Assessment of Carbon Stocks in Shifting Cultivation Lands A Case Study of Nagaland State of India

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Abstract

Shifting cultivation is one of the earliest forms of agriculture system and dates back to about 7000 B.C. when man began to change its mode of life from food gatherers and hunters to cultivators. Shifting agriculture involves clearing a patch of forest land, but retaining useful trees and plant varieties, cultivating it for two to three years and then abandoning it for 10-20 years to allow the natural forest to grow back and the soil to regain its fertility. In India, the people of eastern and north-eastern region practice shifting cultivation on hill slopes. Author has identified the areas under shifting cultivation using the ResourceSAT LISS-III satellite imagery and ESRI ArcGIS 10.1 Software with Image Classification extension. The total land area under shifting cultivation in Nagaland state is 2239.85 Kms^2 in 2003 has increased to 2630.39 Kms^2 in 2012. The estimated carbon stocks in shifting cultivation land is 1.12 million tons of carbon in 2003 has also increased to 1.31 million tons of carbon in 2012.

Keywords: Forest Biomass, Carbon Stocks, Remote Sensing, and Nagaland state

Introduction

The accumulation of CO_2 in the atmosphere due to fossil fuel use, deforestation and other anthropogenic sources are changing the global climate *(Harries et al., 2001; IPCC 2002)*. Current understanding of the global carbon cycle suggests that managing forests to increase the sequestration of carbon provide credible policy options *(Dixon and Turner, 1991)*, *(Winjum et al., 1993)*, *(Brown, 1996a)*, *(Brown et al., 1996b)*. In the Northern Hemisphere, forests are estimated to sequester up to 700 million tons of carbon annually *(Goodale et al., 2002)*, which is nearly 10 per cent of current global fossil fuel carbon emissions *(IPCC, 2007)*. Sustainable forest management aimed at maintaining or increasing forest carbon stocks could generate the largest sustained mitigation benefits *(Nabuurs et al., 2007)*.

Shifting cultivation is a very primitive form of agriculture, which is believed to have originated in the Neolithic period around 7000 B.C. *(Subhramanyam and Sambamurty, 2000)*. Shifting cultivation, locally referred to as Jhum, is the main form of agriculture, most suitable for the state's climate conditions and steep terrain. The north eastern state Nagaland of India faces a major challenge in adapting land use and production systems to meet rising populations and

changing lifestyles, while also maintaining its ecological sustainability. The sinful effects of shifting cultivation are devastating and far-reaching in degrading the environment and ecology of these regions. The earlier 15-20 year cycle of shifting cultivation on a particular land has reduced to 2-3 years now. This has resulted in large-scale deforestation, soil and nutrient loss, and invasion by weeds and other species. The indigenous biodiversity has been affected to a large extent.

Agriculture expansion due to increasing population has been regarded as one of the primary causes of deforestation and a major source of carbon emissions form terrestrial ecosystems. Due to increased population pressure and decreasing land holding in the hilly areas of Northeast India shifting cultivation has seen a drastic change. The fallow period has decreased so much so that the vegetation doesn't get enough time to reestablish. The length of the fallow phase between two successive cropping phases in shifting cultivation practice have come down to even two to three years in Nagaland. This has been seen as a driver of deforestation and has been presumed to be an important contributor of emissions.

Very few studies has been attempted to quantify impacts of shifting cultivation on forest losses and carbon cycle in context of the global change debate *(Zhang et. al 2000)*. Therefore it becomes extremely important to assess the effects of shifting cultivation on carbon stocks in order to formulate effective policies to develop resilience of the communities and sustainable land use in the shifting cultivation areas of the world. This study aiming at understanding the carbon stocks and dynamics of shifting cultivation lands is proposed in Nagaland because Nagaland consists of 11.57 % of all total land under shifting cultivation in the state. Therefore the proposed study assumes importance from both tropical forest conservation and global climate change point of view.

Objectives

The main objectives of this study area: assess terrestrial biomass and soil carbon stocks in lands under shifting cultivation under different fallow regime, Assess carbon emissions from shifting cultivation lands (biomass burning and biomass decomposition) under different fallow cycle, Study the effects of fallow restoration and management practices on carbon sequestration potential of such lands, and assessment of carbon stocks in shifting cultivation lands for year 2003, and 2012 by using ResourceSAT LISS-III satellite imagery and ESRI ArcGIS-10.1 software with image classification extension.

Study Area

Nagaland is one of the eight North-Eastern Hill states in India, located between 25°10' N and 27°4'N Latitude and 93°15'E and 95°20'E Longitude with a total geographical area of 16,579

Kms^2 in the northern extension of the Arakan Yoma ranges (Fig. 1). The state shares a long international border with Myanmar in the East and is bounded by state of Assam in the west and north, Arunachal Pradesh the North and Manipur in the south. The Naga Hills rise from the Brahmaputra Valley in Assam to about 610 m and rise further to the southeast, as high as 1,800 m. Mount Saramati at an elevation of 3,826 m is the state's highest peak; this is where the Naga Hills merge with the Patkai Range in Burma. The state of Nagaland is drained by four chief rivers of Doyang, Jhanji, Dhansiri and Dikhu. The rivers are the tributaries of the mighty Brahmaputra River with their sources in the mountain ranges of the state. 20 percent of the total land area of the state is covered with wooded forest, rich in flora and fauna.
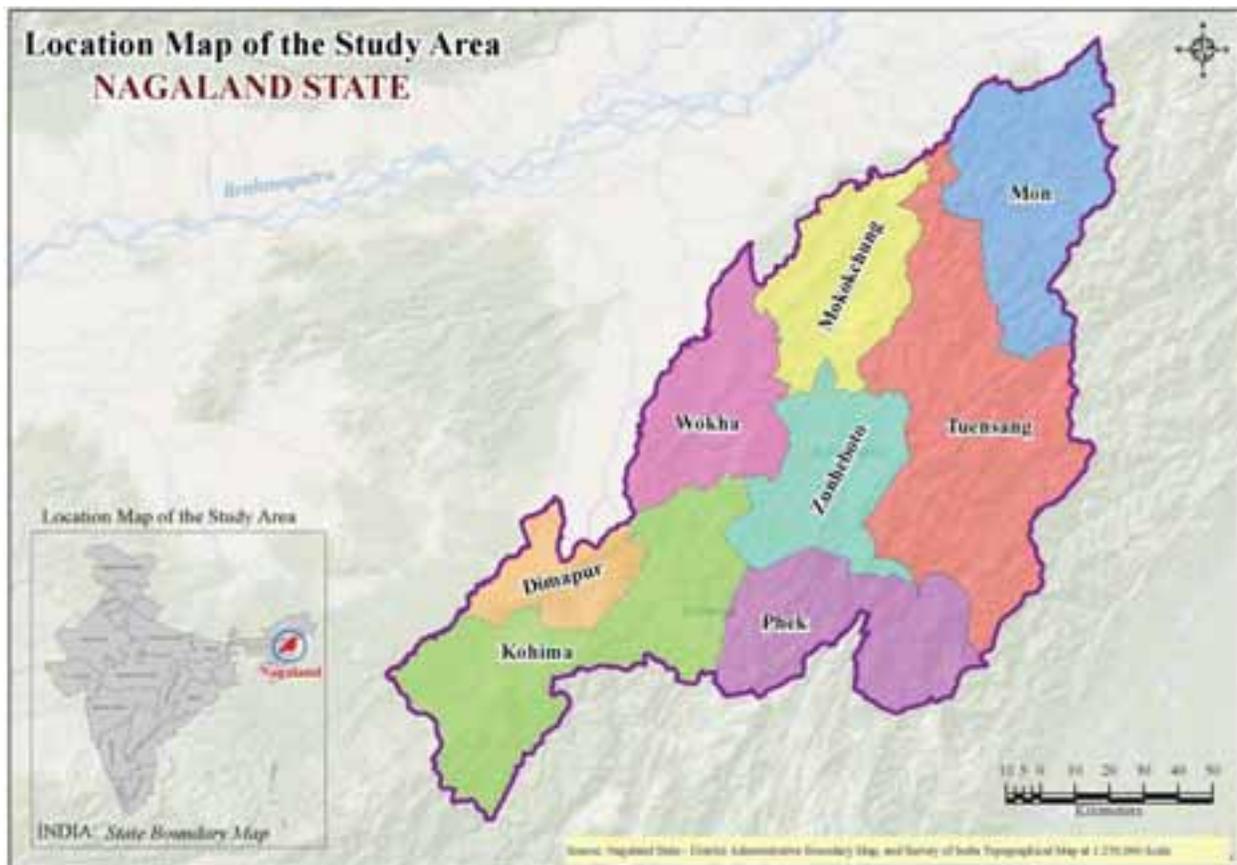
Figure 1: Location Map of the Study Area

