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Development of "Biomass-Infosys" Tool for Above Ground Biomass Estimation Using Geo-Informatics

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Abstract The important processes interacting between biosphere and atmosphere like Carbon cycle, CO_2 storage capacity of an ecosystem etc. are much affected by the plant life and its biomass. But, while estimating the spatial extent of the biomass, the common method of ground estimation of biomass is found deficient. Traditionally biomass estimation involved harvesting of the trees which also contributes to the everlasting problem of forest depletion. In this context, the necessity for non-destructive method like satellite remote sensing data which can be obtained as frequently as required to provide information for determination of quantitative and qualitative changes in biomass in the accessible as well as inaccessible areas needs to be encouraged. The biomass estimation process from satellite data uses calculation of Tasseled Cap brightness index (BI), and wetness index (WI) method which involve long and tedious calculation. In this study an attempt has been taken to develop a tool "Biomass-Infosys" using C# (Microsoft Visual Studio 2008) in Arc Object programming which generalizes the Biomass estimation process from satellite remote sensing images. Using this tool Tasseled Cap brightness index (BI), and wetness index (WI) can be calculated with a single click and also Carbon content and Carbon dioxide content will be estimated. The tool has been tested with some example data and its efficiency has also been examined.
Keywords *Biomass; Brightness Index (BI); Wetness Index (WI); Land Sat TM; Arc Object*

1. Introduction

Broadly, biomass comprises of two categories, above-ground e.g. trees, shrubs, vines etc and below-ground like roots, the dead mass of litter associated with soil etc. Majority of the R & D activities related to biomass estimation consider above-ground biomass (AGB) only because of the complexity associated with data collection on below-ground life forms (Dengsheng, 2006). The name, AGB is mostly acquainted with biomass energy like fuel energy that can be extracted directly or indirectly from bio- resources. The quantification of biomass is essential as principal inventory information to evaluate the productivity dynamics of vegetation (Esser, 1984). Conventional process of biomass estimation includes harvesting of vegetation which is a destructive method. But, with intensifying concern over forest conservation and protection the need for non-destructive method also arises (Kale *et al.*, 2002). Remotely sensed satellite data can be used effectively to estimate biomass in non-destructive way using image processing techniques. In this study, we used the formula given by Roy and Shirish (Roy and Shirish, 1996), which also require calculation of Wetness Index (WI) and Brightness Index (BI) following the formulae given by Crist. *et al* (Crist. *et al.*, 1986). This is manual method of image processing and is very tedious owing to the long and complex formulated calculations. The details formulae are mentioned in the methodology section below. But, without in dept knowledge in image processing, the steps of image processing are quite tough and time consuming.

The recent advancement in Geoinformtics technology plays a significant role in developing a customized solution for any kind of spatial and non spatial information or data. Arc Object desktop programming is a module in Arc GIS which enables to create and integrate a customized tool according to requirement of the user. In this study, we attempted to develop a tool named as “Biomass-Infosys” using the most recent programming language C# (Microsoft Visual Studio 2008) to calculate Biomass, Carbon content and Carbon Dioxide and eventually eliminate the tedious job of mathematical calculation of raster data. The “Biomass- Infosys” tool is based upon DLL (Dynamic Link Library) technology which is based on open structure technology. With open structured DLL technology it is possible to pass object from DLL to ArcMap. The developed DLL files are written using command line in a way to interact directly with ArcGIS (Nejatbakhsh, 2008) to work as customized tool. In this study we also attempted to verify the tool using example data. The example study area falls in Watershed codes BRML106 (Brahmaputra Lower 106).

The area contains parts of Kamrup district, Darrang district and East Khasi hills in Maghalaya. The extent of the study area is approximately 1500 sq km. The base map of the study area was prepared by digitizing all the features like boundary major river, road, railways and permanent features as shown in Figure 1. The watershed is drained by several rivers like Khunda Jan, Bar Nadi, Mora Nadi, Barpani Nadi, Bukat Nadi, Digaru river, Bardong Nadi, Brahmaputtra, SokhajaNadi, Kalhog river, Um Sen, Puthimari Nadi, Kurijani Nadi, Um Tashu, Um Tri, Um Bhanga, Um tru, Um pri etc.

