NESAC-SR-77-2010

BAMBOO RESOURCE MAPPING FOR SIX DISTRICTS OF NAGALAND USING REMOTE SENSING AND GIS

Project Report

Sponsored by

Nagaland Pulp & Paper Company Limited,
Tuli, Mokokchung, Nagaland

Prepared by

NORTH EASTERN SPACE APPLICATIONS CENTRE
Department of Space, Govt. of India
Umiam – 793103, Meghalaya

March 2010

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Project team

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1. INTRODUCTION

1.1 Bamboo in NER

In northeastern India, life without bamboo is unimaginable. This versatile, giant grass plays a key role in the livelihood. A fast growing, versatile woody grass, bamboo was amongst the first materials available in nature with which human ingenuity could interact. Blessed with environment regeneration qualities like carbon sequestering, it is an economic resource with immense potential for improving quality of rural and urban life. Bamboo is used for almost everything— from a nourishing food supplement (shoots) and traditional herbal medicine for minor and major ailments to raw material for cottage and handicrafts industry as well as large industries like paper and pulp.

The Northeast is recognized as one of the largest reserves of bamboo in India. About 89 bamboo species out of 126 recorded in India under 16 genera grow naturally in different forest types of this region or are cultivated across its tropical and sub-tropical belts. The major genera found in the temperate and sub-alpine forests include *Arundinaria, Bambusa, Chimonobambusa, Melocanna, Ochlandra* (exotic), *Oxytenanthera, Phyllostachys, Pleioblastus, Pseudosasa* (exotic), *Schizostachyum*, *Semiarundinaria, Sinobambusa, Thamnocalamus*, and *Thyrsostachys*. Among these, *Schizostachyum, Bambusa* and *Dendrocalamusare* important because they have large number of species. The genus *Schizostachyum* has 27 species followed by *Bambusa* with 21 species and *Dendrocalamus* with 13. *Bambusa* is among the most important genus in terms of usefulness and species diversity. *Melocanna, Phyllostachys, Gigantochloa*, and *Chimonobambusa* have limited number of species but are more important in terms of utilization. In terms of geographical coverage, *Dendrocalamus hamiltonii, Bambusa pallida, Melocanna baccifera, Phyllostachys bambusoides, Arundinaria sp, Chimonobambusa callosa, Schizostachyum polymorphum, S capitatum* are prominent with wider distribution and coverage in the region (1).

It is estimated that more than 66% of India's bamboo stock is located in the North Eastern States of India. Bamboo is found in abundant in all states of the North Eastern Region of India (NER). The state wise distribution of bamboo genera in NER is given in Table 1 (2). The total bamboo cover in the NER states is 30,844 sq. km as given by Choudhury *et al* (1). Details of bamboo cover in NER states is given in Table 2. But at present, overexploitation forest resources including bamboo associated with growing human population, destruction of tropical forests and demands for industrial uses have together contributed to severe loss of stock. The alarming rate of deforestation has also accelerated genetic erosion, especially in areas of indigenous bamboo diversity, in India mostly in the eastern part (3). There is an urgent need to explore ways and means to promote genetic conservation. The situation calls for immediate attention to mapping and monitoring of bamboo resources and area expansion under bamboo plantation to meet the increasing demand of planting materials.

Table1: State wise distribution of bamboo genera in NER

Sl No	States	Genera
1	Arunachal Pradesh	*Arundinaria, Bambusa, Chimonobambusa, Dendrocalamus, Gigantochloa, Phyllostachys, Pleioblastus, Schizostachyum, Sinarundinaria, Thamnocalamus and Thyrsostachys*
2	Assam	*Bambusa, Dendrocalamus, Dinochloa, Gigantochloa, Melocanna, Oxtenanthera, Phyllostachys, Racemobambos and Schizostachyum*
3	Manipur	*Bambusa, Chimonobambusa, Dendrocalamus, Dinochloa, Melocanna, Racemobambos, Schizostachyum and Sinarundianaria*
4	Meghalaya	*Bambusa, Chimonobambusa, Dendrocalamus, Dinochloa, Gigantochloa, Melocanna, Recemobambos, Phyllostachys, Schizostachyum and Sinarundianaria*
5	Mizoram	*Bambusa, Chinonobambusa, Dendrocalamus, Gigantochloa, Melocanna, Oxytenanthera, Schizostachyum and Siarundinaria*
6	Nagaland	*Bambusa, Chimonobambusa, Dendrocalamus, Racemobambos, Schizostachyum and Sinarundianaria*
7	Sikkim	*Arundinaria, Bambusa, Dendrocalamus, Melocanna, Phyllostachys, Racemobambos, Schizostachyum, Sinarundinaria and Thamnocalamus*
8	Tripura	*Bambusa, Dendrocalamus, Dinochloa, Gigantochloa, Melocanna, Pseudosasa, Schizostachyum, Sinarundinaria, Thamnocalamus and Thyrsostachys*

There are about 22 species reported to be available in the state of Nagaland. The distribution pattern of some of important species growing in Nagaland is given in Table 3. The dominant species in Nagaland are Kako (*Dendrocalamus hamiltonii*), Dolo (*Teinostachyum dulloa*) and Jati (*Bambusa tulda*). They occur all along the lower belts in the border with Assam. While Kakoo and Daloo clumps are characterized in moist localities along the nalas and streams, Jati occupies better-drained sites. In more accessible localities along the roads bamboos have been over cut while, in other areas they have been left untouched for many years (4).

Table 2: Distribution of bamboo in Northeast India (Area in sq. Km.)

State	Geographical area	Recorded forest area	Actual forest cover	Area under Bamboo	Bamboo area (%)	
					Geographical	Forest area
Arunachal Pradesh	83,743	51,540	68,602	4,590	5.5	6.7
Assam	78,438	30,708	23,824	8,213	10.5	34.5
Manipur	22,327	15,154	17,418	3,692	16.5	21.2
Meghalaya	22,429	9,496	15,657	3,102	13.8	19.8
Mizoram	21,081	15,935	18,775	9,210	43.7	49.1
Nagaland	16,579	8,629	14,221	758	4.6	5.3
Tripura	10,486	6,292	5,546	939	8.9	16.9
Sikkim	7,096	5,676	3,540	340	5.9	9.6

Source: Choudhury et al 2008 (1)

Table 3: Spatial distribution of bamboos in Nagaland.

Species	Distribution
Bambusa balcooa	Wokha
Bambusa pallida	Wokha, Kohima and Peren region
Bambusa tulda	Kohima, Jalukie region
Chimonobambusa callosa	Puliebadze above Kohima and Mao
Dendrocalamus calostachys	Phekerkrima, Dimapur and Kohima
Dendrocalamus giganteus	Kohima, Mao
Dendrocalamus hamiltonii	Dimapur-Kohima road, and Wokha
Dendrocalamus hookeri	Kohima, Wokha
Melocanna baccifera	Jalukie
Neomicrocalamus prainii	Puliebadze, Japfu Range
Schizostachyum fuchsianum	Kohima, Zulhami-Kilomi area
Schizostachyum polymorphum	Longsachu near Workha
Schizostachyum polymorphum	Yikum near Wokha
Sinarundinaria elegans	Puliebadze, near Kohima
Sinarundinaria griffithiana	Saramati region
Sinarundinaria nagalandiana Naithani	Niriyo Peak, Wokha
Sinarundinaria rolloana	Japfu Range, Kohima

(Source: http://www.nagaland.nic.in)

The present work has been taken up by the North Eastern Space Applications Centre (NESAC), Umiam with the specific request from the Nagaland Pulp & Paper Company Limited (NPPCL), Tuli, Nagaland for mapping the bamboo growing areas of six districts of the State.

1.2 Mapping and monitoring of bamboo resources using satellite technology

Mapping and monitoring of natural resources is one of the foremost requirements for its planning, management and conservation. Monitoring & management of these resources need accurate mapping of existing growing stock. Due to lack of proper resource information i.e. actual growing areas, total available growing stock, etc, bamboo has never achieved the status of high value commercially used resources. The spectacular development in space technology, particularly, the repetitive satellite remote sensing across various spatial and temporal scale, offers the most economic means of assessing, planning, managing and monitoring the forestry resources. The spectral reflectance of a plant is determined by characteristics its leaves. The spectral reflectance of an individual leave or needle is controlled by a number of factors, the most important of which are absorption by photosynthetic pigments and water (5, 6, 7). Linear Imaging Self Scanner (LISS) III & IV of Indian Remote Sensing Satellites (IRS) sensor with spatial resolution 23.5m & 5.8m respectively enables us to discriminate different forest types, grassland and plantations etc. using different spectral bands. The spectral bands available in this sensor are green (0.52 - 0.59 μm), red (0.62 - 0.68 μm), NIR (0.77 - 0.86 μm) and SWIR (1.55 - 1.70μm in LISS III only).

2.0 STUDY AREA

Six districts i.e. Mon, Longleng, Mokokchung, Wokha, Dimapur and Peren out of eleven districts of Nagaland were taken up for preparing the bamboo resource mapping study as per request for the Nagaland Pulp & Paper Company Limited, Tuli, Mokokchung, Nagaland. The locations of the study areas in Nagaland state are shown in Fig. 1.

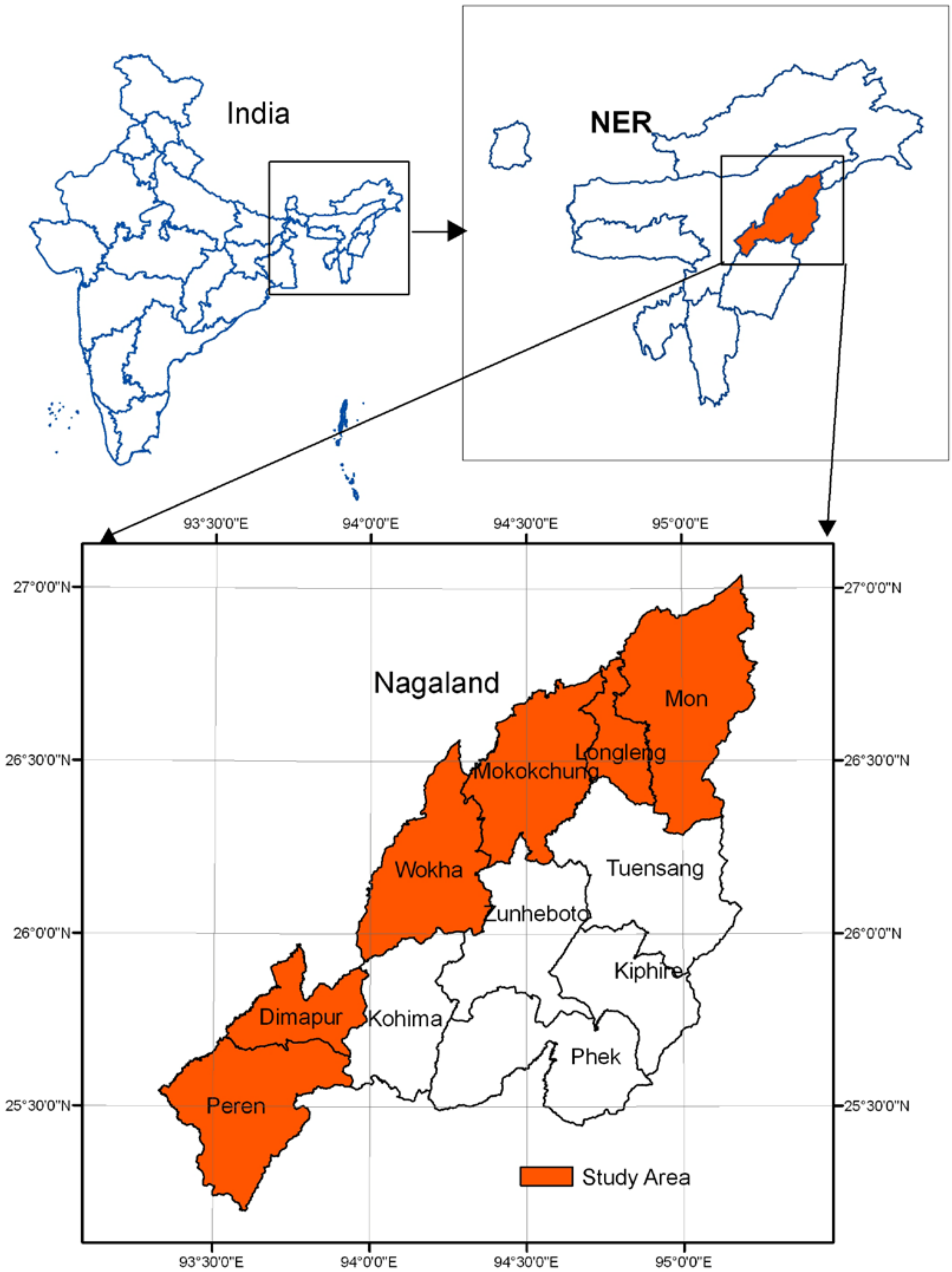

Fig.1. Study Area

3.0 METHODOLOGY:

A hybrid knowledge based approach, combining the strengths of human skills of object identification, machine-capability of image enhancement was used in the study. Purely digital image classification does not provide bamboo areas delineation at an accuracy desired by the user due to differences in radiometry, geometry and seasonal changes between different scenes. The emphasis here is to combine the visual interpretation techniques, fully supported by ground truth, heritage data/maps from State Forest Department and Survey of India to get best results from the remotely sensed data. The thematic maps were subjected to overall accuracy assessment and quality control. Bamboo growing areas were mapped on 1:12,500 scales as per the NNRMS Standards.