Shifting Cultivation Practice in Nagaland

In general, hill people practice shifting cultivation. Shifting cultivation is mainly confined to medium to high rainfall zones, between 100 metres and 2,000 metres above sea level. It is practiced in three types of vegetation, forests, bush and grasslands. As per *Wasteland Atlas of India - 2008 (NRSC)* the total land area under shifting cultivation in Nagaland as in the year 2008 was 2357.42 Sq Kms (Table 1).

Table 1: Shifting Cultivation Area in Nagaland, 2008

S. No.	Class Description	AREA	
		Sq Kms	%
1.	Scrub Land	2,893.68	17.45
2.	Degraded Forest	13.52	0.08
3.	Shifting Cultivation	2,357.42	14.22
4.	Other Land	11,314.38	68.25
	Total	16579.00	100.00

Source: Wasteland Atlas of India 2008, NRSC

Data Used and Sources

Table 2: Data Used and Sources

S.No.	Data Layer	Sources
1.	Base Map	Survey of India Toposheets (1:50,000 and 1:250,000 Scale) Various Satellite Imagery
2.	LULC Map and NDVI	2012: ResourceSAT LISS-III Satellite Imagery (23.5 m) 2003: LANDSAT-7 ETM$^+$ Satellite Imagery (30 m)
3.	Elevation Map	Survey of India Toposheets IRS-P5 CartoSAT-1 DEM (30 m) and ASTER - DEM (30 m)
4.	Soil Map	National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) Soil map updated through Multi-Spectral Satellite Imagery
5.	Demography	Census of India - 2001 and 2011
6.	Climate	India Meteorological Department (IMD) - 2003 to 2012

Climate

Nagaland has a typical monsoon climate with variations ranging from tropical to temperate conditions. Altitude variation in Nagaland is among the prime factors affecting climate and weather conditions. Relief features such as high mountains act as barriers for the movement of the Monsoon winds. Low temperature, high rainfall on windward slopes, comparatively dry on the leeward side and heavy precipitation in the form of snow at the mountain tops are the main features of the climate. Monsoon is the longest lasting for five months from May to September with May, June and July being the wettest months. Owing to varied topography and relief annual rainfall varies from 1000 mm to over 3000 mm at different places with an average of 2000 mm. Atmospheric temperature varies from 15^0 C to 30^0 C in summers and from less than 5^0 to 25^0C in winters. The state enjoys a salubrious climate. Summer is the shortest season in the state that lasts for only a few months. Monthly mean climatic data at Kohima Center from 2006 to 2011 are shown in Table 3, and Table 4.

Table 3: Precipitation (mm) Statistics at Kohima Centre

Year	2011		2010		2009		2008		2007		2006	
Months	Pmm	D	Pmm	D	Pmm	D	Pmm	D	Pmm	D	Pmm	D
Jan	9.8	2	1.4	1	-	-	43.8	4	-	-	-	-
Feb	5.2	1	8.2	2	5.3	2	5.0	6	70.3	10	39.2	2
Mar	56.8	5	56.9	6	24.6	4	54.1	9	16.1	4	8.6	5
Apr	34.9	5	60.8	9	32.1	10	35.0	8	146.5	18	80.7	15
May	265.6	19	119.5	17	138.4	19	170.7	24	343.5	18	170.0	18
Jun	308.2	27	347.1	27	205.7	20	398.4	29	241.5	20	278.7	25
Jul	437.7	28	530.6	26	277.2	25	453.1	24	314.5	28	206.4	21
Aug	239.9	21	464.3	25	388.2	24	393.3	25	416.5	26	139.5	18
Sep	336.3	23	226.5	19	216.0	18	320.0	21	182.2	23	283.5	20
Oct	31.7	7	162.0	14	129.7	12	127.7	10	191.4	15	83.7	11
Nov	9.7	3	2.1	1	13.4	1	-	-	79.4	8	26.2	8
Dec	-	-	21.2	1	-	-	-	-	1.8	1	1.0	1
Annual	1,735.8	141	2,000.6	148	1,430.6	135	2,001.1	160	2,003.7	171	1,317.5	144

Pmm = Precipitation in mile meter (mm), D = Number of Rainy Days
Source: Statistical Handbook of Nagaland, 2009 & 2011

Table 4: Temperature (^{0}C) Statistics at Kohima Centre

Year	2011		2010		2009		2008		2007		2006	
Months	Temperature in ^{0}C		Temperature in ^{0}C		Temperature in ^{0}C		Temperature in ^{0}C		Temperature in ^{0}C		Temperature in ^{0}C	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Jan	17.9	1.4	19.6	3.7	19.3	4.3	18.6	3.7	19.5	3.2	19.5	5.5
Feb	22.4	4.9	20.7	4.0	22.7	6.0	20.8	3.5	20.5	3.5	24.5	7.5
Mar	25.7	8.0	28.6	12.0	24.0	9.3	26.0	6.9	25.5	6.6	26.5	10.0
Apr	26.3	9.3	29.2	10.9	27.9	10.0	27.5	10.5	27.0	10.0	28.2	10.0
May	27.0	11.9	29.4	20.8	28.4	22.0	27.5	13.6	29.0	14.1	28.5	20.0
Jun	27.4	15.5	27.5	14.0	28.9	15.6	27.0	15.4	28.5	16.6	28.0	16.6
Jul	28.1	16.2	27.5	17.4	29.8	17.0	28.0	17.0	29.0	16.8	30.0	17.5
Aug	29.2	15.2	28.4	18.5	28.5	16.3	29.1	15.0	28.9	17.2	31.1	17.0
Sep	29.5	14.5	26.5	15.4	29.5	15.4	27.0	17.0	28.9	16.0	27.5	16.5
Oct	27.4	10.1	26.9	10.0	28.5	10.0	25.5	10.7	28.1	10.0	25.6	12.0
Nov	24.0	6.6	22.8	7.6	24.5	7.0	24.0	7.0	23.5	8.2	23.8	5.0
Dec	21.0	2.6	19.1	3.2	19.8	4.5	20.6	6.0	18.2	4.5	20.0	5.5