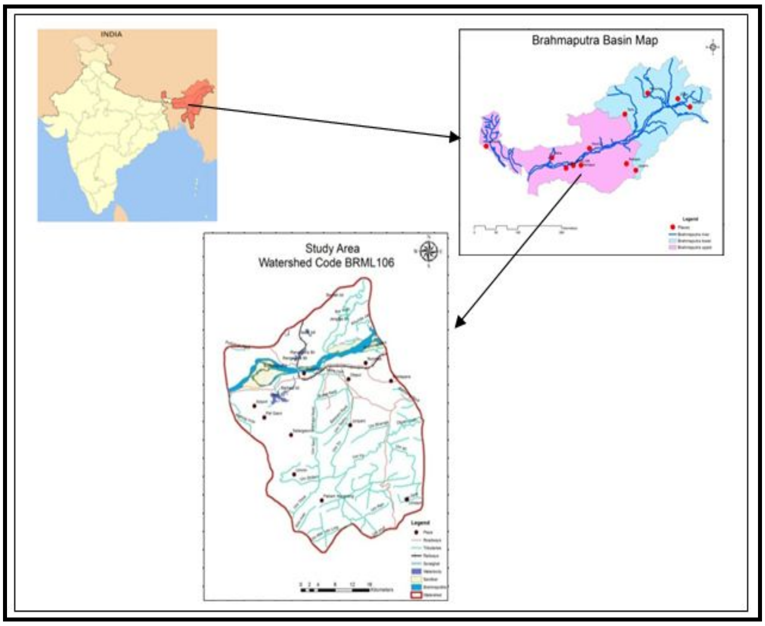

Figure 1: *Base Map*

2. Materials and Methods

2.1. Data Used

The top sheets, watershed atlas and published maps were the source for delineation of the watershed. LANDSAT TM Satellite image of 2010 was used.

2.2. Software

Arc GIS 9.3 was used for vectorization, thematic database generation and analysis. Microsoft Visual studio 2008 was used for Arc Object Desktop customization and development of “Biomass-Infosys”. The codes were run on Arc GIS 9.3 platform for raster analysis.

2.3. Methodology

2.3.1. Formulae Used

The formula for calculating Wetness Index (WI) and Brightness Index (BI) includes:

$$BI = .2909 \times (TM1) + .2493(TM2) + .4806 \times (TM3) + .5568 \times (TM4) + 4438 \times (TM5) + .1706 \times (TM7) \quad (1)$$

$$WI = .1446 \times (TM1) + .1761 \times (TM2) + .3222 \times (TM3) + .3393 \times (TM4) - .6210 \times (TM5) + .4186 \times (TM7) \quad (2)$$

Where TM1, TM2, TM3, TM4, TM5, and TM7 are Blue band (Band1), Green band (Band2), Red band (Band3), NIR band (Band4), MIR band (Band5) and FIR band (Band7) respectively.

The expression for BI and WI was used from the published work by Crist. *et al.* (Crist. *et al.*, 1986).

Biomass was calculated using the following formula:

$$\text{Log}_{10}y = 3.7163 - .01078 \times BI + .007065 \times WI \quad (3)$$

Where ‘y’ is biomass (kg) (Roy and Shirish, 1996).

Carbon content has been calculated using the following formula:

$$\text{Carbon content (C)} = \text{Biomass(y)} \times .5 \quad (4)$$

Carbon Dioxide content has been calculated using the following formula:

$$\text{Carbon Dioxide equivalent } (CO_2) = \text{Carbon content (C)} \times 3.6667 \quad (5)$$

Equation 5 and 6 are from Canada’s model forest program (2000) (Canada's Model Forest Program, 2000).

2.3.2. Development of “Biomass-Infosys”

Biomass information system “Bio-Infosys” tool was developed from Arc Object programming(C#) which is shown in Figure 2.

