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The Application of Satellite Data to Monitor the Encroachment of Agriculture on Forest Reserve in the Phu Luang Wildlife Sanctuary, Loei Province, Northeast of Thailand

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Abstract: Control and preventive measures are enforced rigidly to minimize the encroachment on forest reserves in the Phu Luang Wildlife Sanctuary (PLWS), a forest area set aside as a wildlife habitat in the North of Thailand, near the Laos border. However, even with these measures in place the forest area is still continuously encroached upon due to a population increase. The purpose of this study was to monitor the encroachment of agriculture on forest reserve in the PLWS. In order to achieve this, remote sensing technology, which is ideal for monitoring the forest change, coupled with multi-dates satellite data were used to meet the objective. Four dates of Landsat data acquired in 1994, 1997, 2001, 2005 and two dates of THEOS data acquired in 2010 were used to produce multi-temporal land use maps in the study area by visual interpretation. These maps were then overlaid using GIS technology to analyze the forest area that had been converted to agricultural land. The results showed that the forest had been gradually depleted by 6,247 ha (6.96%), from 61,069 ha in 1994 to 54,822 ha in 2010. Agriculture had increased by 5,879 ha (6.44%), from 27,107 ha in 1994 to 32,986 ha in 2010.

Key words: Landuse change, encroachment of agriculture, forest reserve, Phu Luang wildlife sanctuary.

1. Introduction

The Phu Luang Wildlife Sanctuary is one of the 57 wildlife sanctuaries of Thailand. As a sanctuary it is one of the best ways to maintain forest areas as a wildlife habitat. Control and preventive measures are enforced rigidly to minimize the encroachment on forest reserves, which is considered to be one of the largest sources of flora and fauna in Thailand with a diverse ecosystem and abundant forestry resources that makes it unique in the area [1, 2]. However, even with the preventive measures in place at the wildlife sanctuary the forest area is still being encroached upon and converted to agricultural land using slash-and-burn techniques. To enhance the efficiency of the protection, regeneration and utilization of forest resources, information about these changes is required. These include an inventory, periodical monitoring and the causes of changes [3, 4]. Change detection has become a major application of remotely sensed data because of repetitive coverage at short intervals and consistent image quality [5]. Satellite imagery has been used to monitor discrete land cover types by spectral classification or to estimate biophysical characteristics of land surfaces via linear relationships with spectral reflectance or indices [6]. The resulting updated and multi-temporal information can be employed to detect the changes. GIS technology provides a flexible

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environment for storing, analyzing, and displaying digital data necessary for change detection and database development [7, 8]. This information can be used for wildlife habitat protection, planning and long-term policy setting.

2. Objective

The purpose of this study is to monitor the encroachment of agriculture on a forest reserve with the use of multi-temporal satellite data.

3. Study Area

The study area, PLWS, is located in the Phu Luang District in the southern part of the Loei Province, NE of Thailand (Fig. 1). Its coverage area is approximately 897 square kilometers (89,697 ha). It lies between