*Source: Statistical Handbook of Nagaland, 2009 & 2011*

Land Use / Land Cover Classification

Land use refers to "man's activities and various means of use of land for different purposes, while land cover refers to phenomena like natural vegetation, water bodies, rocks/soils, artificial cover and others manifested on the surface of the terrain. Although land use is generally inferred based on the cover, yet both the terms are closely related and are interchangeable. Examination of the concept of "land use" further emphasizes the virtues of macro and meso rather micro-scale analysis. In order to understand 'why' land use changes as well as 'how' the changes occur, it may be necessary to have information on cause and effective relationships of the factors having influence on it. The multi-faceted character of interest in land is illustrated by *Rowley (1978)* who listed ten items of information required by those concerned with land utilization - such as current use or activity, intensity of use, restrictions on use, value and ownership.

Timely, accurate, reliable and comprehensive spatio-temporal information on land use practices and spatial distribution in a region is prerequisite for planning, utilization and formulation of policies and implementing any sustainable land management plan at micro as well as macro level. Better management and rationale use of land calls for accurate and timely changes in the dimension, nature, and spatial balance between exploitation and regeneration. The timely information about the land use changing pattern plays a significant role in land use planning and sustainable land and water resource development.

One of the biggest advantage of remote sensing is its excellent temporal resolution, as the imagery records the finest information of terrain and land cover conditions pertain to a specific time, which is by any other means is not possible. This information on land cover can also be converted to land use information, by proper methodology of interpretation, association, collateral data, reference level and selectivity with support from ground visits.

On the other hand, GIS is best utilized for integration of various data sets to obtain a homogeneous composite land development unit which helps in identifying the problem areas and suggest conservation measures. Various studies conducted by different authors suggests that the remote sensing technology in combination with GIS is an ideal tool to identify, locate and map various types of lands associated with different landform units *(Palaniyandi and Nagarathinam, 1997; Murthy and Venkateswara Rao, 1997; Khan et al., 1999)*. The objective of the study is to implement a remote sensing/GIS-based methodology that classifies land use and land cover to a much finer level so that it can be monitored as an index of shifting cultivation land. A methodology flow chart is shown in Fig. 2.
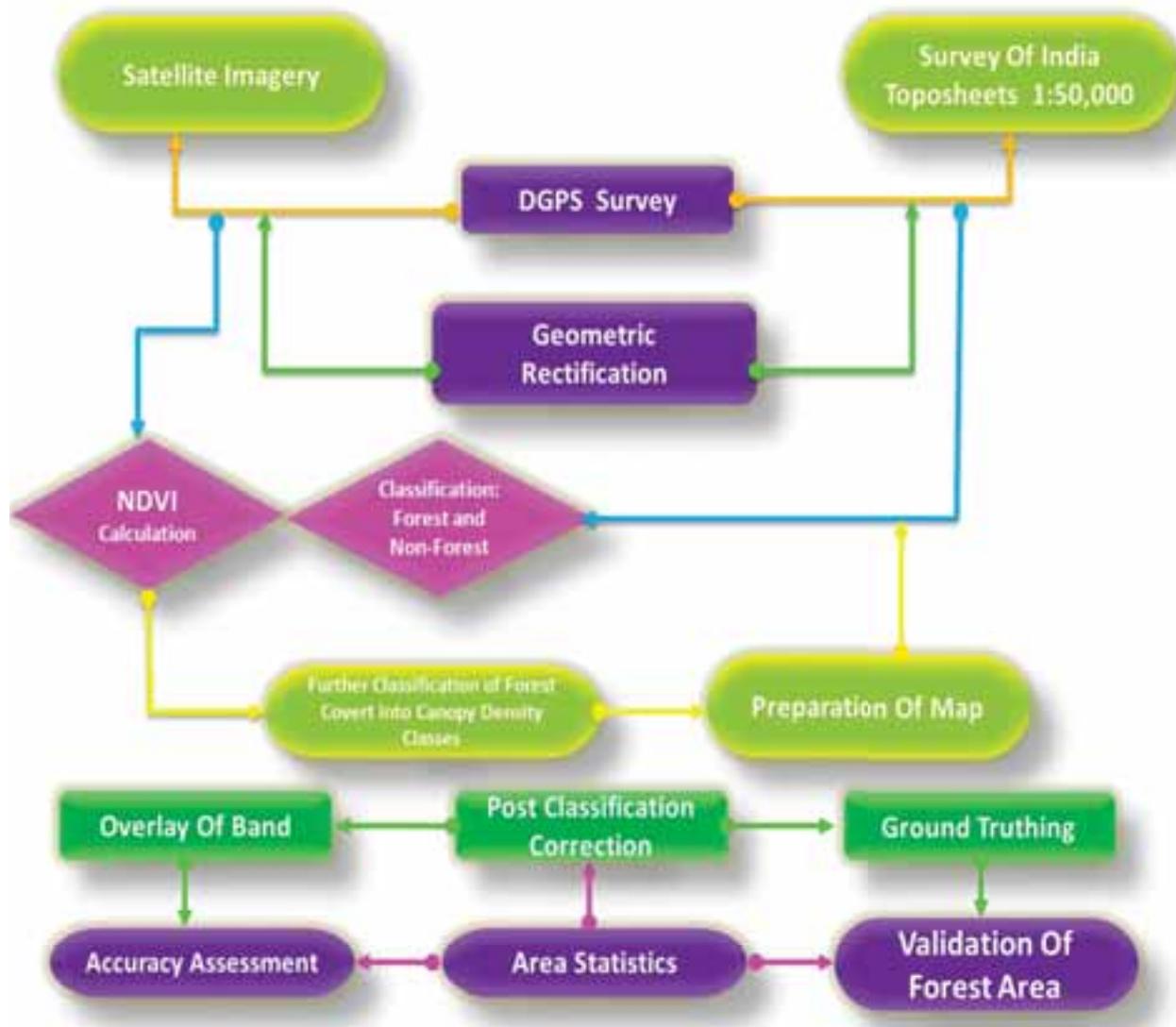
Figure 2: A Methodology Flow Chart for LULC and Forest Cover Mapping

Accuracy Assessment

No land cover classification scheme would be considered complete without an accuracy assessment. The need for accuracy assessment arises as part of classification algorithm development, and it was extended as an important tool for land cover mapping accuracy assessment. Various studies have been conducted on the methods of accuracy assessment, and accuracy measures by different renowned authors like *Hord and Brooner (1976)*, *Thomas and Allcock (1984)*, *Rosenfield and Fitzpatrick Lins (1986)*, *Congalton (1991)*, *Hammond and Verbyla (1996)*, and *Edwards et al., (1998)*. Author has convinces high level of accuracy and has definitely achieve the standard set forth by LEAF i.e.90% between forest and non-forest classes and 80% accuracy between various forest classes. For this purpose author has allocate 30% of the GPS points collected during field survey. The following is a brief about the accuracy assessment methodology has been adopted.