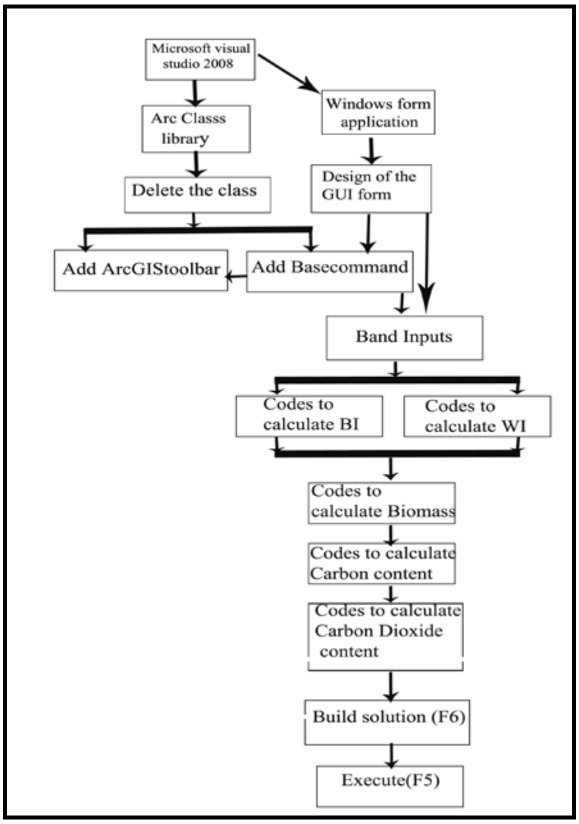

Figure 2: *Flow Chart for "Biomass-Infosys" Tool Development*

2.3.2.1. Connecting ArcGIS with Microsoft Visual Studio 2008

To customize ArcGIS 9.3 through Microsoft Visual Studio 2008 an extension of Arc GIS 9.3, Arc SDK.exe needs to be installed. It will enable to customize Arc GIS 9.3 under Microsoft Visual studio 2008.NET(C#) environment.

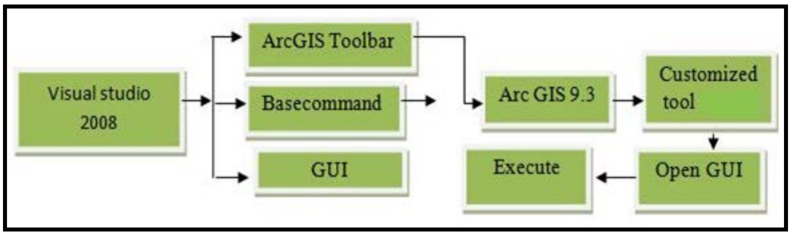

Figure 3: *Flow Chart for "Biomass-Infosys" Customization*

2.3.2.2. GUI & Base Command

GUI stands for Graphical User Interface is an interface that helps the user to understand the complex matter in a generalized form. The quality of the user interface (UI) has a great bearing on the utility of a GIS. Thus, the UI is one of the strong points of GIS. To increase the efficiency of GIS, the UI must provide a simple conceptual model of what is happening to the database (Collins *et al.,* 1983). The UI should not launch complex algorithms or data structure etc to the users. Instead, it should be effortless to understand, appear natural. In order to do that, UI should be programmed to appear as a user friendly arrangement for the users not as complex collection of algorithms (Driver and Liles, 1983).

The combination of graphical representations as well as non-programming users can be beneficial for both GIS software and application program designers. The algorithmic processing of the data can better be understood by the programmers interacting with the GUI representation of their data (Boecker *et al*., 1986). Both the beginners and expert programmers can think about what a program executes as well as the procedure of execution through writing codes, testing and debugging. GUI representation of the algorithms applied to the data structures of great use. Data flow diagrams have been automated and animated using GUIs to demonstrate the internal execution of programs and are helpful for both designing tool and documentation mechanism. For this study purpose the GUI for "Biomass-Infosys" (Figure 4) is created with the option for the input of the required bands as well as the directory of the input bands are displayed in the text boxes nearby each band name. To execute the interface with ArcGIS toolbar appropriate codes are essential and that can be written in Arc GIS base command under over ridden class.

Tool "Biomass-Infosys" includes calculation of Brightness Index (BI) and Wetness Index (WI) and estimation of biomass which requires application of raster math. Finally Brightness Index, Wetness Index (WI) and Biomass are displayed in ArcGIS and are also saved in specified directory in .img format.