3.1 Satellite imagery used in the study

In this study, Indian Remote Sensing Satellite (IRS) P6 Linear Imaging Self Scanning (LISS) sensor type IV has been used to identify the bamboo growing areas of Nagaland. Due to non availability of cloud free LISS IV imagery of certain areas for the required period, IRS P6 LISS type III imagery was used to substitute the gap.

3.2 Preparation of satellite imagery for processing

3.2.1 *Acquisition of Remote Sensing Data*

The IRS P6 LISS IV imagery of February, 2008 – January, 2009 were acquired in the form of a CD-ROM product from NRSC Data Center ensuring cloud free coverage. It was subjected to various preprocessing techniques in order to obtain geographically referenced data. Steps involved in geometric correction, digital classification and extraction of area statistics are briefly discussed. The list of satellite imagery used in the study is given in table 4 & 5.

3.2.2 *Geometric Correction*

Remotely sensed data usually contain both systemic and non-systematic geometric errors. Some of the important systematic errors are Scan Skew, Mirror scan velocity, Panoramic distortion, Platform velocity, Earth rotation, Perspective, Altitude, etc. Because of these geometric errors, the satellite data immediately after acquisition is planimetrically not true to the ground features and standard topomaps.

Table 4: IRS LISS IV imagery used in the study

Sl. No.	Orbit No.	Path/Scene	Date of Pass
1	22819	101/51	10.03.2008
2	22819	101/52	10.03.2008
3	22819	101/53	10.03.2008
4	26570	101/44	29.11.2008
5	26570	101/45	29.11.2008
6	26570	101/46	29.11.2008
7	17363	101/51	20.02.2008
8	17363	101/51	20.02.2008
9	17363	101/53	17.01.2008
10	17363	101/54	17.01.2008
11	17363	101/55	17.01.2008
12	27181	102/30	11.01.2009
13	27181	102/31	11.01.2009
14	27181	102/32	11.01.2009
15	27181	102/33	11.01.2009
16	17022	101/52	27.01.2008
17	17022	101/53	27.01.2008
18	17022	101/54	27.01.2008
19	25888	102/30	12.10.2008
20	25888	102/31	12.10.2008
21	25888	102/32	12.10.2008
22	27181	102/34	11.01.2009
23	27181	102/35	11.01.2009
24	27181	102/36	11.01.2009
25	26158	101/09	31.10.2008
26	26158	101/10	31.10.2008

Table 5: IRS LISS III imagery used in the study

Sl. No.	Path	Scene	Date of Pass
1	113	053	08.01.2006
2	112	053	11.01.2009
3	112	054	04.02.2009

Hence, in order to measure/estimate area from the satellite data it has to be initially rectified to correct the geometric errors and made planimetrically true to standard topomaps. The systematic errors can be corrected through analysis of sensor characteristics. These errors are corrected in the preprocessing of data after initial data acquisition from satellite data. However, nonsystematic errors caused due to attitude (Pitch, Roll and Yaw) can be corrected only through the use of common Ground Control Points (GCP) (5).

The topomaps pertaining to the study area were referred for ancillary information. Common ground control points were selected on the raw satellite data as well as geo-referenced topographic sheets with proper spatial distribution covering the entire study area. The coordinates of the GCPs on the reference image and the corresponding coordinates of the similar GCPs on the raw satellite data were used in the geometric correction of the uncorrected satellite data. This was achieved using a first order polynomial transformation fit.

The geometric correction of the satellite data with reference to geo-referenced topo-base has been evaluated by superimposing geometrically corrected satellite data over mosaiced topomaps in the digital domain. Co-registration of spatial features on rectified image with that of topo-maps was verified using the swipe procedure. Such geometric rectification of satellite data facilitates overlaying of different administrative and infrastructure boundaries to extract and analyze the information at different functional units/levels. It was ensured that RMSE (Root Mean Square Error) was not more than a pixel for geometric rectification.

3.2.3 Visual Image Interpretation:

The satellite data (LISS IV MX) visually interpreted based on the tone, texture in conjunction with Survey of India topomaps and available literature on the subject. Different band combinations coupled with image enhancement techniques have been tried for better visualization. But it was found that standard false colour composite (FCC) with green, red and NIR band combination with image enhancement best suited for identifying the bamboo in hilly terrains under study.

Limited ground truth verification was carried out during January 11 – 15, 2010 and February 23 – 25, 2010 to check some of the doubtful areas after preliminary interpretation of imagery. GPS was used to reach the required places. Subsequently, this information was integrated in the interpreted thematic layers for generating the final output.

3.2.4 Quality Checking and Verification

After the maps are ready, quality assessment was done by QAS team of NESAC from the point of view of accuracy of interpretation by checking randomly a few polygons for their correctness from the ground truth information. The quality team also looked at digitization errors like node errors, sliver polygons, label errors etc.

3.3 Generation of statistics

3.3.1 Extraction of area statistics

After getting clearance from the quality team, area coverage for each polygon within each district was summarized to estimate the districtwise statistics for bamboo growing areas were generated in GIS environment.

3.3.2 Estimation of growing stock

Due to the time constraint, physical field survey for estimation of growing stock was not possible for this study. However, we have made some attempt to estimate the growing stock, readily available data sources. It is reported that the annual yield of bamboo per hectare in India varies from 0.2 and 0.4 tonnes with an average of 0.33 tonnes per hectare (dried bamboo). It is also reported that on average, 250 air-dried culms weigh one tone (9). Considering the fact, the average yield of such bamboo per hectare should be 80 to 90 culm per hectare which is very low in the NER region. Therefore, since, NPPCL has already conducted the extensive field survey, the data generated by them was used to estimate bamboo stock available in the six districts under study. It is also to be noted that, since, there is no field sample statistics available for Dimapur and Peren district, the data available for Wokha district (nearest available data) was used to calculate the growing stock for these two districts .

3.4 Base layers

Different base layers like road network, village locations, river/ water channels etc. used in map composition for the study area were from the available database at NESAC generated under ongoing activities carried out in the state.

4.0 RESULTS AND DISCUSSION

The False Colour Composite (FCC) image and the base map showing road network, river channels, village location for all six districts under study are given in figures 2, 3, 5, 6, 8, 9, 11, 12, 14, 15, 17 and 18.

Since the study was emphasized to identify the bamboo growing areas of six districts of Nagaland, accordingly the statistics generated only for bamboo areas of the state. The study is well supported by ground truth data and achieved accuracy of more than 80%. It is to be noted that the maps as well as the statistics generated in this study are for pure bamboo patches with maximum 20% mixed up with other forest categories. There may be more growing stock available in the state within the mixed bamboo areas (i.e. bamboo occupies less than 80% in the forest type).

Total Bamboo growing area in the six districts of Nagaland estimates as 41151.15 ha as compared to the total geographic area of 849600.00 ha of the districts. Individual districtwise estimate of bamboo growing areas are given in table 6. The actual geographic area of individual district has been calculated based on district boundary readily available at NESAC, which may have difference with the notified record.

Table 6: Districtwise estimate of bamboo growing areas of Nagaland (in ha)

SL. No	DISTRICTS	Geographical Area (TGA)	Area Under Bamboo (ha)	% Area covered
1	Mon	216200.00	5681.40	2.63
2	Longleng	56200.00	2174.79	3.87
3	Mokokchung	161600.00	12155.78	7.52
4	Wokha	160600.00	15888.35	9.89
5	Dimapur	81100.00	2672.20	3.29
6	Peren	173900.00	2578.63	1.48
Total		**849600.00**	**41151.15**	**4.84**

From the table 6, it is seen that the Wokha district has the largest share i.e 9.89% of the total geographic areas covers under bamboo followed by Mokokchung (7.52%) and Longleng (3.87%). The spatial distribution of bamboo areas in each district is shown in figure 4, 7, 10, 13, 16, and 19 respectively.

The estimated bamboo area in the Mon district is 5681.40 ha which only the 2.63 percent of the total geographic area. It is reported that Hill Jati (*Bambusa tulda*) occupy around 15.43 percent of total bamboo cover and rest is by Kako

(*Dendrocalamus hamiltonii*) and Tuli (*Melocanna baccifera*) species. The estimated average number of culms per hectare for Hill Jati is 4528 and for Kako/Tuli it is 1880. Therefore, 39.69 lakh culms of hill jati occupies around 876.64 ha in the Mon district. Accordingly, the Kako/Tuli bamboo occupies around 4807.76 ha growing approximately 9.03 lakh culms.

The estimated bamboo area in the Longleng district is 2174.79 ha which comprises 3.87 percent of the total geographic area. It is reported that Hill Jati occupy around 64.54 percent of total bamboo cover and rest is by Kako and Tuli species. The estimated average number of culms per hectare for Hill Jati is 7208 and for Kako/Tuli is 1661. Therefore, 101.17 lakh culms of hill jati occupies approximately 1403.61 ha in the Longleng district. Accordingly, the Kako/Tuli bamboo occupies around 771.18 ha growing approximately 1.28 lakh culms.

The estimated bamboo area in the Mokokchung district is 12155.78 ha which comprises 7.52 percent of the total geographic area. It is reported that Hill Jati occupy around 23.3 percent of total bamboo cover and rest is by Kako and Tuli species. The estimated average number of culms per hectare for Hill Jati is 7682 and for Kako/Tuli it is 1805. Therefore, 217.58.17 lakh culms of hill jati occupies around 2832.30 ha in the Mokokchung district. Accordingly, the Kako/Tuli bamboo occupies around 9323.48 ha growing approximately 168.29 lakh culms.

The estimated bamboo area in the Wokha district is 15888.35 ha which comprises 9.89 percent of the total geographic area. It is reported that Hill Jati occupy around 10 percent of total bamboo cover and rest is by Kako and Tuli species. The estimated average number of culms per hectare for Hill Jati is 6860 and for Kako/Tuli it is 2595. Therefore, 108.99 lakh culms of hill jati occupies around 1588.84 ha in the Wokha district. Accordingly, the Kako/Tuli baboo occupies around 14299.51 ha growing approximately 371.07 lakh culms.

The estimated bamboo area in the Dimapur district is 2672.20 ha which comprises 3.29 percent of the total geographic area. Since there is no field sample available for this district as mentioned earlier, nearest data available (wokha district) is used to calculate the growing stock. It is estimated that, 18.33 lakh culms of hill jati occupies around 267.22 ha in the Dimapur district. Accordingly, the Kako/Tuli baboo occupies around 2404.98 ha growing approximately 62.41 lakh culms.