The accuracy of a classification system is usually assessed by comparing the classified data with some reference data that is believed to accurately reflect the true land cover. Has used some of GPS points collected during the field survey for assessment. A confusion matrix has been generated to describe the accuracy of the classified image. A confusion matrix contains information about actual and predicted classifications done by a classification system. There are three components in the matrix: (a) User's Accuracy - Indicates the accuracy from the users point of view (Field GPS Data), (b) Producer's Accuracy - Indicates the accuracy of the classification performed and, (c) Kappa Coefficient - This indicates the overall accuracy of the classification methodology.

LULC and Forest Cover Mapping

The study area base map is prepared by the Survey of India (SOI) topographic maps on 1: 50,000 scales numbered 83G/06, 83G/07, 83G/09, 83G/10, 83G/11, 83G/12, 83G/13, 83G/14, 83G/15, 83J/03, 83J/04, 83J/06, 83J/07, 83J/08, 83J/10, 83J/11, 83J/12, 83J/13, 83J/14, 83J/15, 83J/16, 83K/01, 83K/02, 83K/05, 83K/06, 83K/09, 83K/10, 83K/11, 83K/13, 83K/14, 83M/04, 83N/01, 83N/02, 83N/03, 83N/04, and 83O/01. Land use and land cover map have been prepared by using ResourceSAT LISS-III satellite imagery (2012), and LANDSAT-7 ETM$^+$ satellite imagery (2003) and were verified through necessary field check.

Topographic maps pertaining to the study area have been geo-referenced and projected UTM, WGS84, Zone 46 North projection and spatial reference coordinate systems applied to rectify and resample both the imageries using ArcGIS-10.1 software. A toposheets mosaic has been generated. The remote sensing image data has been then rectified with reference to geo-referenced topographic maps. A total of 33 ground control points (GCP's) were collected by global positioning system (GPS) to assist with topographic maps to register the data sets with RMS error of less than 0.83. Various image enhancement techniques were applied to make the imagery more interpretable. State imagery subsets have been created by intersecting the geo-referenced input imagery with state boundary AOI delineated from SOI toposheets mosaic. ArcGIS-10.1 software with image classification extension is employed to LULC classification and to perform subsequent change analysis. Various land use land cover classes were delineated from the both the images by means of digital imager classification i.e. unsupervised/supervised methods for finally producing the land use/land cover datasets and maps for the two reference years. Land use and land cover change pattern analysis was done to record the temporal changes in land use and land cover change during the 10 year period of time. Keeping the above views in mind, the land use / land cover maps have been prepared for the year 2003 and year 2012 respectively using remote sensing data pertaining to Landsat-7 ETM$^+$ of 30m resolution (Fig. 3) and ResourceSAT LISS-III of 23.5m resolution (Fig. 4) respectively.
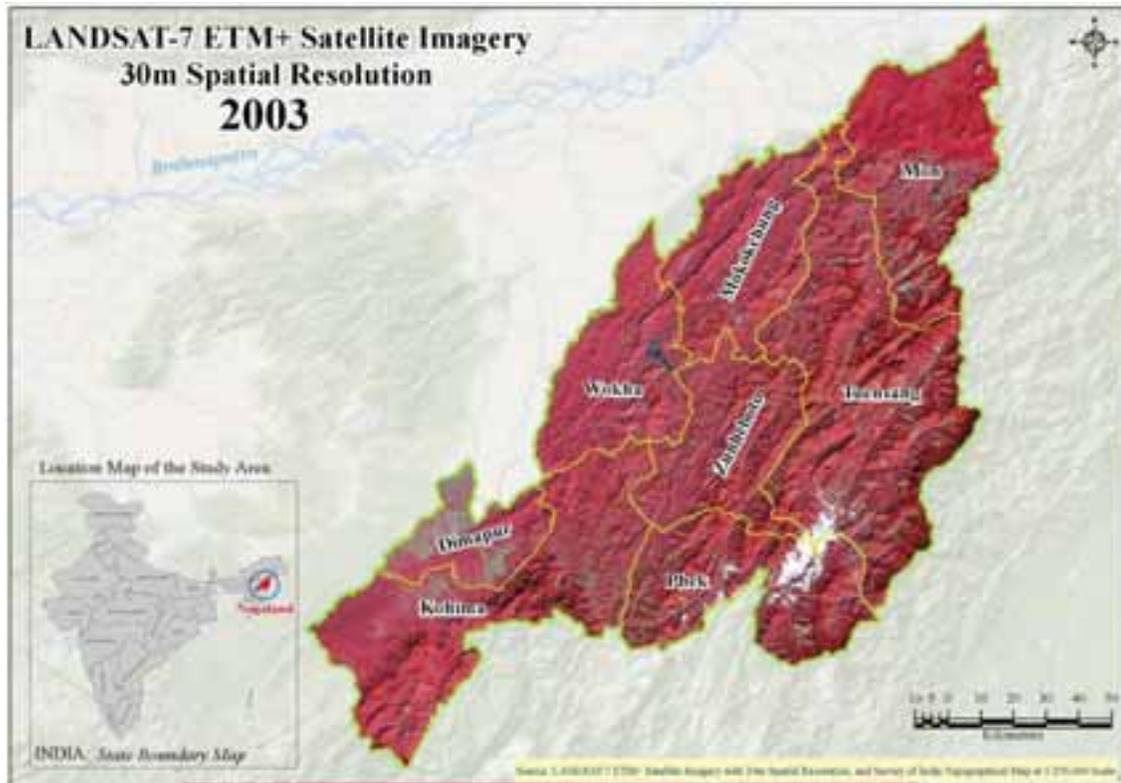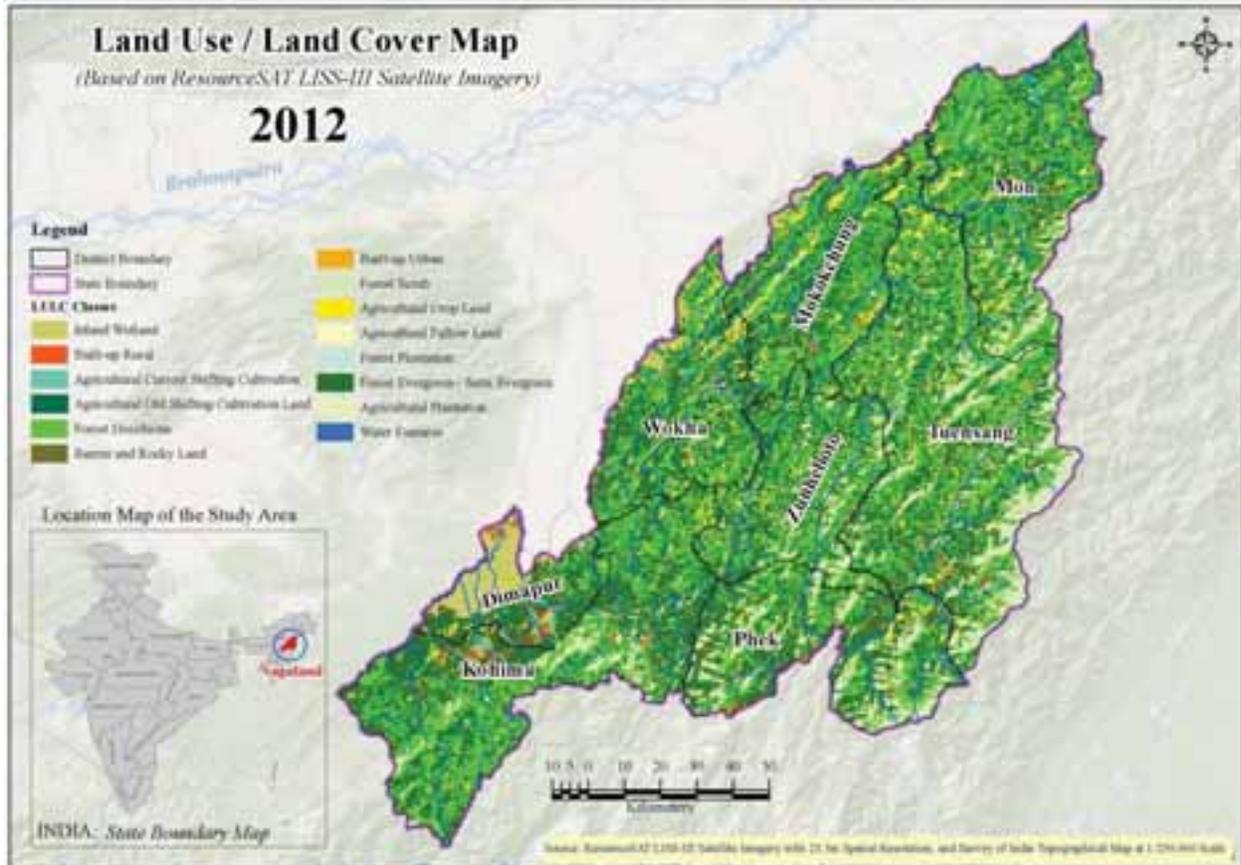
Figure 3: Landsat-7 ETM$^+$ Satellite Imagery with 30m Spatial Resolution
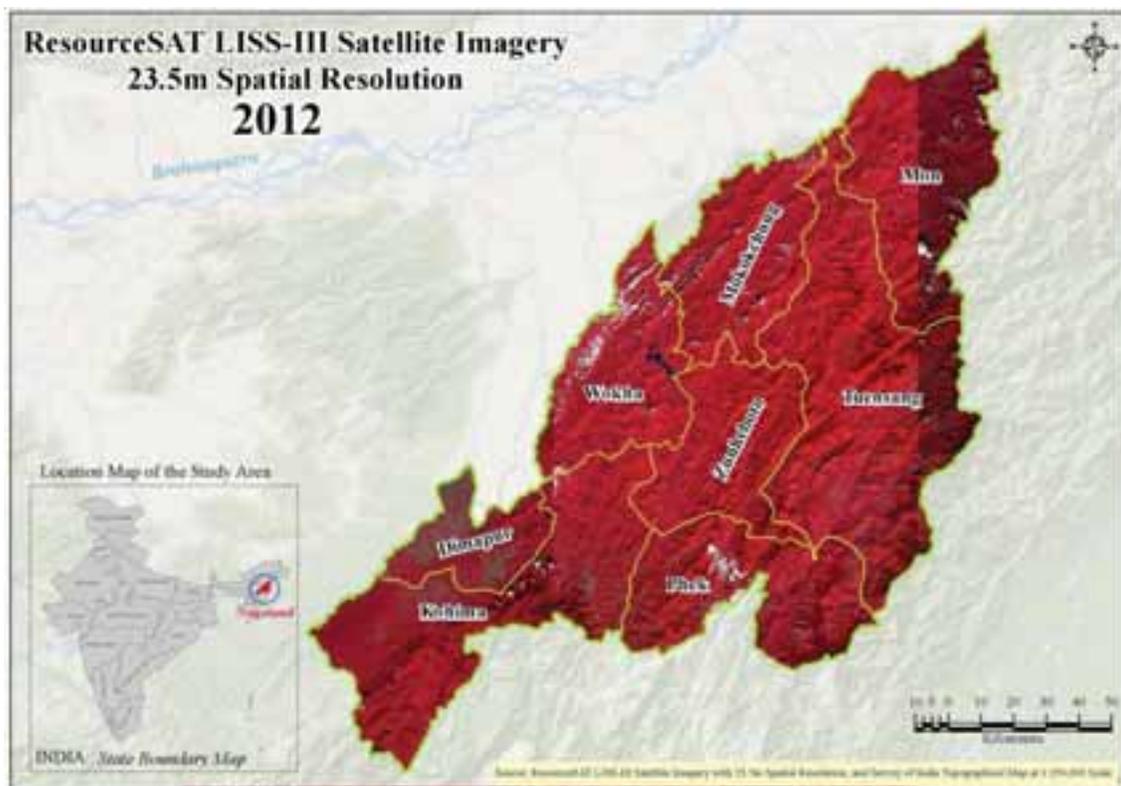
Figure 4: ResourceSAT LISS-III Satellite Imagery with 23.5m Spatial Resolution