For "Biomass-Infosys" tool the references required are added through Arc class library. The basic reference required is ESRI.ArcGIS.GeoAnalyst, ESRIArcGIS.SpatialAnalyst, ESRI.ArcGIS.Carto, ESRI.ArcGIS.Geodatabase, ESRI.ArcGIS.Geo.Analyst, ESRI.ArcGIS.SpatialAnalyst, ESRI.ArcGIS. DataSourcesRaster, ESRI.ArcGIS.Carto, ESRI.ArcGIS.Geodatabase, ESRI.ArcGIS. DataSources Raster, ESRI.ArcGIS.ArcMapUI, System.Runtime.InteropServices, System.Windows.Forms.

As the next step ArcToolbar and Basecommand options are created. The Basecommand is called in the ArcToolbar option by calling the Program ID of Basecommand in ArcToolbar. The codes to execute "Biomass-Infosys" tool is written inside overriden class of Basecommand. The Arctoolbar is created to call the codes written to execute "Biomass-Infosys" tool through Basecommand. The "Biomass-Infosys" tool has been tested using example data as mentioned above.

4. Results and Discussion

a. Creation and designing of GUI (Figure 4). The GUI is used to input the bands (Band 1 to Band 5). This is a user friendly interactive interface which will guide the users to select proper band and displays the directory of input bands and output indices.

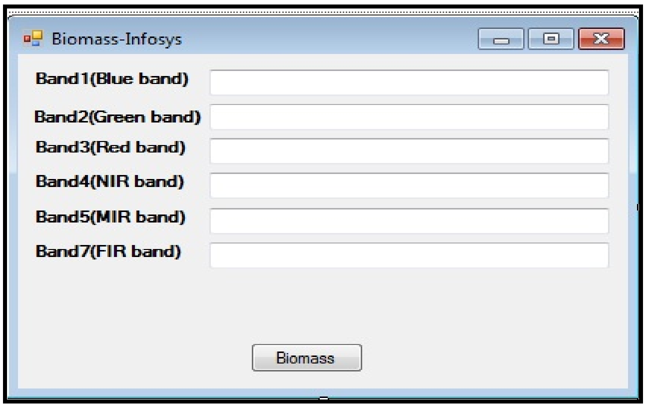

Figure 4: *GUI Created for "Biomass-Infosys" Tool*

b. Writing code in Microsoft Visual Studio 2008 for display of the input bands, calculating, saving and displaying AVI, BI and SSI in ArcGIS and execution of ArcGIS using Microsoft Visual

Studio 2008 (Figure 5). On successful debugging, ArcMap.exe has been executed and ArcMap opens.

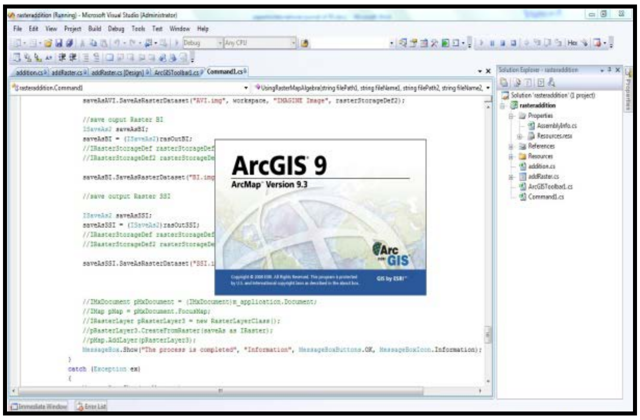

Figure 5: *Execution of ArcGIS using Microsoft Visual Studio 2008*

c. Adding the new tool "Biomass-Infosys" to ArcGIS 9.3 (Figure 6). The new tool "Biomass-Infosys" may not be directly visible. To display it in the ArcGIS toolbar, it needs to be enabled from View tab and then Toolbar option.