The estimated bamboo area in the Peren district is 2578.63 ha which comprises 1.48 percent of the total geographic area. Since there is no field sample available for this district as mentioned earlier, nearest data available (wokha district) is used to

calculate the growing stock. It is estimated that, 17.69 lakh culms of hill jati occupies around 257.86 ha in the Peren district. Accordingly, the Kako/Tuli baboo occupies around 2320.77 ha growing approximately 60.22 lakh culms.
Details of estimation of bamboo culm growing in the six districts of Nagaland based on the information available from the user department are given in table 7.

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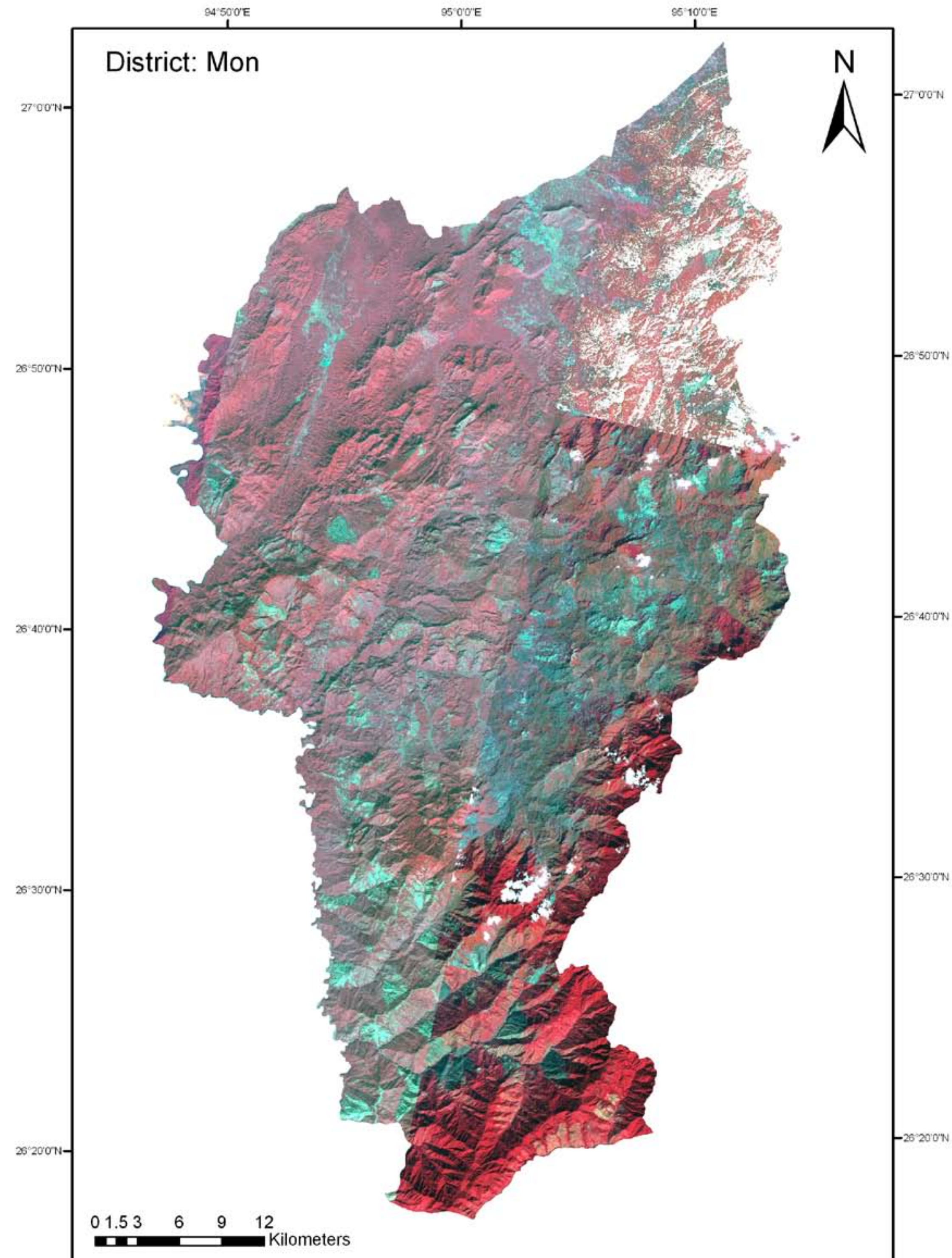
Table 7: Districtwise estimated bamboo culm in six districts of Nagaland

District	Total Bamboo area	Bamboo area (ha)		Average culm /ha		Total number of culms	
		Jati	Kako	Jati	Kako	Jati	Kako
Mon	5681.40	876.64	4807.76	4528	1880	3969426	9038589
Longleng	2174.79	1403.61	771.18	7208	1661	10117221	1280930
Mokokchung	12155.78	2832.30	9323.48	7682	1805	21757729	16828881
Wokha	15888.35	1588.84	14299.51	6860	2595	10899442	37107228
Dimapur	2672.20	267.22	2404.98	6860	2595	1833129	6240923
Peren	2578.63	257.86	2320.77	6860	2595	1768920	6022398
Total	**41151.15**	**7226.47**	**33927.68**			**50345867**	**76518949**



Satellite imagery of IRS P6 LISS - IV (2008-2009)

