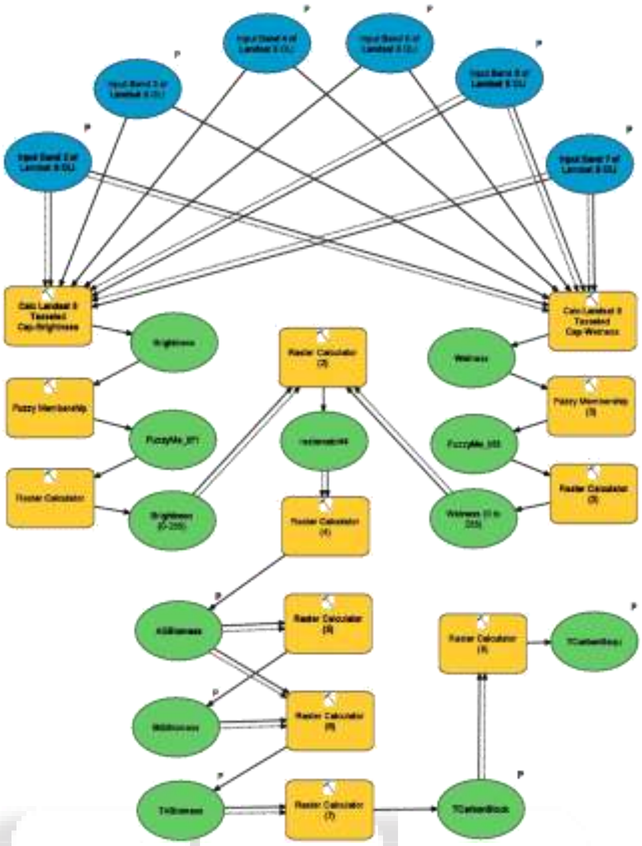

Fig. 1: Landsat 8 Spatial Model flowchart for Carbon Stock and Carbon Sequestration Tool

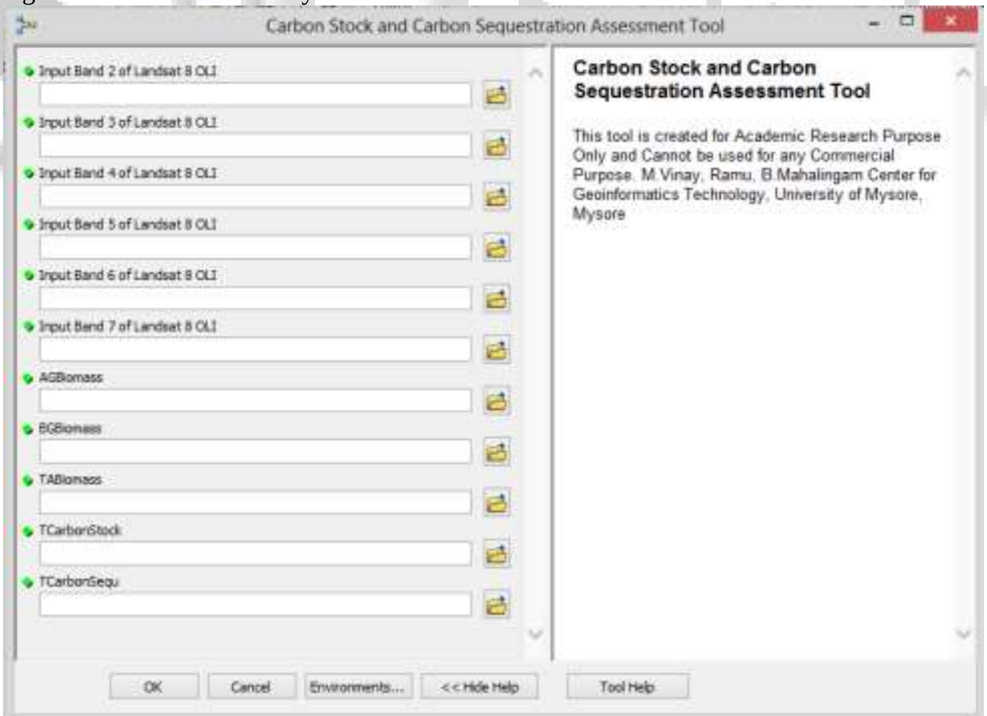

Fig: 2: Executed Spatial Model showing window to assess carbon stock and carbon sequestration using Landsat 8

IV. CONCLUSION

This research is conducted to develop a graphical user interface to calculate forest carbon stock and carbon di oxide sequestrated using ArcGIS spatial modeller. The study used Landsat imageries and existing regression model and formulas of above ground biomass, tasselled cap transformation, brightness index, wetness index, below ground biomass, total accumulated biomass, total carbon stock and total carbon di oxide sequestered. These were integrated in model builder utility to develop new

Geoprocessing toolbox to run within ArcGIS environment. The result from this model can be used for further studies.

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