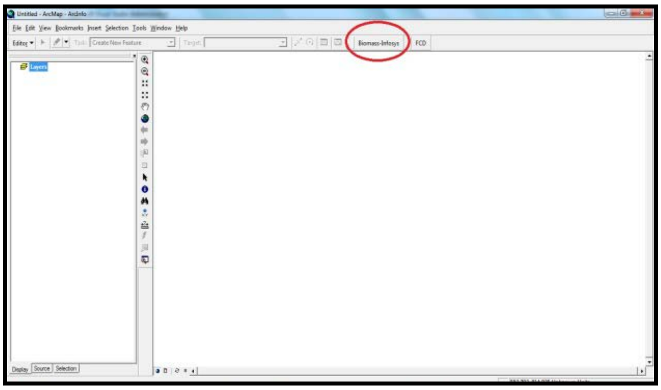

Figure 6: *Adding the new Tool "Biomass-Infosys" to ArcGIS 9.3*

d. Execution of GUI using ArcGIS (Figure 7). After displaying the "Biomass-Infosys" tool in toolbar, when it is clicked it executes and displays the GUI mentioned above.

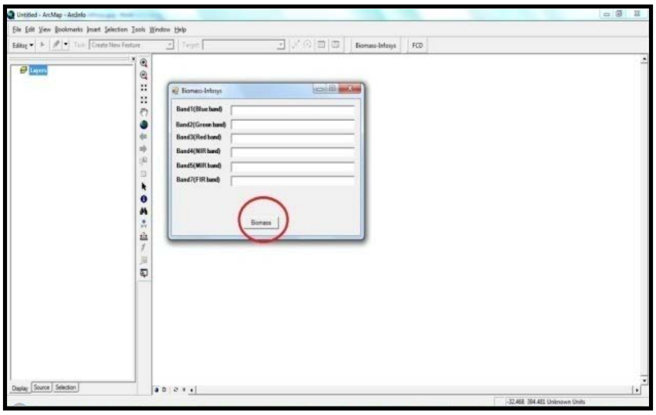

Figure 7: *Execution of GUI "Biomass-Infosys" Using ArcGIS*

e. Information box asking the user to input Band1 (Blue Band) (Figure 8). An information box will appear asking the user to give input for the Band 1.

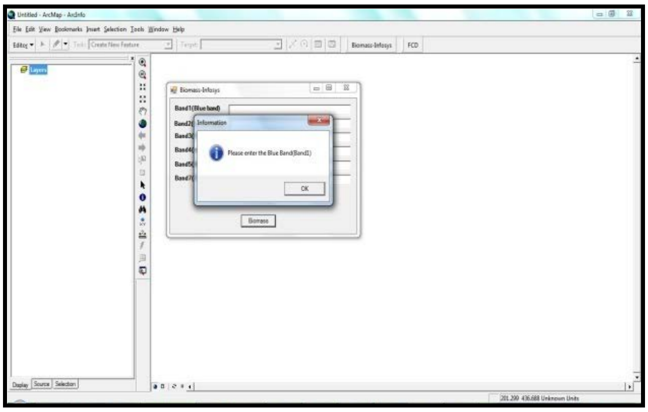

Figure 8: *Information Box Asking User to Input Band1 (Blue Band)*

f. Browsing window for Band1 (Blue Band) selection (Figure 9). On clicking the "ok" button browsing window will appear where the user can select required band and the directory of the input band appears in the textbox in the GUI adjacent to respective bands.

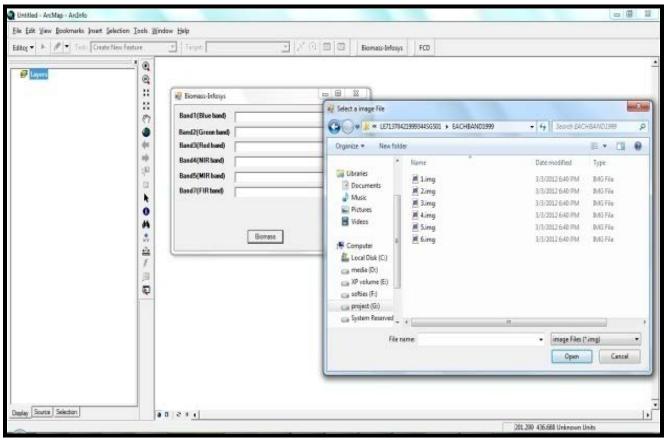

Figure 9: Browsing Window for Band1 (Blue Band) Selection

g. The directory of Band1 (Blue band) displayed in the text box.

h. The input for all the 6 bands are given as mentioned in step 7, 8 and 9.

i. When all the band inputs has been given, processing starts and WI, BI and biomass has been calculated and shown in TOC and displayed in ArcGIS (Figure 10).