Study of land use and land cover pertaining to the year 2003 suggests that, the study area mostly comprises the forest land of 73.63 % and agricultural land of 23.10 % (Fig. 5). The initial observations confirmed by the statistics are shown in Table 5. It is evident from the Table 5 that built-up land in the form of settlements (rural as well as urban) accounts for a 352.43 Km^2 which is only a 2.13 % of the total area while water features accounts for 1.12 %. Other land use / land cover categories noticed in the area are barren & rocky land with 0.02 %, and inland wetland with 0.0008 %. The old shifting cultivation land and current shifting cultivation land area covered only 13.49 % (2236.74 Kms^2), and 0.02 % (3.11 Kms^2) respectively in the state.

In year of 2012, the study area mostly comprises the forest land of 74.10 % and agricultural land of 22.21 % (Fig. 6). The initial observations confirmed by the statistics are shown in Table 5. It is evident from the Table 5 that built-up land in the form of settlements (rural as well as urban) accounts for a 408.05 Km^2 which is only a 2.46 % of the total area while water features accounts for 1.20 %. Other land use / land cover categories noticed in the area are barren & rocky land with 0.03 %, and inland wetland with 0.0015 %. The old shifting cultivation land and current shifting cultivation land area covered only 15.82 % (2622.67 Kms^2), and 0.05 % (7.72Kms^2) respectively in the state.

Figure 5: Land Use and Land Cover Map - 2003

Figure 6: Land Use and Land Cover Map - 2012

LULC Change Pattern Analysis

The change analysis presents a brief summary of change in the pattern of land use & land cover during the period between year 2003 and year 2012. To evaluate the detailed land use changes between 2003 and 2012, a land use and land cover change pattern map has been prepared combining the two classified land use and land cover maps in ArcGIS-10.1 software.

Due to various anthropogenic activities which took place during the period of 2003-2012, the dynamic change is obvious and prominent in the study area, especially in the case of forest land (Table 5). Similarly, agricultural land, which was 23.10 % in 2003, has decreased to 22.21 % showing a falloff of 0.90%. The forest land which was 73.63 % in 2003 has increased to 74.10 % in 2012, with a growth of 0.47 %. Rural settlement, and urban settlement which accounts for 258.92 and 93.51 Km^2 in 2003, are increased to 299.78, and 108.27 Km^2 in 2013, with growth of 1.81 % and 0.65 % respectively. It is noted that agricultural old shifting cultivation land, and agricultural current shifting cultivation, which were occupying 2,236.74 and 13.03 Km^2 in 2003, have increased to 2622.67 and 7.72 Km^2 in 2012, with growth of 15.82 % and 0.05 % respectively.