Fig.2. FCC image of Mon district

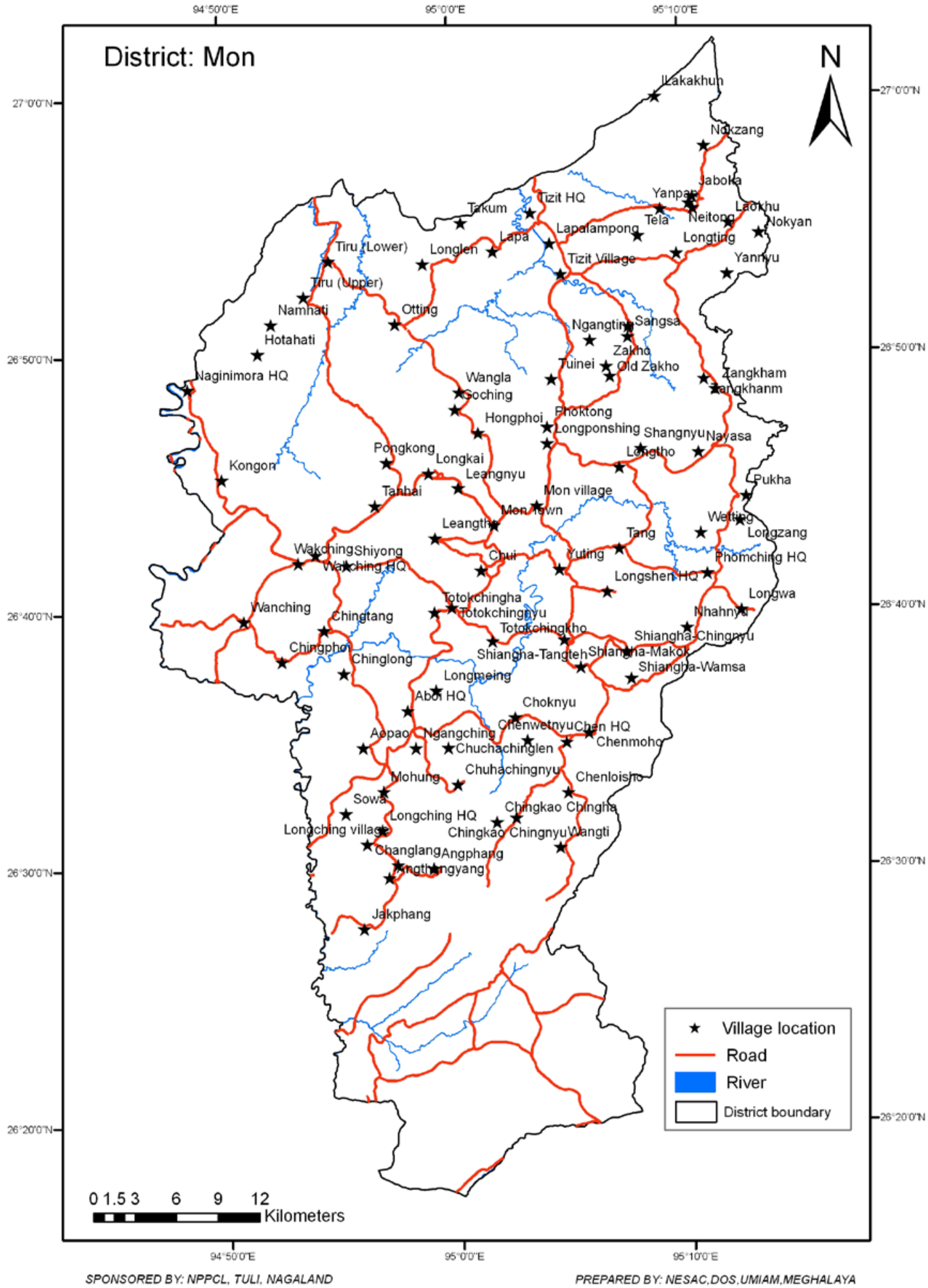


Fig.3. Base map of Mon district

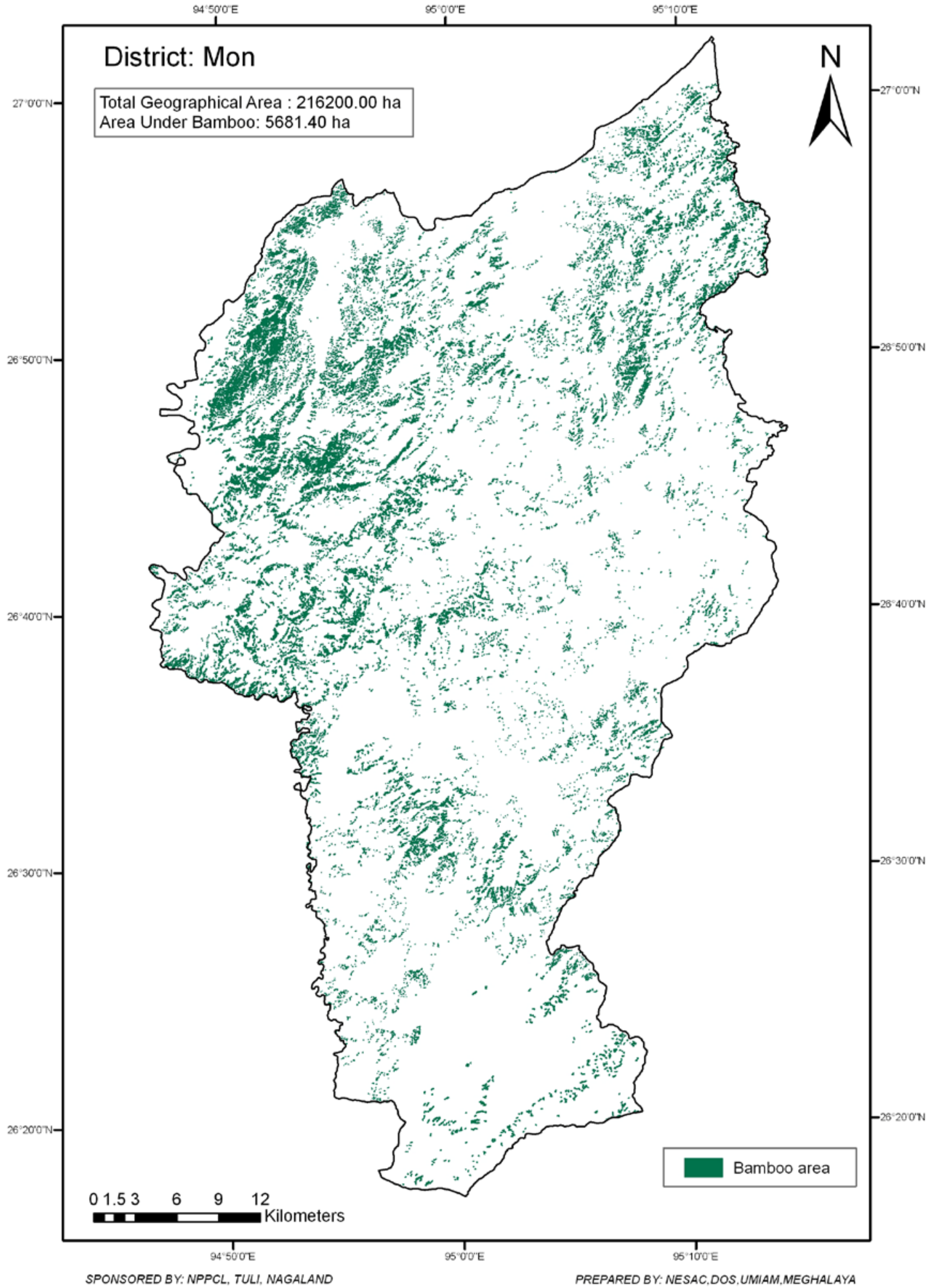


Fig.4. Bamboo cover map of Mon district

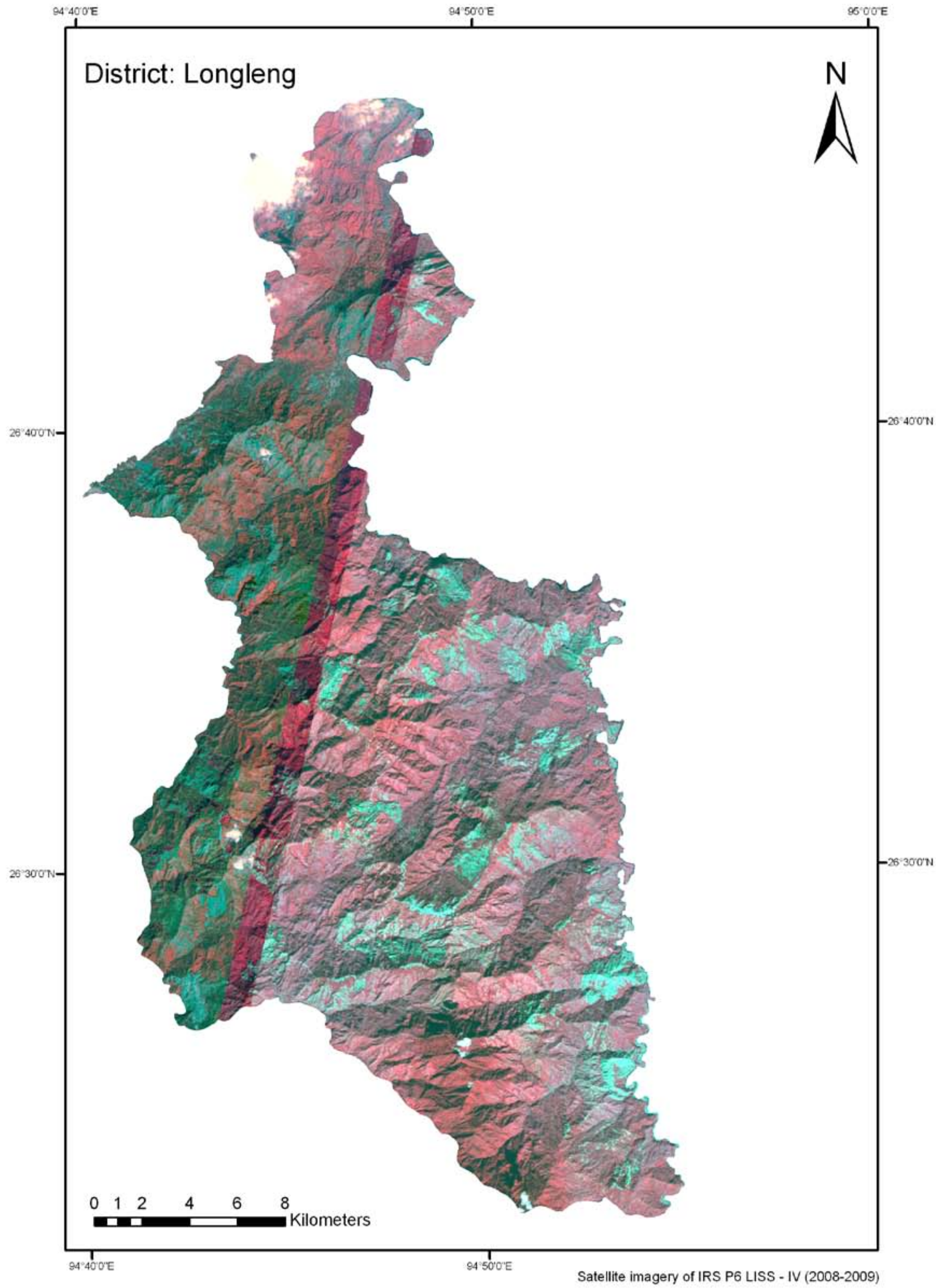


Fig.5. FCC image of Longleng district

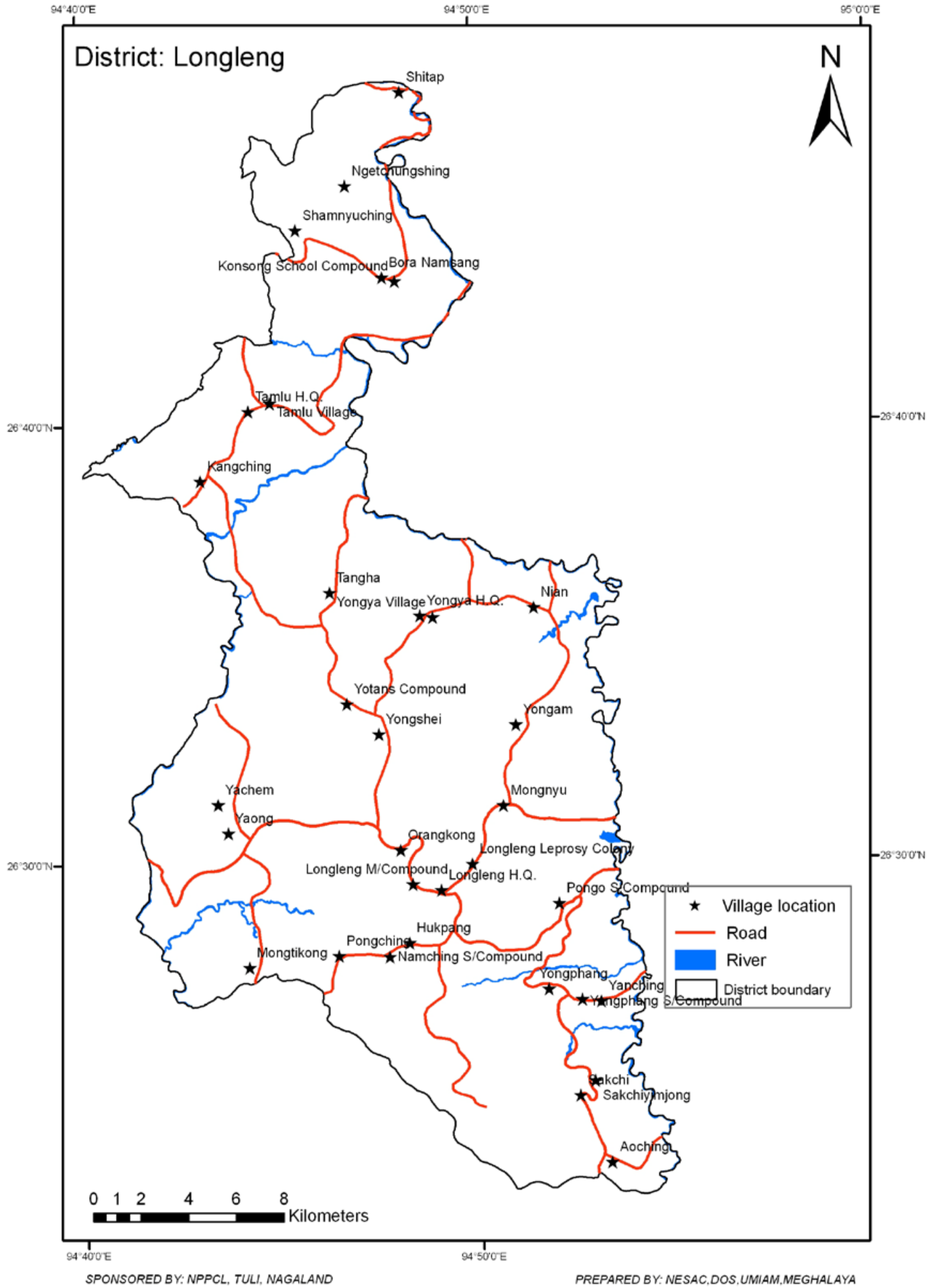