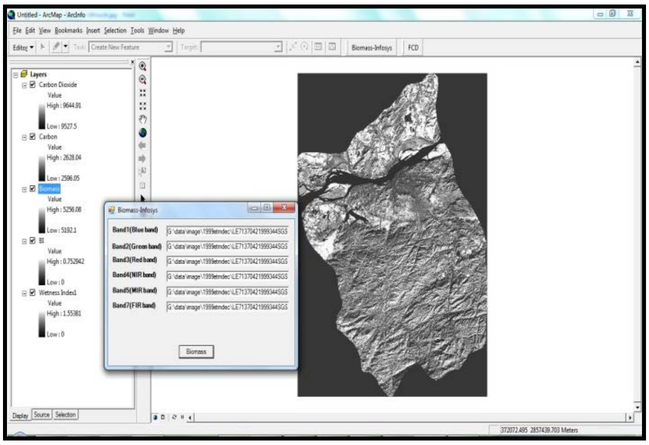

Figure 10: *Displayed in ArcGIS*

The developed tool “Biomass-Infosys” has been applied on example data which is a watershed boundary named as BRML106 (Brahmaputra Lower 106). The LANDSAT TM data for the year of 2010 has been collected from Earth Explorer (*earthexplorer.usgs.gov).* As a part of Pre-processing, each of the 7 bands has been subsetted using the boundary of the watershed (BRML 106). The subsetted 7 bands are processed using “Biomass-Infosys” tool.

WI and BI, Biomass, Carbon content and Carbon Dioxide have been calculated for the year of 2010 using “Biomass-Infosys” tool. The biomass estimation maps for the year of 2010 are shown in Figure 11.

The minimum and maximum quantity of Biomass observed for the year of 2010 is .33 t hac^{-1} and 271.44 t hac^{-1} respectively (Figure 11). It is estimated that in Guwahati region the amount of biomass is approximately 19 t hac^{-1} for the year of 2010.

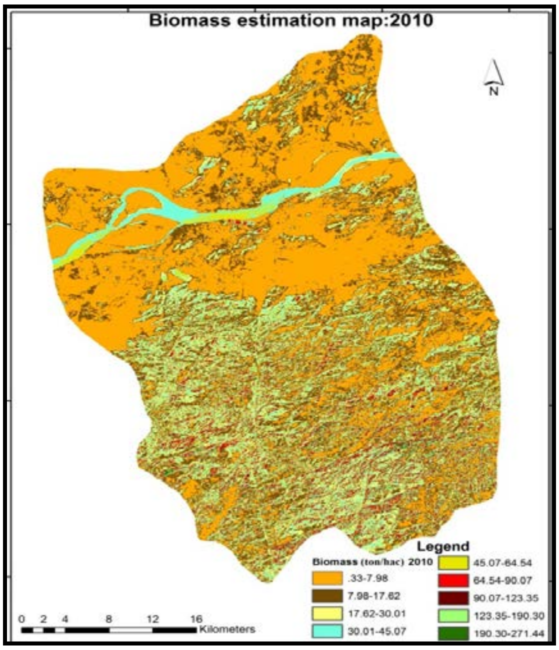

Figure 11: *Biomass Estimation Map – 2010*

It is estimated that in Guwahati region the amount of carbon content is approximately 8 t hac^{-1} for the year of 2010 (Figure 12). The carbon content of Pabam Nongrang region is observed as very low as it is estimated at 24 t hac^{-1} for the year of 2010 and some patches towards south of Umdam is classified with moderate carbon content as the carbon content estimation is approximately 120 t hac^{-1}.