Table 5: Land Use and Land Cover Statistics, and Change Analysis in Year 2003 & 2012

| S. No	Land Use / Land Cover Classes	2003		2012		Change	
		Sq Kms	%	Sq Kms	%	Sq Kms	%
1	Built-up Urban	93.51	0.56	108.27	0.65	14.76	0.09
2	Built-up Rural	258.92	1.56	299.78	1.81	40.86	0.25
3	Agricultural Crop Land	1549.19	9.34	1000.54	6.03	-548.65	-3.31
4	Agricultural Plantation	14.37	0.09	17.59	0.11	3.22	0.02
5	Agricultural Fallow Land	27.14	0.16	33.04	0.20	5.90	0.04
6	Agricultural Current Shifting Cultivation	3.11	0.02	7.72	0.05	4.61	0.03
7	Agricultural Old Shifting Cultivation Land	2236.74	13.49	2622.67	15.82	385.93	2.33
8	Forest Evergreen / Semi Evergreen	334.13	2.02	366.95	2.21	32.82	0.20
9	Forest Deciduous	10700.36	64.54	9879.81	59.59	-820.55	-4.95
10	Forest Plantation	74.07	0.45	81.36	0.49	7.29	0.04
11	Forest Scrub	1098.69	6.63	1956.88	11.80	858.19	5.18
12	Barren and Rocky Land	3.68	0.02	5.48	0.03	1.80	0.01
13	Inland Wetland	0.13	0.00	0.25	0.00	0.12	0.00
14	River / Stream / Canals	166.93	1.01	178.44	1.08	11.51	0.07
15	Reservoir / Lakes / Ponds	18.03	0.11	20.22	0.12	2.19	0.01
	Total	16579.00	100.0	16579.0	100.0		

Soil Type

The soil map layer is generated in the GIS environment using soil maps collected from *National Bureau of Soil Survey and Land Use Planning (NBSS & LUP).* The soil map was updated using ResourceSAT LISS-III satellite imagery (Fig. 7). Input data layers from the soil map were scanned in the highest possible resolution. Subsequently, scanned maps were geometrically registered to the base geometric dataset, the ResourceSAT LISS-III satellite imagery mosaic of study area. Having the geo-reference parameters in place the flat image file was then converted to a GIS layer by digitizing the individual soil type polygons using ArcGIS-10.1 software and adding the relevant attribute from the hard copy maps. This conversion to proper digital GIS dataset will facilitate the use of the dataset for spatial analyze.

The soil of Nagaland belongs to 4 orders, 7 sub-orders, 10 great groups, 14 sub-groups and 72 soil families. The 4 orders found in Nagaland are *(i) Alfisols (ii) Entisols (iii) Inceptisols, and (iv) Ultisols.* Inceptisols dominate the soils of the State with 66% followed by Ultisols 23.8%, Entisols 7.3% and Alfisols 2.9% of the total area 16579 Sq Kms of the State (Fig. 7).

Alfisols: Alfisols are base-rich mineral soils of sub-humid and humid region. They have light coloured surface horizon over a clay enriched sub-surface horizon that is rich in exchangeable cations with base saturation of more than 35%. This type of soil order is found on the western flank of the state bordering Assam. They are deep and well drained of fine to fine loamy texture.

Common families of Alfisols which have been identified in Nagaland are: *(a) Fine typic Kanhapludalfs, and (b) Fine loamy typic Paleudalfs.*
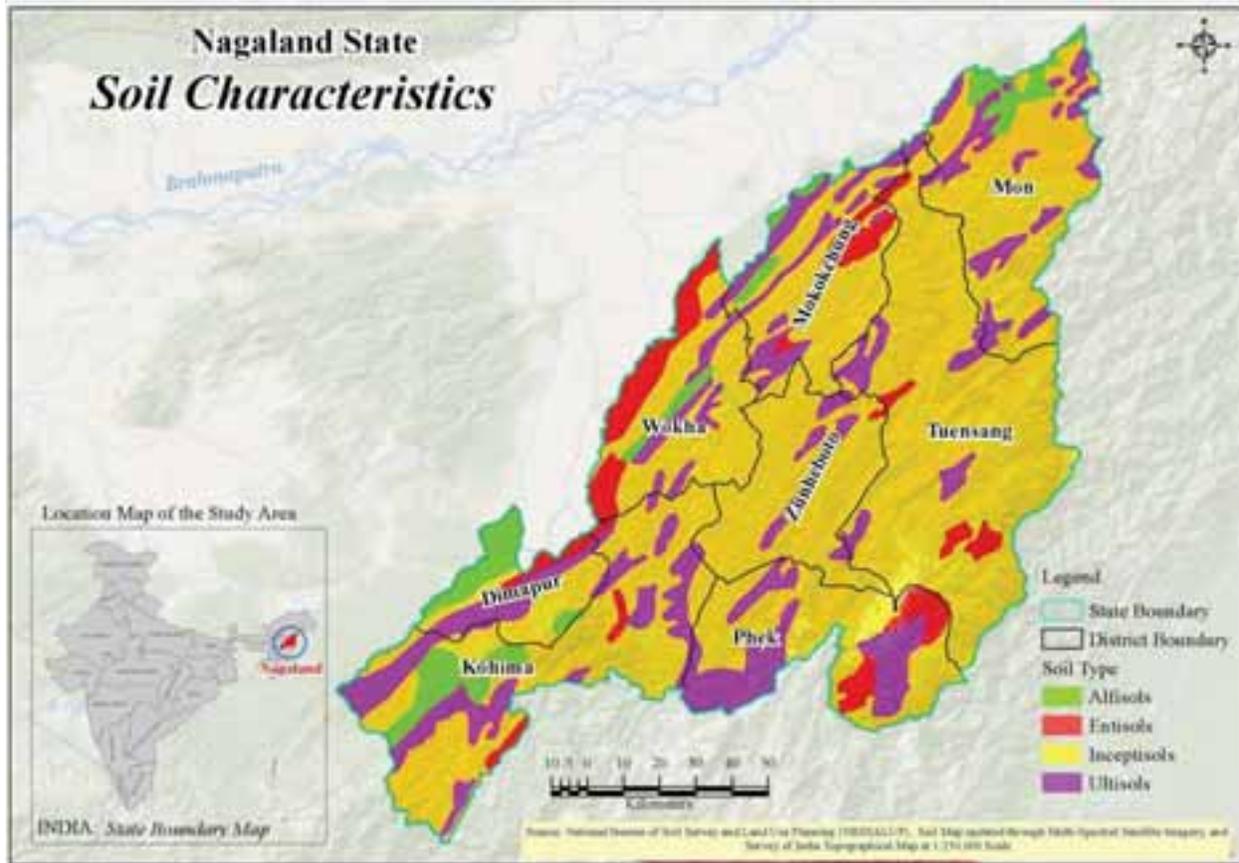
Figure 7: Soil Map of Nagaland State