Fig.6. Base map of Longleng district

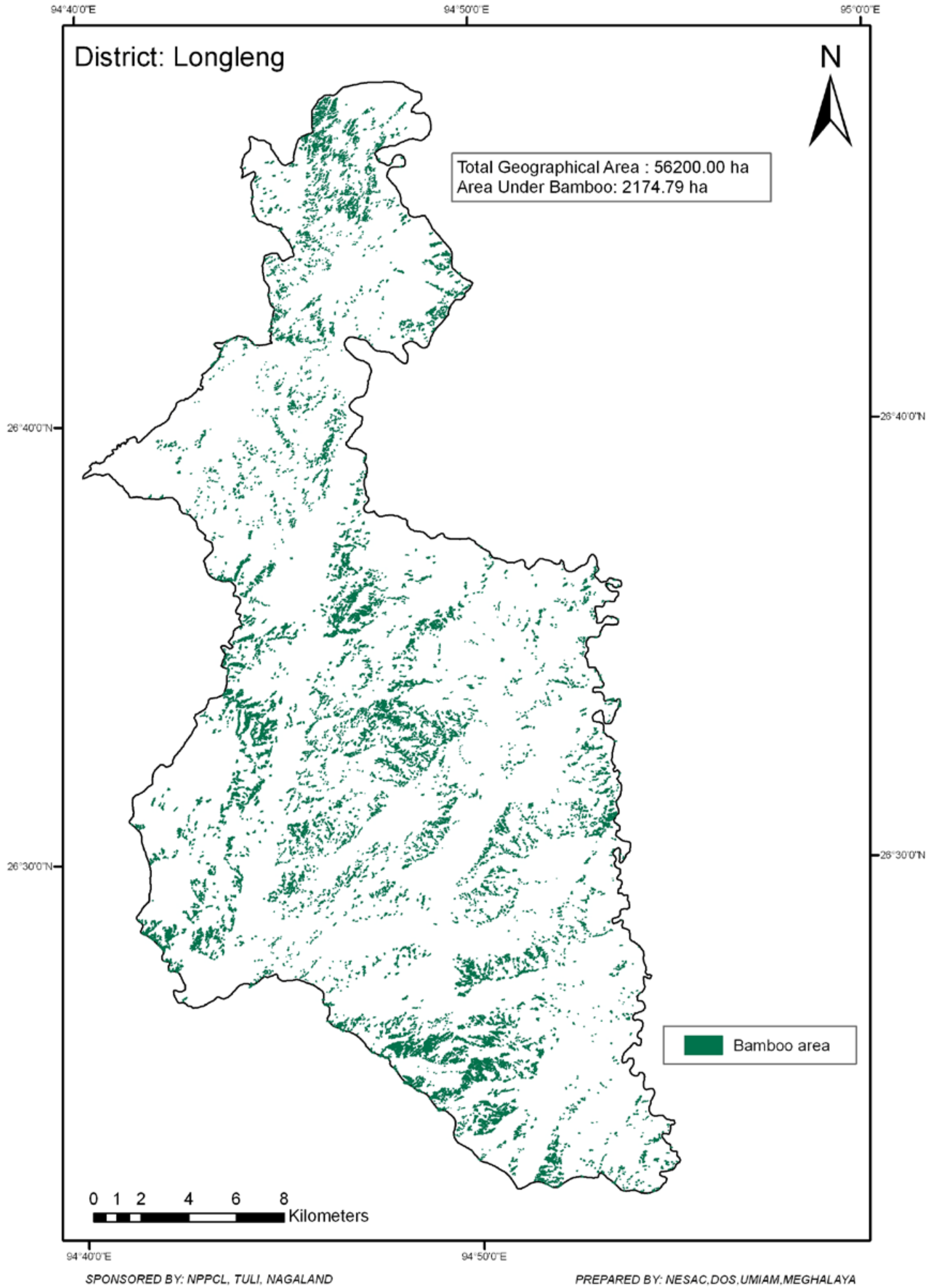


Fig.7. Base cover map of Longleng district

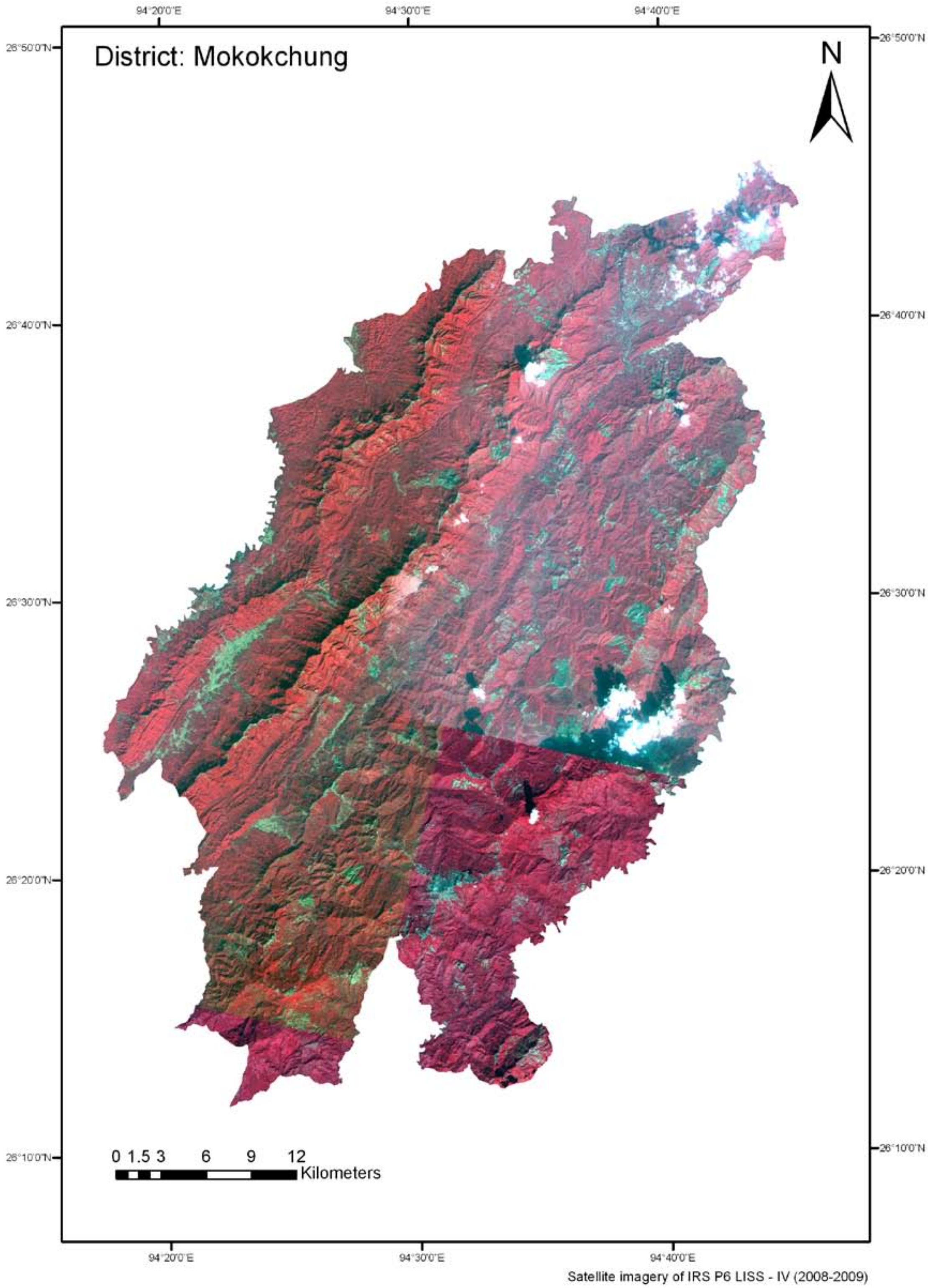


Fig.8. FCC image of Mokokchung district

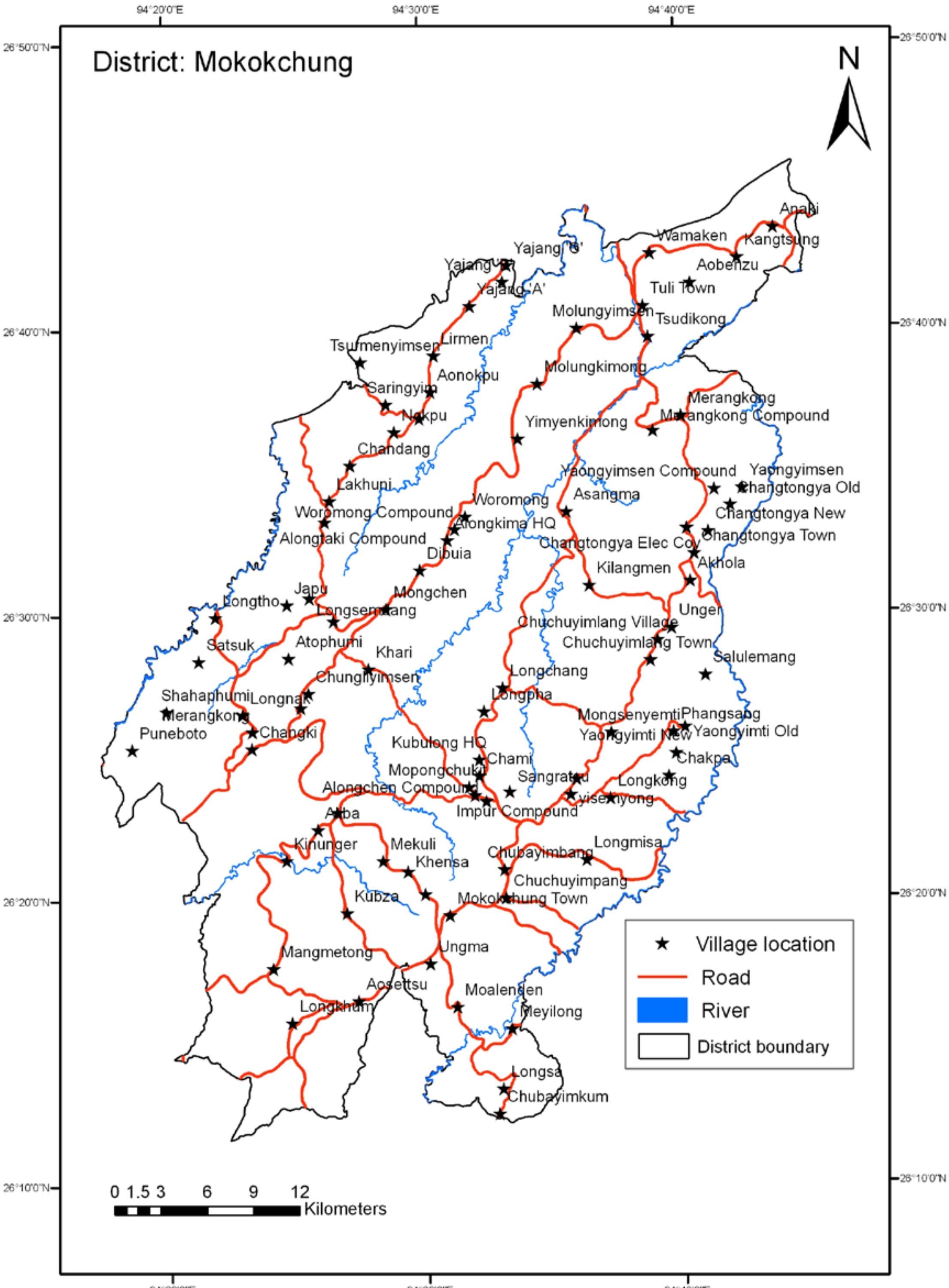


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Fig.9. Base map of Mokokchung district