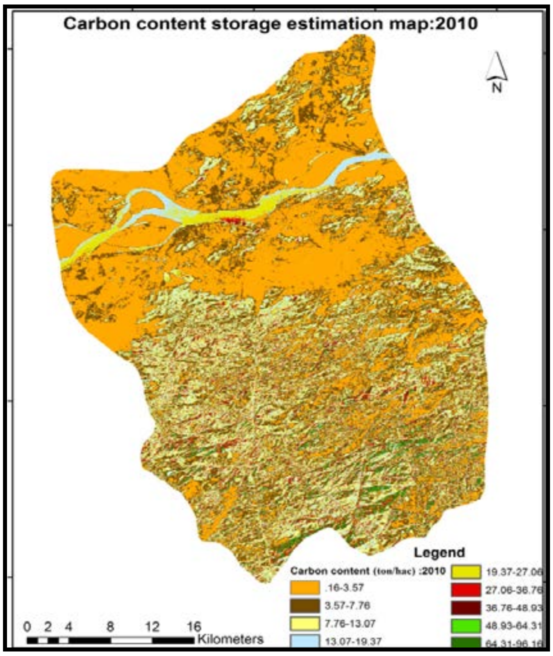

Figure 12: *Carbon Content Storage Estimation-2010*

Figure 13 shows the Carbon Dioxide storage estimation for the year of 2010.The minimum amount of Carbon Dioxide storage estimated as 0.60 t hac^{-1} and maximum amount of Carbon Dioxide storage as 498.09 t hac-^{1} for the year of 2010. It is observed that in Guwahati region the amount of Carbon Dioxide storage is approximately 32.7 t hac^{-1} for the year of 2010. The Carbon Dioxide storage of Pabam Nongrang region is observed as very low as it is estimated 40 t hac-1 for the year of 2010. The Carbon Dioxide storage is high towards the south of Umdam as the estimation is approximately 440.4 t hac^{-1}.

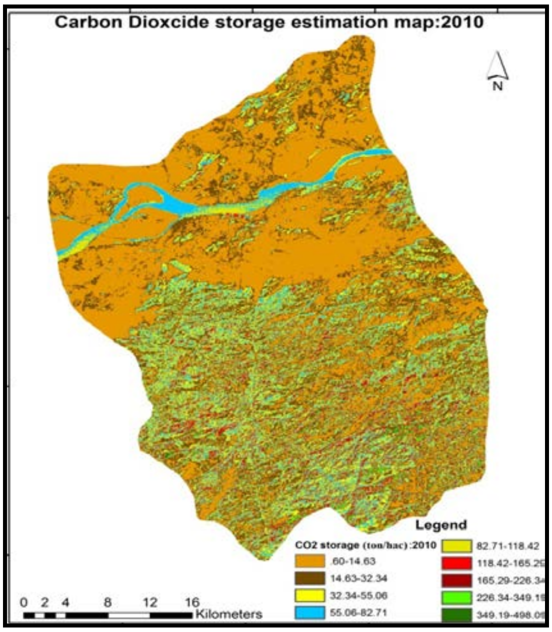

Figure 13: *Carbon Dioxide Storage Estimation- 2010*

5. Conclusion

From the biomass study the amount of stock of biomass is predicted. Comparatively area which is less disturbed is having high biomass. This study provides a tool named as “Biomass-Infosys” for eliminating the exhaustive manual procedure for biomass estimation. It is clearly understood that this tool can be effectively be used in biomass estimation with single click. The analysis part for calculation of Biomass, Carbon content and Carbon Dioxide was done effectively with “Biomass-Infosys” tool, whereas the reclassification and map layout part only was carried out with Arc GIS 9.3 predefined tools. A rough comparison was made between the time required to compute Biomass, Carbon content and Carbon Dioxide manually using models in ERDAS 9.2 and raster calculator in Arc GIS 9.3 and the time requirement to calculate the same using “Biomass-Infosys”. The time required for ordinary process was approximately 4-5 hrs whereas the same is only 30 minutes to 1 hr only in case of “Biomass-Infosys”. This gives an idea about the effectiveness of the tool. So, coding with Arc Object for generating customized tool for Arc GIS may be good solution for shortening the lengthy steps and same tool can be used repetitively to get output in the quickest possible way.

Limitation and Recommendation

Coding with Arc Object requires good bundle of knowledge on programming language which is not a primary objective of most of the Institutes offering GIS courses in India. As, a result the use of capabilities of Arc Object customization is still not popularized in India which needs to be addressed very soon.

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