Entisols: They are recently developed, mineral soils with no diagnostic horizon. This is because either of limiting time available for development or because of exceedingly unfavourable conditions. This soil order is found on the Western and North Western part of the State on the low hill slope and narrow river valleys. They are moderately to deep, well drained, fine to fine loamy textured soils. Families which have been identified under these orders are: *(a) Fine-loamy typic Udifluvents, (b) Fine-loamy typic Udorthents, (c) Coarse-loamy typic Udorthents, (d) Fine-loamy Lithic Udorthents, and (e) Coarse loamy Lithic Udorthents.*

Inceptisols: This soil order represents beginning stage of soil formation which is belong to that of Entisols but still short of the degree of development found in Alfisols. They may have some accumulation of clay in the sub-surface horizon, limiting in depth, organic matter content, and base saturation. This soil dominates the entire State having fine loamy, fine clay, clay loam etc. soil textures with moderately shallow to deep soils with moderately to excessively drained. The identified families under this order are: *(a) Fine- loamy Umbric Dystrochrepts, (b) Fine loamy*

typic Dystrochrepts, (c) Fine Umbric Dystrochrepts, (d) Loamy , skeletal Umbric Dystrochrepts, (e) Fine typic Dystrochrepts, (f) Loamy-skeletal typic Dystrochrepts, (g) Clayey-skeletal Umbric Dystrochrepts, (h) Loamy-skeletal Pachic Haplumbrepts, (i) Fine Pachic Haplumbrepts, (j) Fine-loamy typic Haplumbrepts, (k) Clayey-skeletal Pachic Haplumbrepts, (l) Fine loamy Pachic Haplumbrepts, (m) Fine-loamy Dystric Eutrochrepts, (n) Coarse loamy typic Dystrocrepts, (o) Loamy skeletal typic Dystrocrepts, and (p) Loamy skeletal Dystric Eutrocrepts.

Ultisols: The Ultisols are similar with Alfisols, except for having low base saturation on the exchange complex due to advance stage at weathering. These are base-poor mineral soils of humid region developed under high rainfall and forest vegetation. They are characterized by low, less than 35% base saturation and clay enriched sub-surface horizon. This soil is sparely scattered in all parts of the State having fine loam, clay loam and clayey texture. Well to excessively drain with moderate to deep soils. The families under this order which have been identified so far are: *(a) Fine Humic Hapludults, (b) Fine Typic Paleudults, (c) Fine Typic Haplohumults, (d) Fine loamy typic Hapludults, and (e) Fine typic Hapludults.*

Assignment of Carbon Stock

No satellite technology allows for carbon stocks being directly measured across landscapes *(GOFC-GOLD, 2009)*. Carbon stocks can be measured using LULC map with various classes through the assigning carbon stock mass in particular LULC classes (in tons of carbon per hectare). Author has tracked this approach for assessment of carbon stock, and has used standard above-ground biomass (AGB) data and forest growth rates provided by the *International Panel on Climate Change (IPCC, 2006)* as the base data to determine carbon stock density values for lulc classes in Nagaland for both year 2003 as well as 2012. The carbon stock mass for our lulc classes were derived from IPCC biomass data following the procedure described by *Ruesch & Gibbs (2008)*. Table 6 is showing the assigned value within the lulc classes.

Table 6: LULC Classes wise Carbon Value (t C/Ha)

S.No.	LULC Categories	IPCC Aboveground Biomass	Carbon Value (t C/Ha)
1.	Built-up Area	-	0.00
2.	Cultivated and Managed Land		5.00
3.	Forest Evergreen	280	180
4.	Forest Deciduous	180	105
5.	Forest Plantation	130	78
6.	Forest Scrub	130	78
7.	Inland Wetland	50	33
8.	Barren and Rocky Land	-	1.00
9.	Water and Artificial Surfaces		0.00

Source: International Panel on Climate Change (IPCC), 2006

Carbon Stocks in Different LULC Classes

Carbon stocks data has been utilized to determine carbon dioxide sequestration by different components of the above ground biomass using standard procedures prescribed by *International Panel on Climate Change (IPCC)*. Table 7 shows the results of assigning carbon stock mass to the refined land cover classes of Nagaland.

Table 7: Estimated Carbon Stocks in Different LULC Classes

| LULC Categories	Carbon Value Tons of Carbon/Ha	Area (Hectare)		Carbon Stock (tons of C)	
		2003	2012	2003	2012
Built-up Area	0	35243	40805	0	0
Cultivated Land	5	159070	105117	795350	525585
Agri. Shifting Cultivation	5	223985	263039	1119925	1315195
Forest Evergreen	180	33413	36695	6014340	6605100
Forest Deciduous	105	1070036	987981	112353780	103738005
Forest Plantation	78	7407	8136	577746	634608
Forest Scrub	78	109869	195688	8569782	15263664
Inland Wetland	33	13	25	429	825
Barren and Rocky Land	1	368	548	368	548
Water/Artificial Surfaces	0	18496	19866	0	0

This initial observation is confirmed by the statistics shown in Table 7. Amount of carbon stored in forest, agricultural land, shifting cultivation, wetland and barren land are 127.52 (98.52 %), 0.79 (0.61 %), 1.1 (0.87 %), 0.00042 (0.00033 %), and 0.00036 million tones (0.00055 %) respectively in 2003, while the amount of carbon stored in forest, agricultural land, shifting cultivation, wetland and barren land in 2012 are 126.24 (98.56 %), 0.52 (0.41 %), 1.32 (1.03 %), 0.00082 (0.00064 %), and 0.000354 million tones (0.00043 %) respectively. Table 8 is showing the district wise distribution of carbon stock amount (Fig. 8, and Fig. 9).

Table 8: District wise Distribution of Carbon Stock (Million Tons of Carbon)

S. No.	District	Area (in Sq Kms)		Carbon Stock (in Million Tons of Carbon)	
		2003	2012	2003	2012
1	Dimapur	1.13	1.33	0.001	0.001
2	Kohima	343.37	403.24	0.172	0.202
3	Mokokchung	289.12	339.54	0.145	0.170
4	Mon	375.52	440.99	0.188	0.220
5	Phek	149.84	175.97	0.075	0.088
6	Tuensang	854.02	1,002.93	0.427	0.501
7	Wokha	77.44	90.94	0.039	0.045
8	Zunheboto	149.41	175.46	0.075	0.088
	Total	2,239.85	2,630.39	1.120	1.315