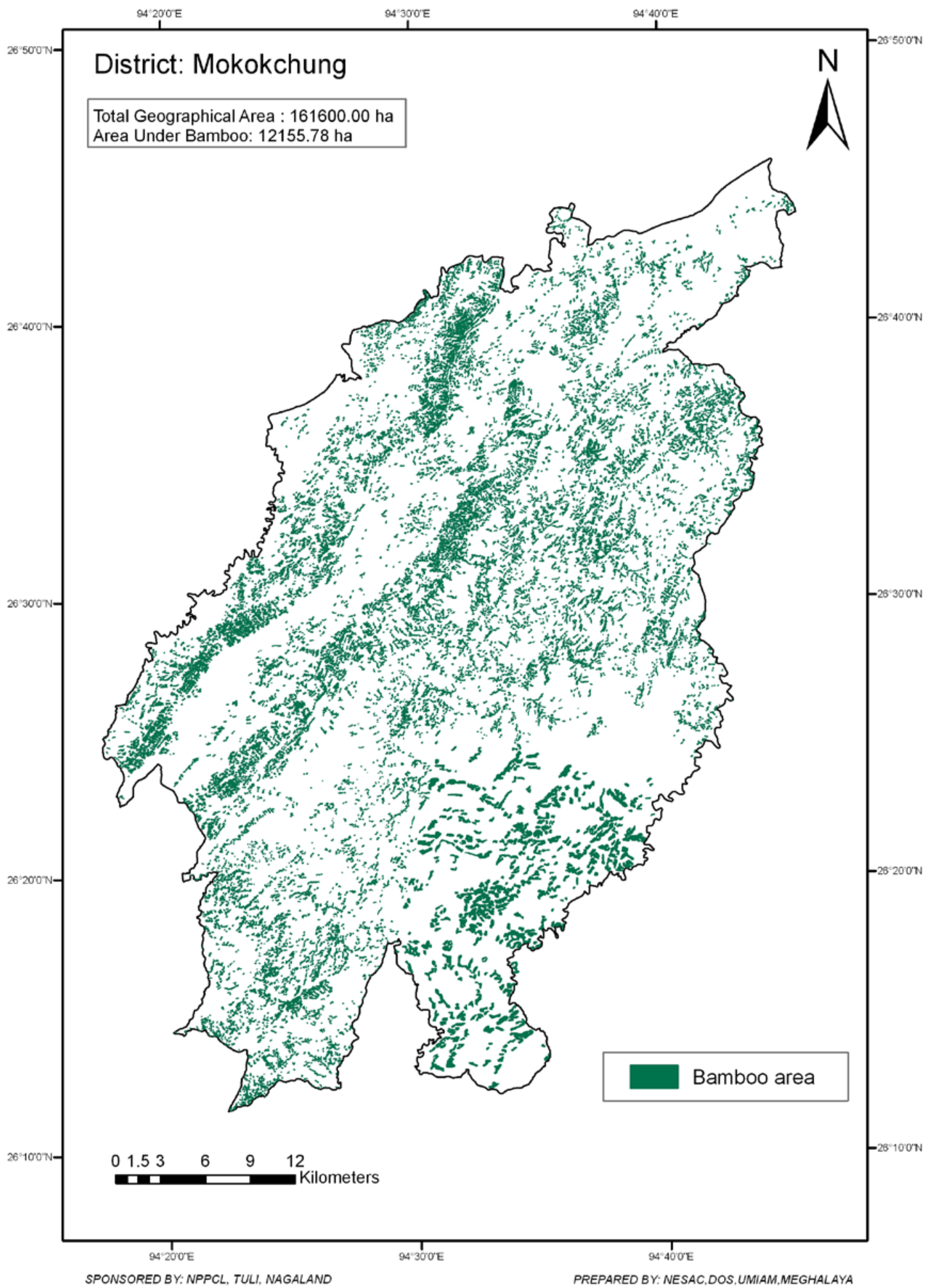

Fig.10. Bamboo cover map of Mokokchung district

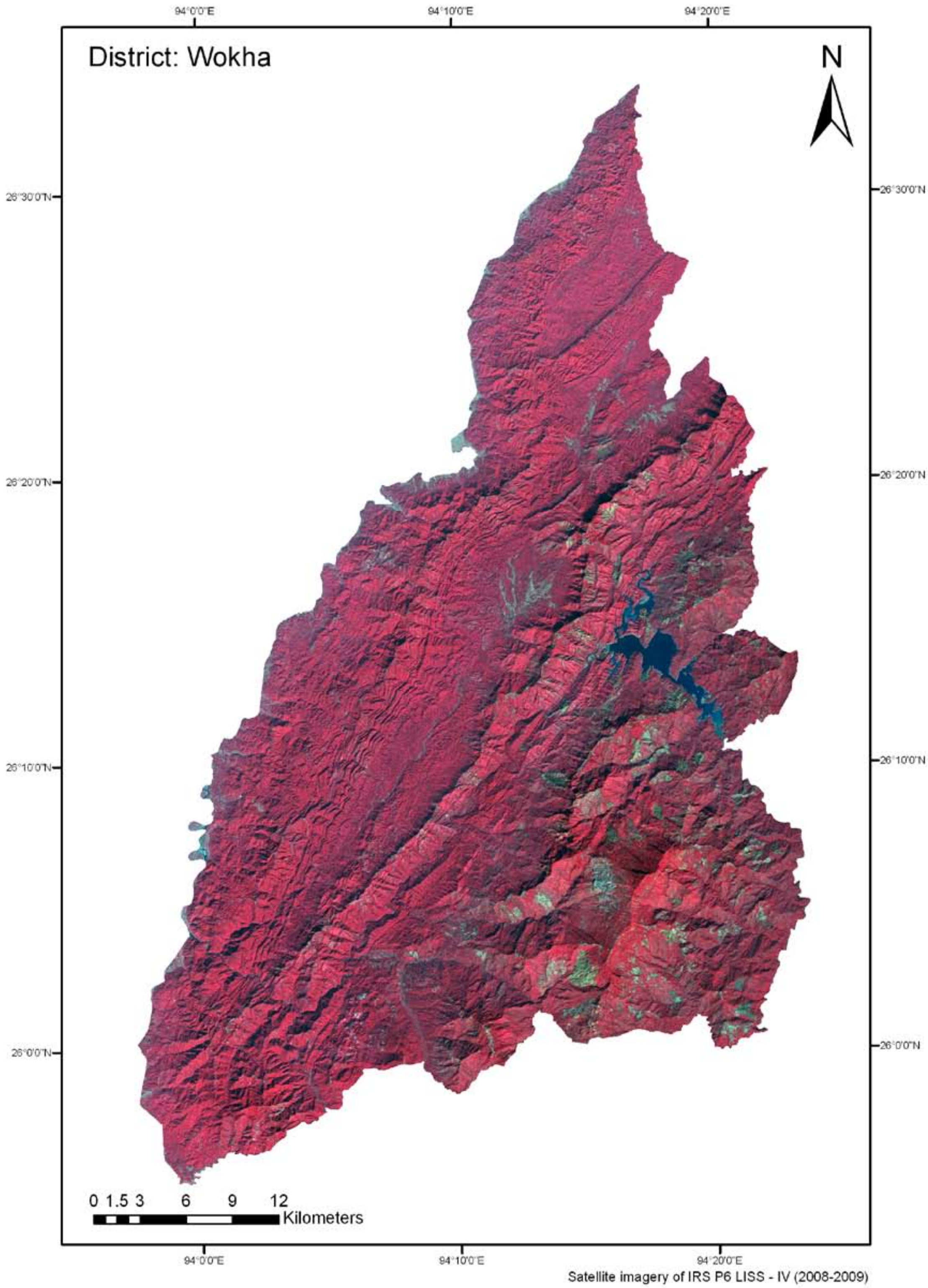

Fig.11. FCC image of Wokha district

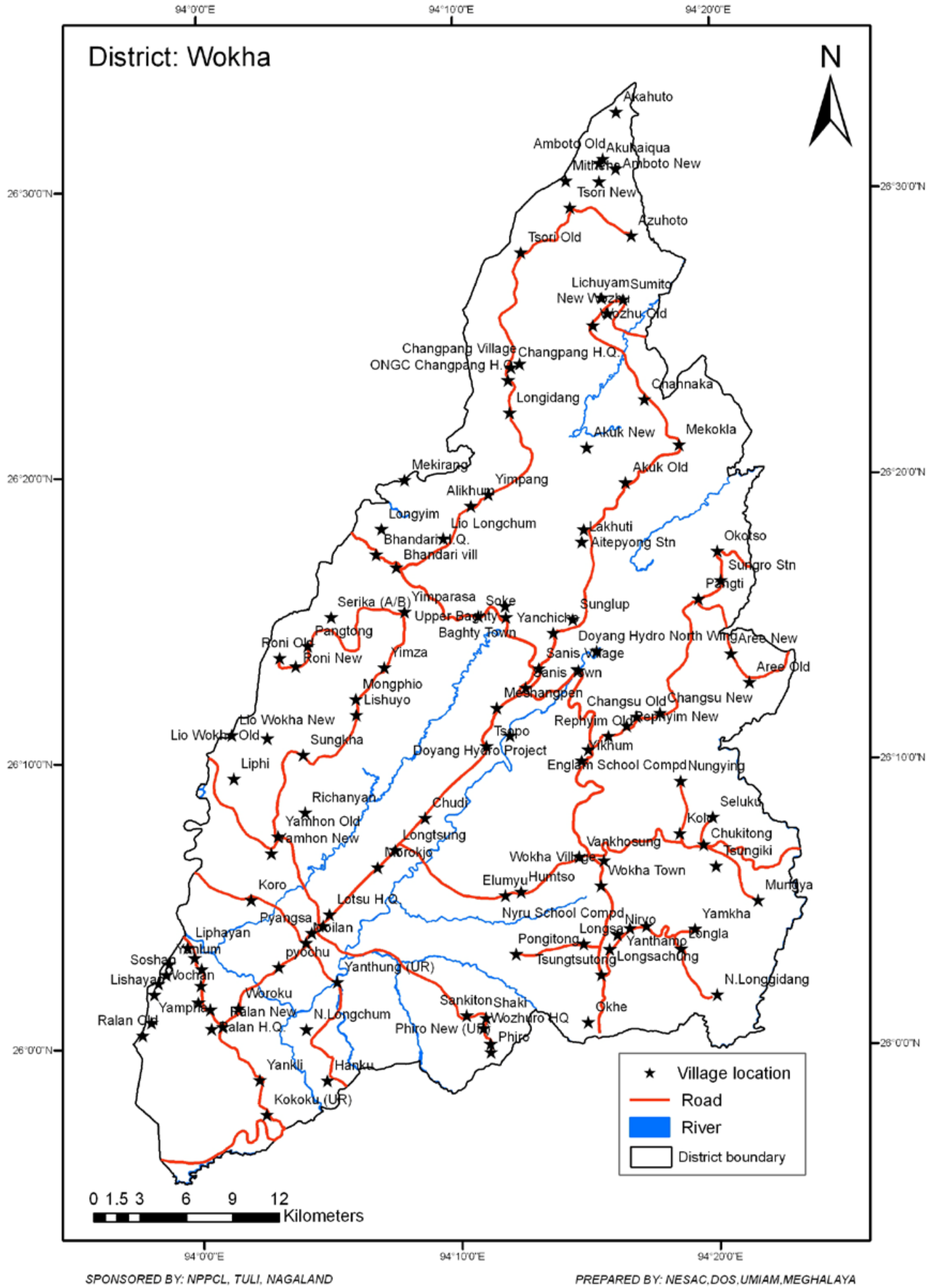

Fig.12. Base map of Wokha district

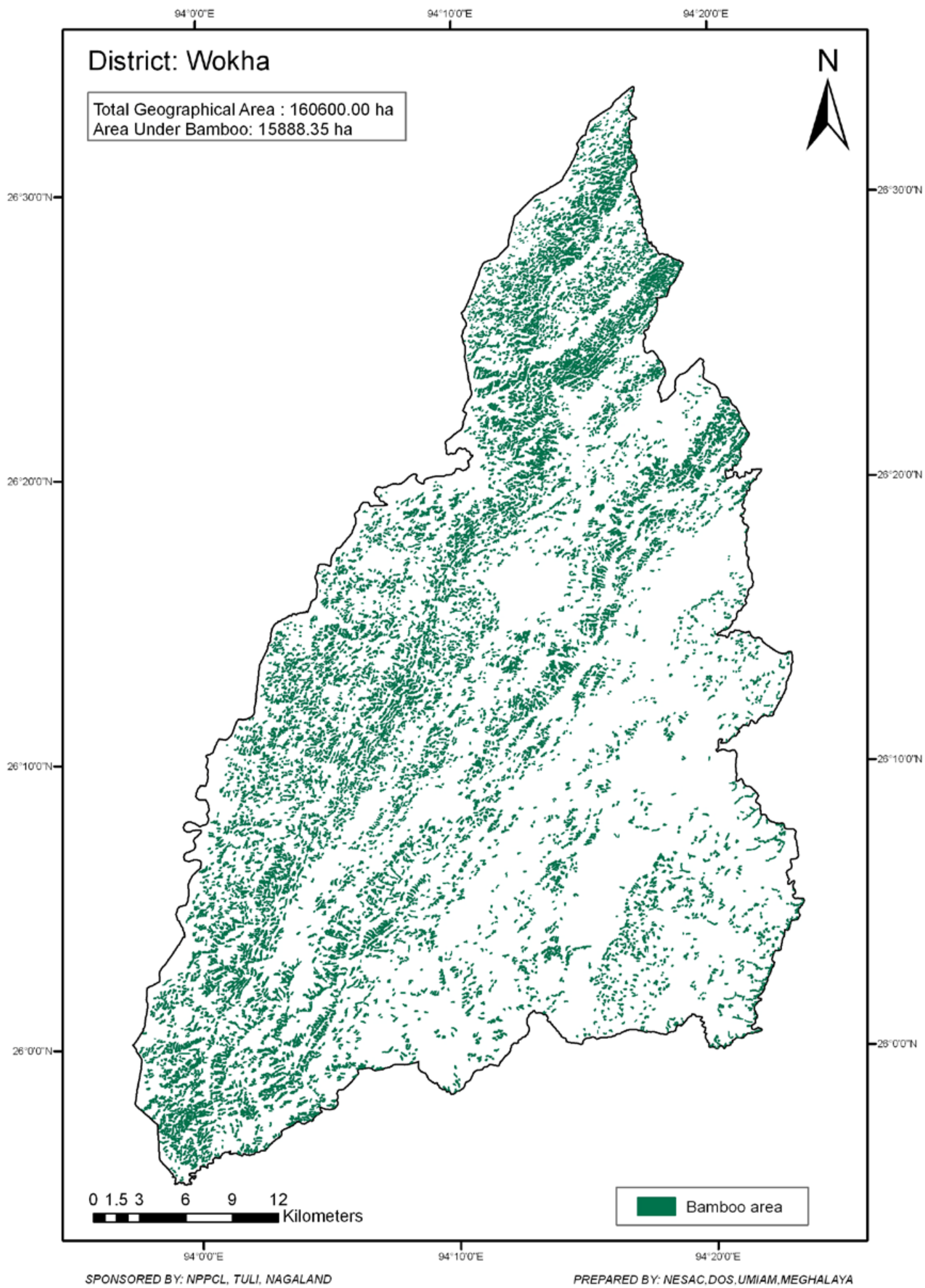

Fig.13. Bamboo map of Wokha district

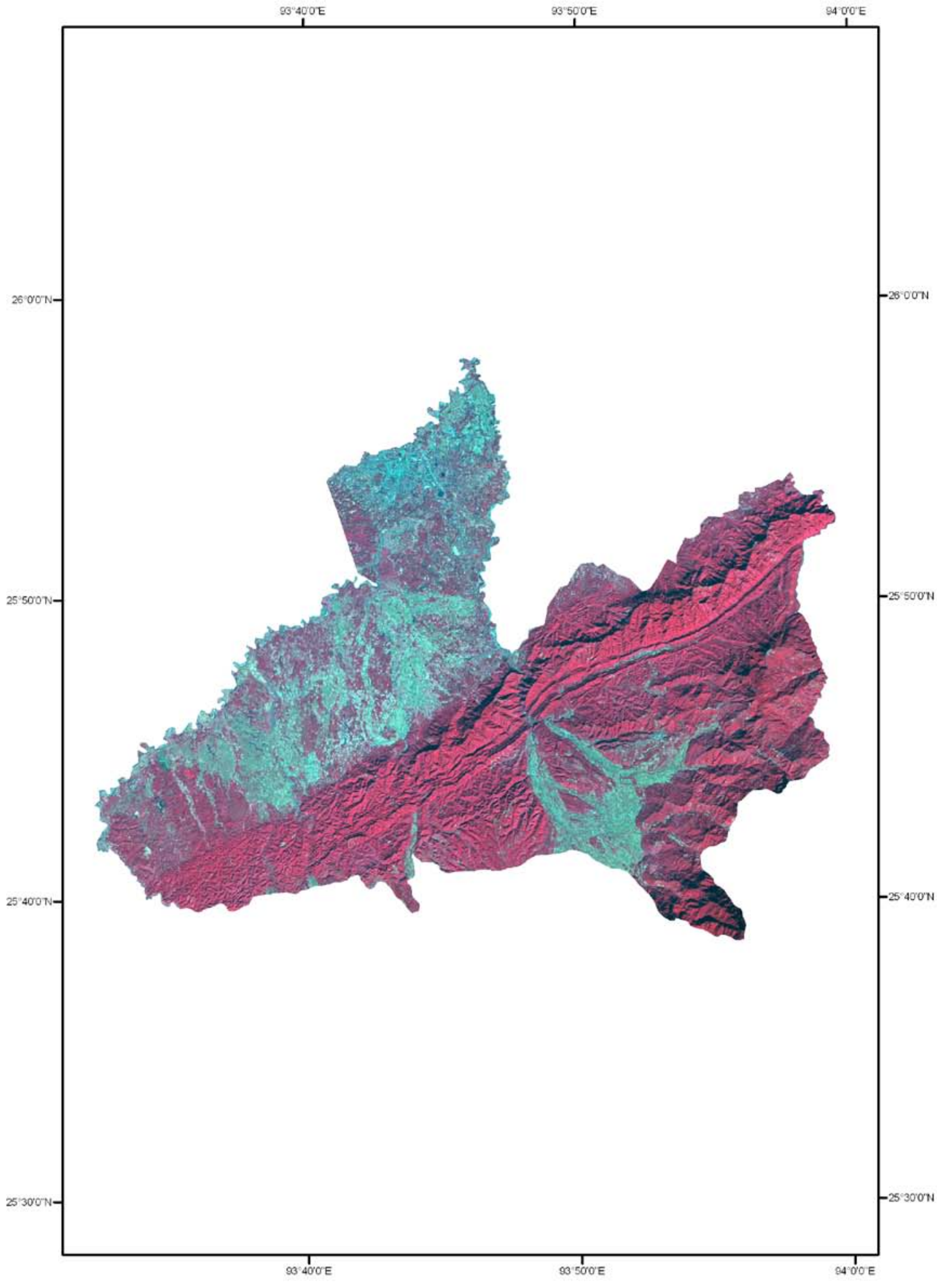

Fig.14. FCC image of Dimapur district

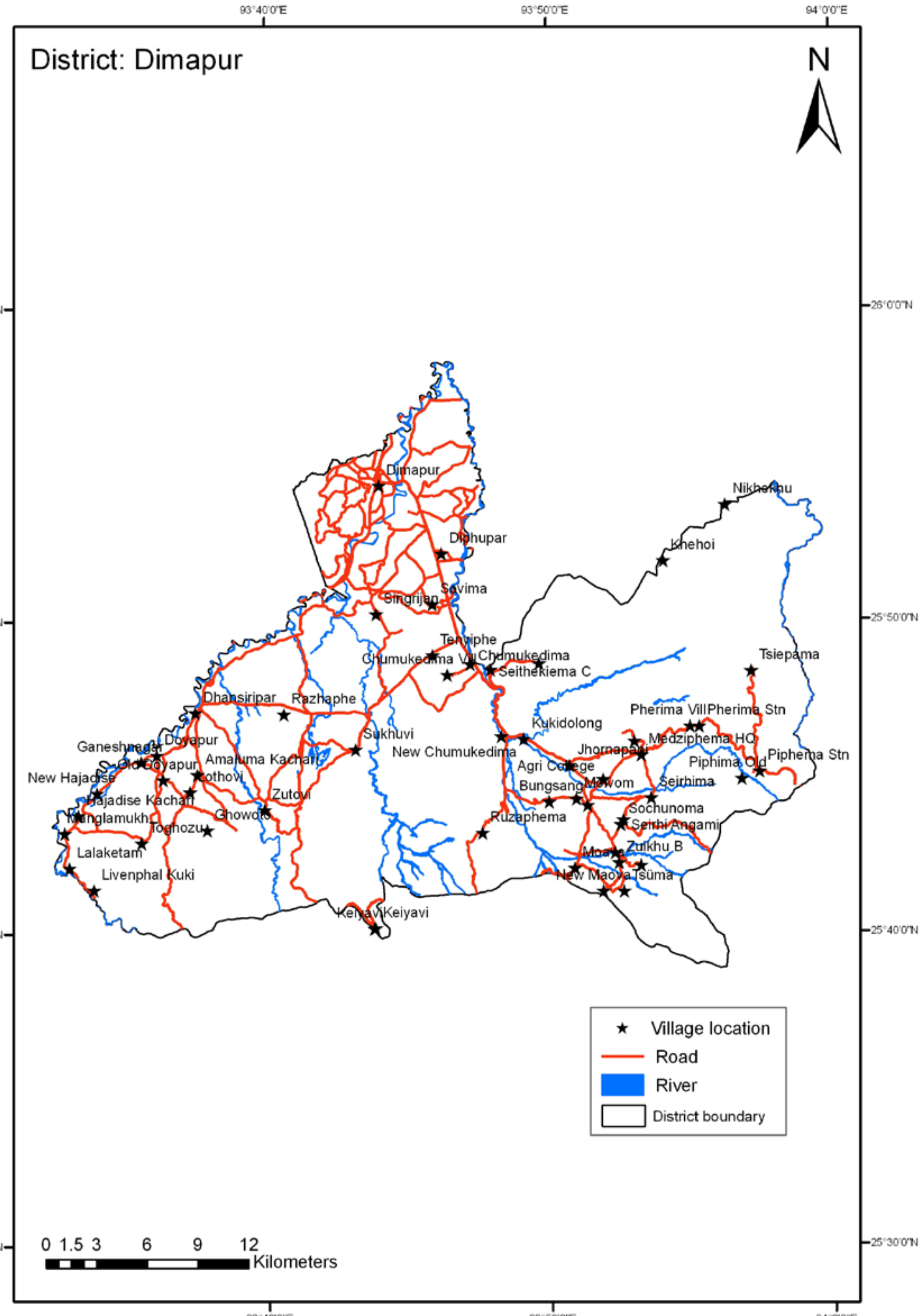

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Fig.15. Base map of Dimapur district