**Estimation of Carbon Emission in Shifting Cultivation**

Carbon emissions due to site preparation, biomass burning and biomass decay has been determined based on IPCC guidelines for LULUCF projects to estimate carbon emissions from slash and burn practice. Carbon emissions due to decay of slashed vegetation and also due to subsistence use of NTFP and wood products has also be estimated using IPCC good practice guidance for LULUCF. Estimated Carbon Stocks in shifting cultivation land is 1.12 million tons of carbon in 2003 has increased to 1.31 million tons of carbon in 2012.
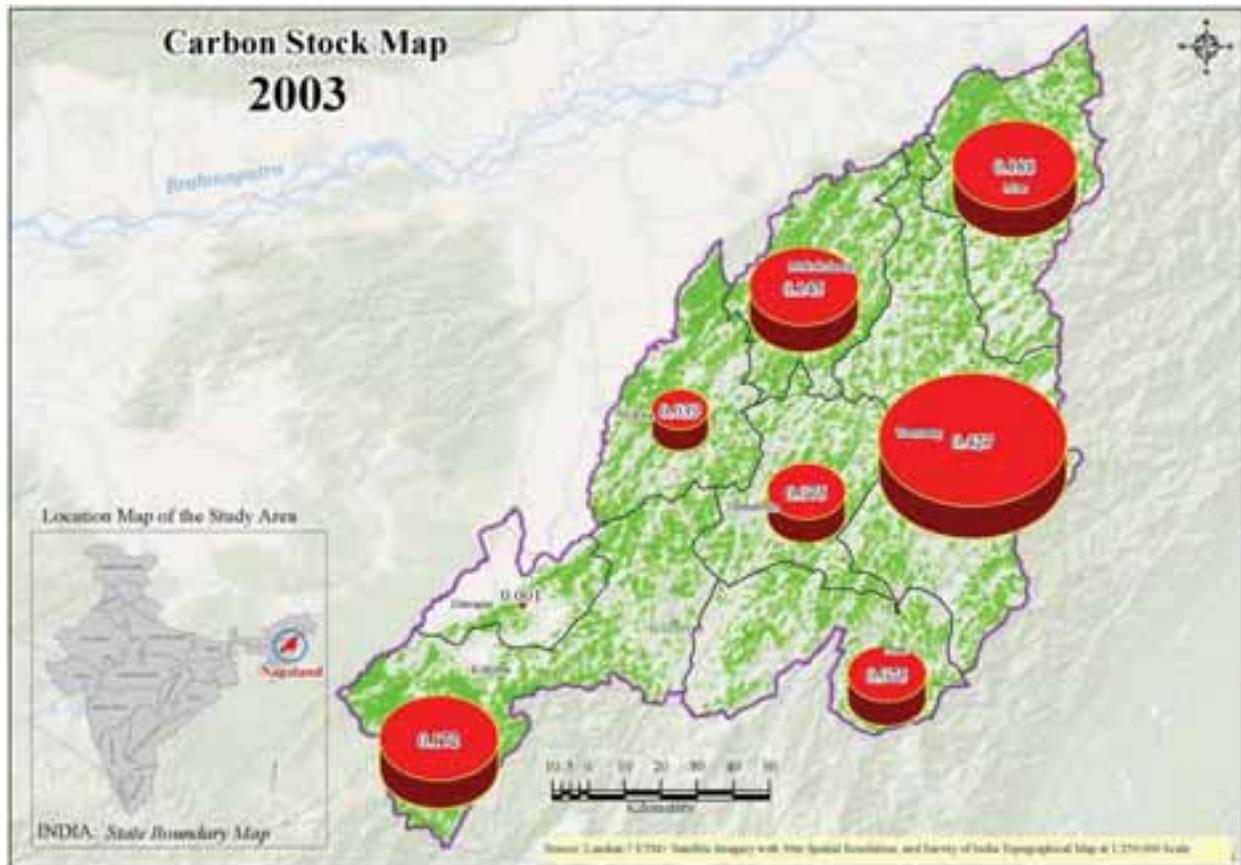
Figure 8: District wise Distribution of Carbon Stock - 2003

Conclusion

Carbon sequestration in forests has assumed a great significance owing to its ability to mitigate climate change. The market mechanisms under Kyoto Protocol and expected REDD and REDD[+] regime in the post Kyoto regime have made carbon a tradable commodity and hence the renewed political and economic attention on forests and plantations. All countries participating in a future REDD mechanism will need to demonstrate substantial capacity for monitoring, reporting and verification of their carbon emissions and removals from land use change. The outcome of this paper has provide an important baseline from which to evaluate long term carbon dynamics and forest sustainability in shifting cultivation lands throughout the world.
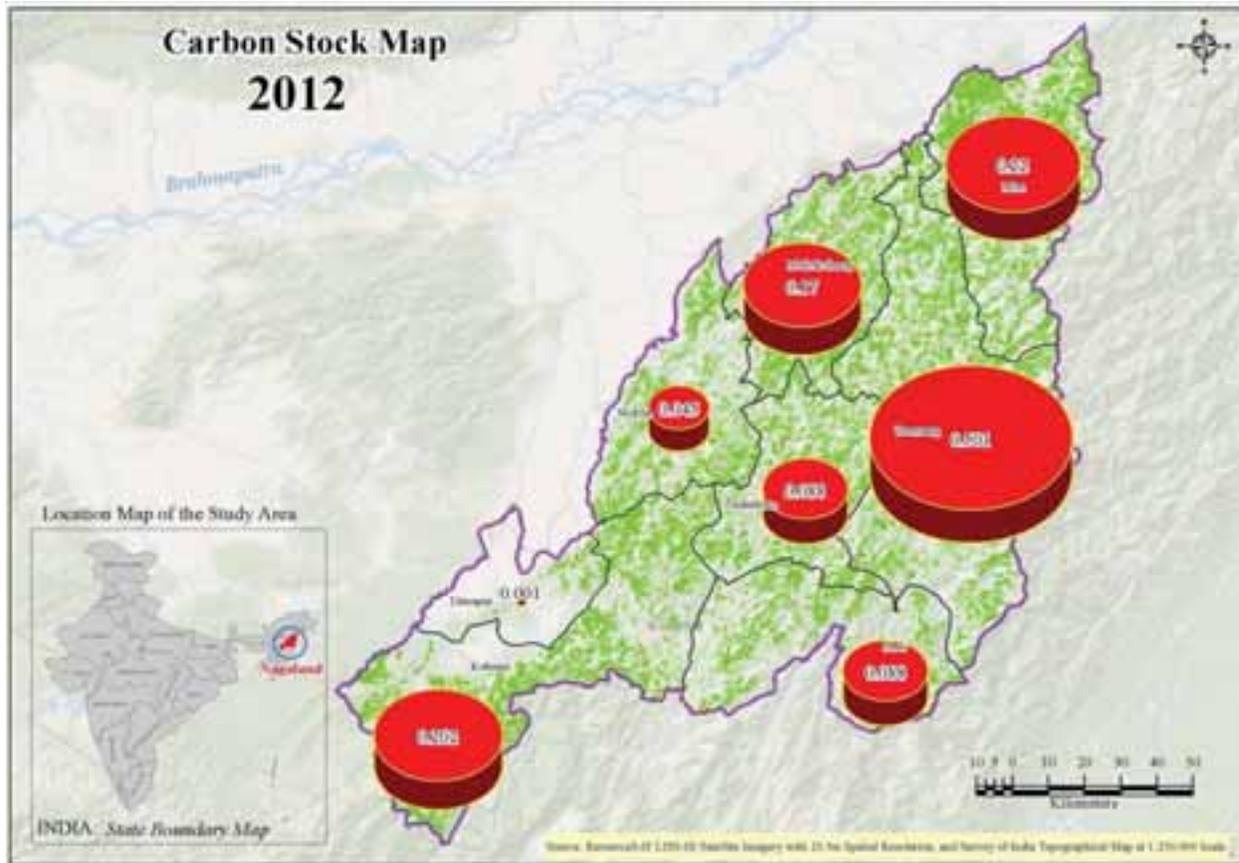
Figure 9: District wise Distribution of Carbon Stock - 2012

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