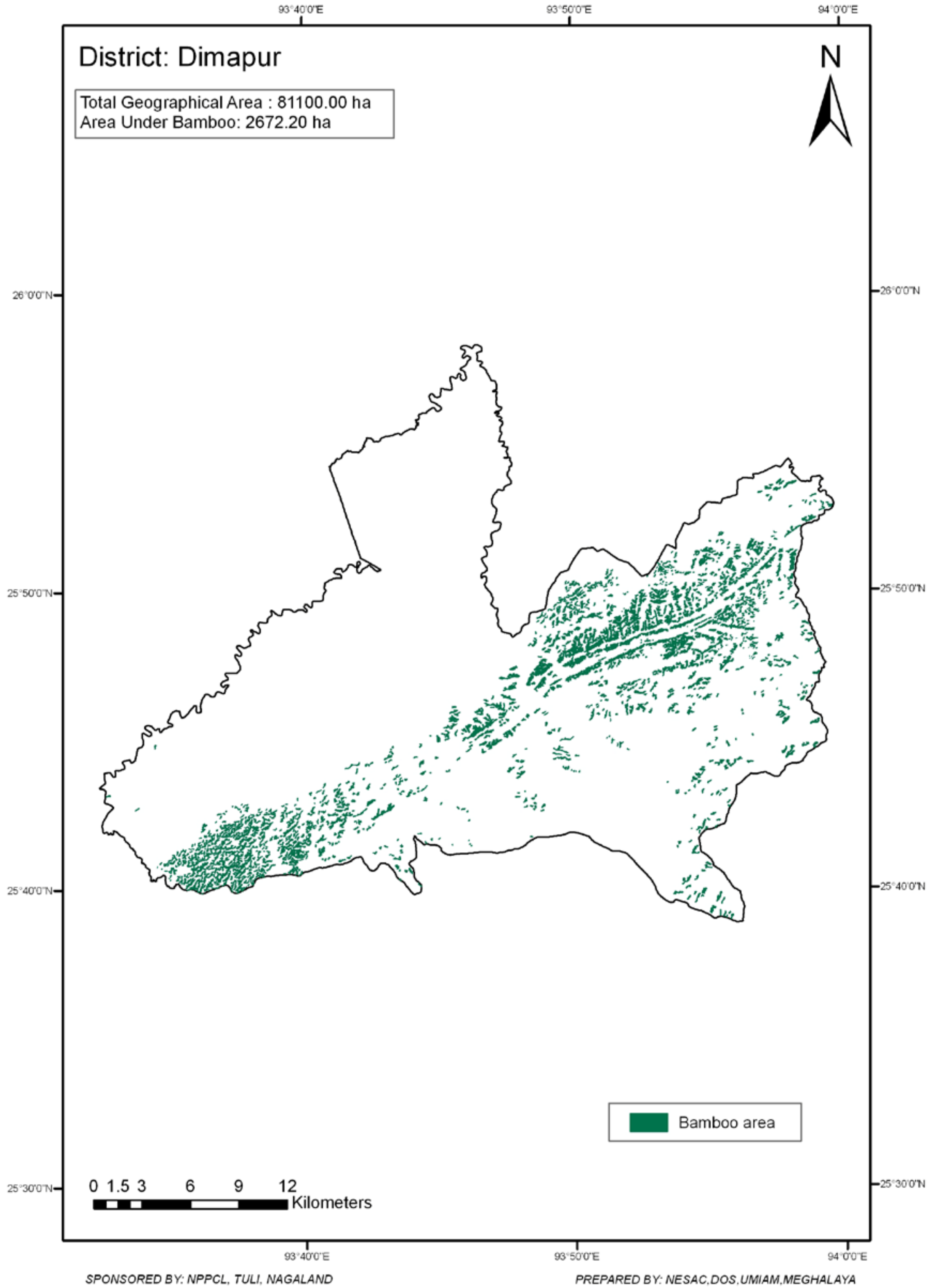

Fig.16. Bamboo cover map of Dimapur district

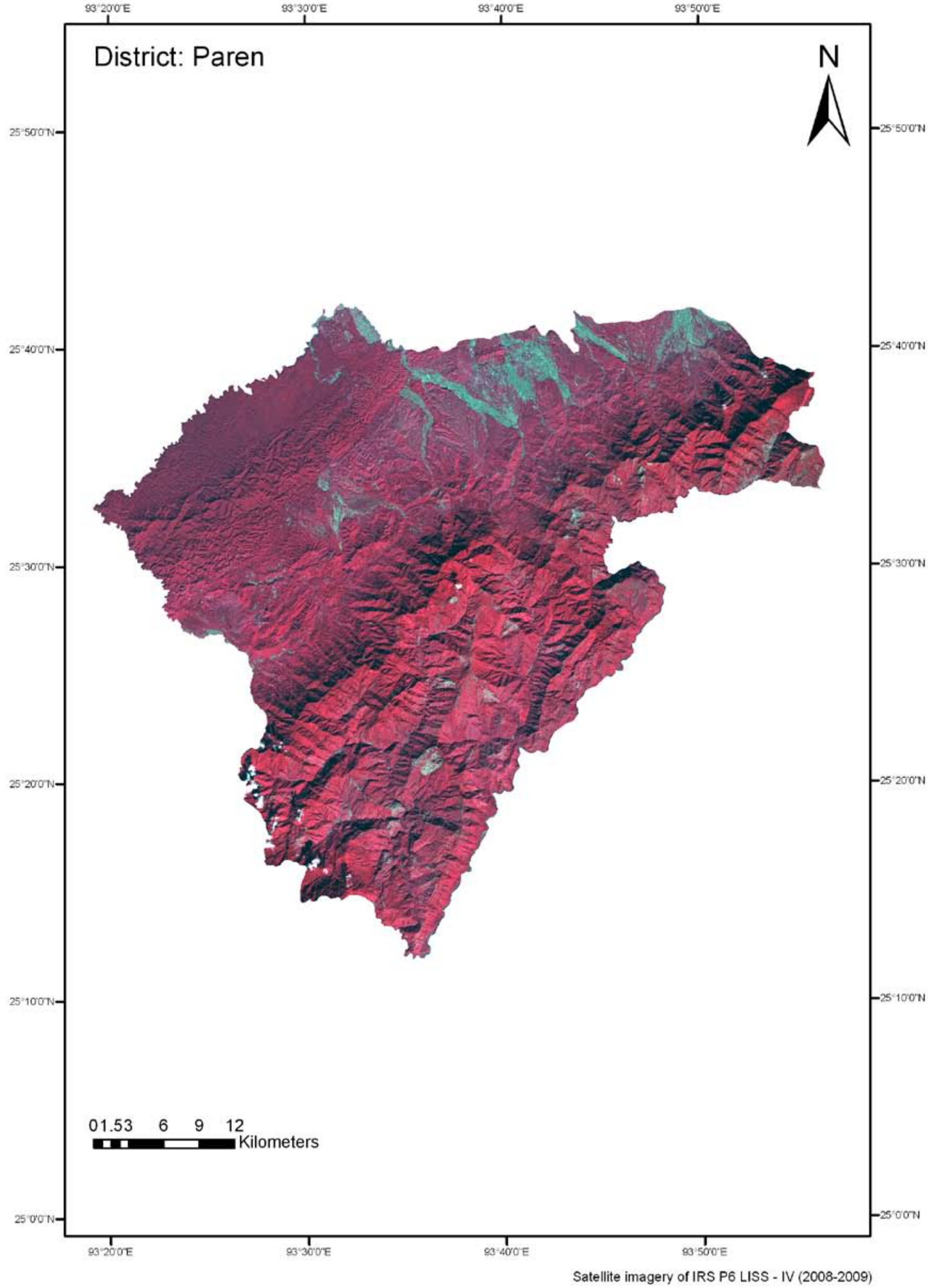

Fig.17. FCC image of Paren district

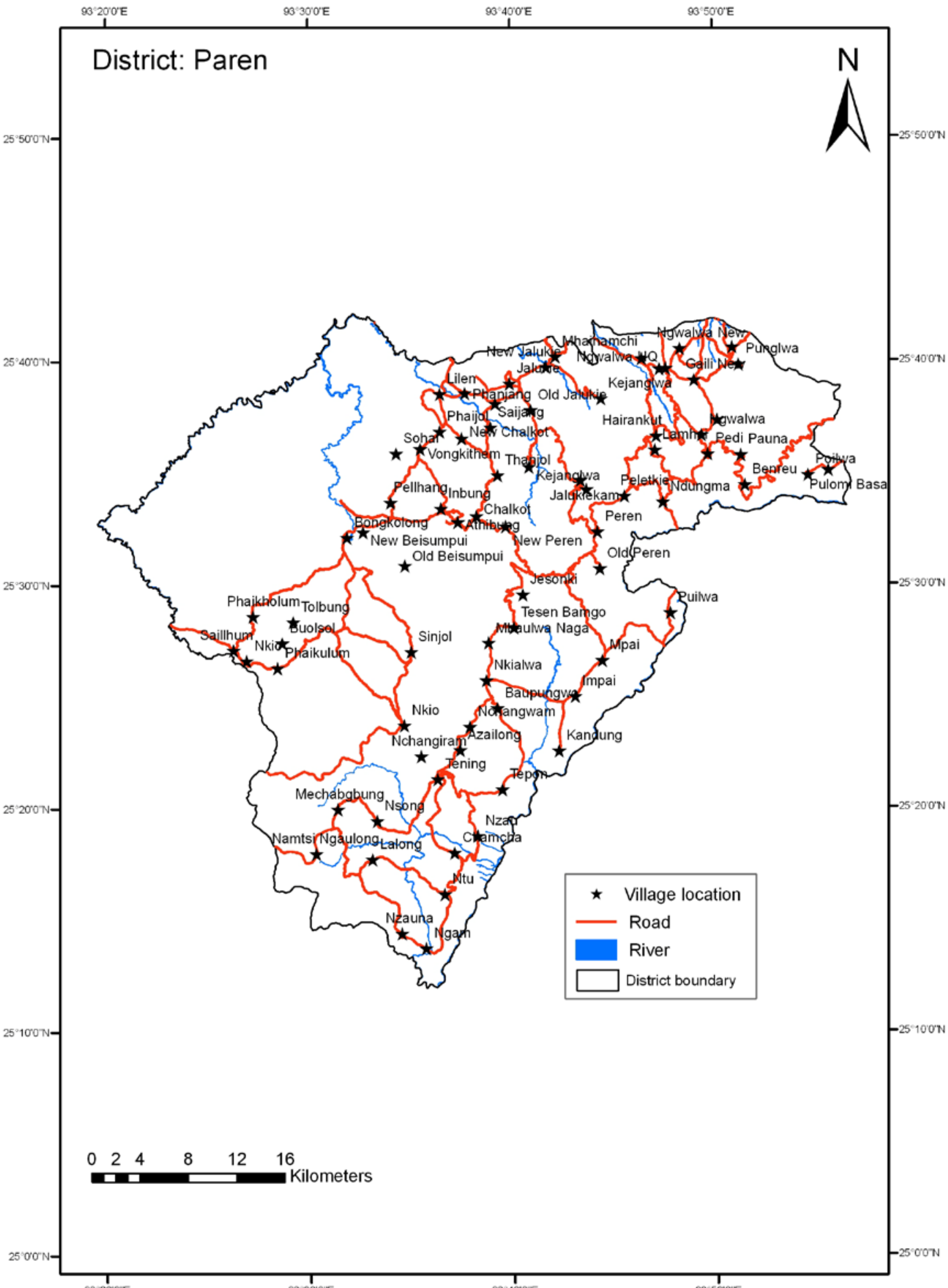

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Fig.18. Base map of Paren district

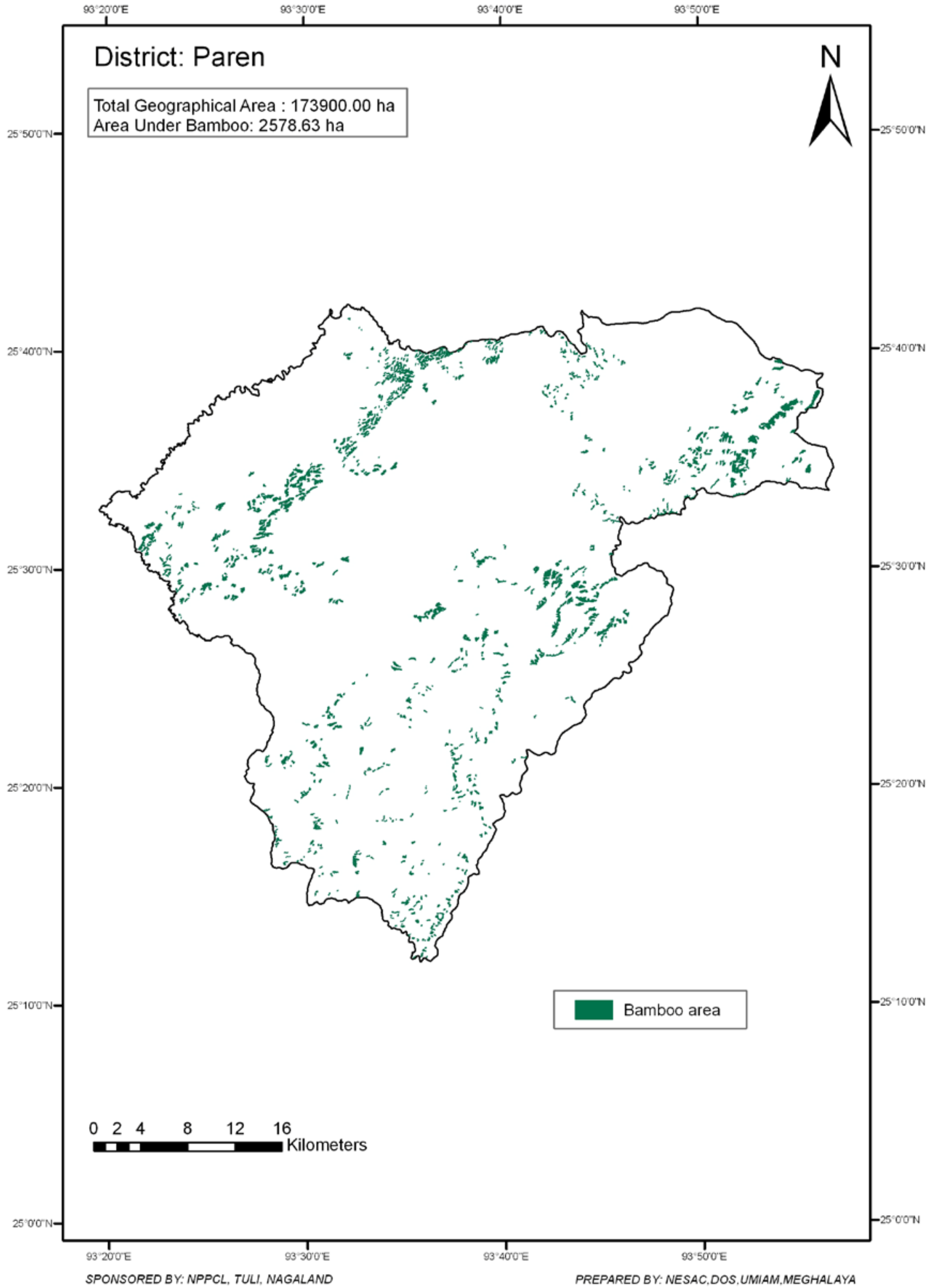


Fig.19. Bamboo cover map of Paren district

Plate 1: Glimpses of Ground truth Survey

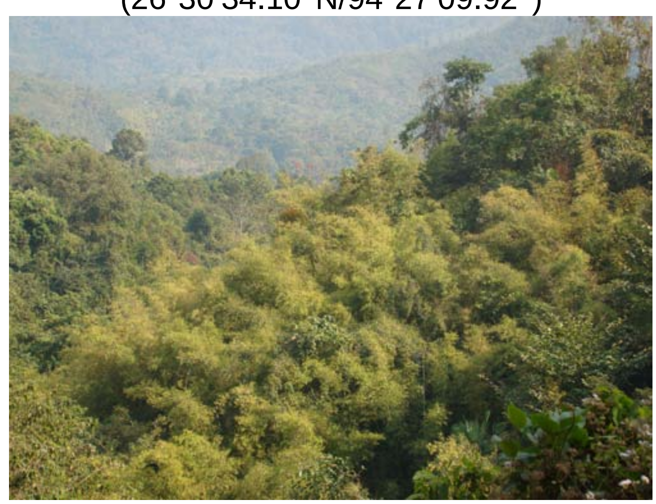
Pure Bamboo
(26°37’48.92’’N/94°33’59.02’’)

Pure Bamboo
(26°35’41.95’’N/94°33’41.18’’)

Roadside Bamboo
(26°30’22.22’’N/94°34’00.11’’)

Mixed Bamboo
(26°30’34.10’’N/94°27’09.92’’)

Bamboo patch
(26°29’53.44’’N/94°43’03.56’’)



Bamboo in valley
(26°24’07.11’’N/94°25’05.93’’)