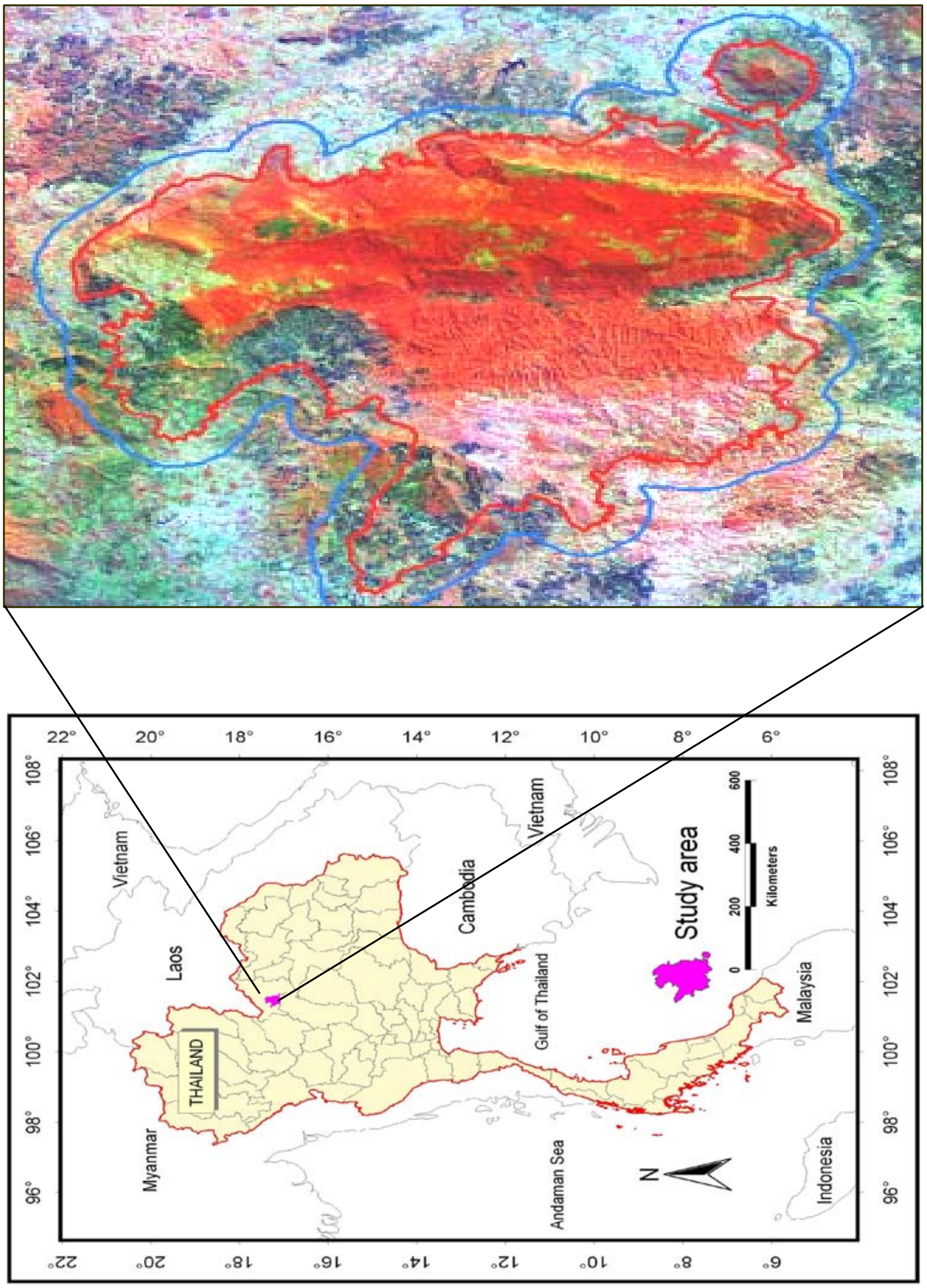

Fig. 1 Study area.

latitude 17°3′ and 17°24′ N and longitude 101°16′ to 101°21’ E. It is a mountainous area with an escarpment in the East. The height of its summit is about 1,600 m.msl.

It is characterized by a number of hills with a thick sequence of Mesozoicrock of Phu Kradung, Soa Khua, Pha Dua, Phu Phan and Phra Wihan Formations. The areas support two main forest types: evergreen and deciduous forests. The mean annual rainfall of the area varies from 1,200-1,400 mm, with over 60% of the annual rainfall falling in August and September [1]. The average temperature in summer (February-April) is between 20 degrees Celsius and 24 degrees Celsius, and it varies from 0 degrees Celsius to 16 degrees Celsius in winter which starts from November to January.

4. Methods and Data

The procedure of methodology and data used are illustrated in Fig. 2. The details are as follows:

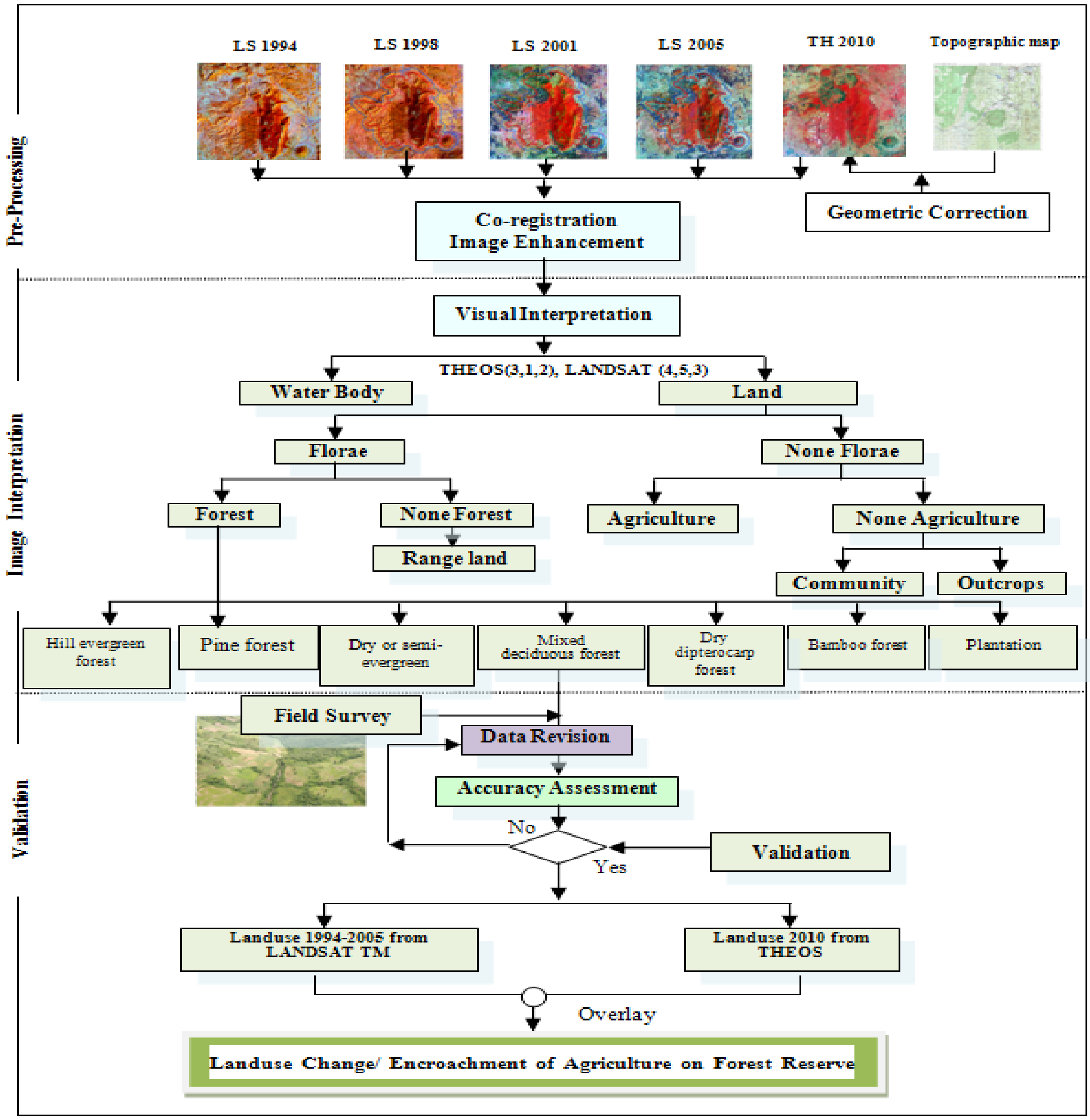

Fig. 2 The methodology procedure.

Four Landsat data acquired in 1994, 1998, 2001 and 2005 were obtained from the Regional Centre for Geo-Informatics and Space Technology, Northeast Thailand and two scenes of THEOS data, acquired on March 1st and 6th, 2010, from the Geo-Informatics and Space Technology Development Agency (GISTDA) were used to produce multi-temporal landuse maps.

Topographic maps of the Royal Thai Survey Department at the scale of 1:50,000 were used for geo-referencing and supplementary information.

Landuse maps in 1998 and 2005 obtained from the Regional Centre for Geo-Informatics and Space Technology, Northeast Thailand were used for reference.

Two scenes of THEOS data were mergec into one image which was geo-referenced using the ground control points obtained from the topographic map at scale of 1:50,000. A nearest neighbor interpolation algorithm was performed. The four dates of Landsat TM data were co-registered to the geo-coded THEOS image.

The colour combination of bands 3, 1, 2 (RGB) of the THEOS data and bands 4, 5, 3 (RGB) of the Landsat TM data were visually interpreted landuse categories. ARCGIS software was used to delineate landuse type. A hierarchical interpretative scheme [9] was devised which consisted of the following steps: firstly, directly-observable features such as water bodies water channels, roads and community areas were identified; secondly, stratification of the target area, based on colour, texture and pattern of the imagery was carried out and general features of the area being mapped were noted. Sampling sites for field survey were also identified at this stage; landuse patterns were identified with particular reference to the classification schemes as used by the Land Development Department [10].

Field surveys were carried out to increase map accuracy. The field investigation provided site characteristics as related to the image features. The 221 ground sites of different landuse categories were explored to identify cover type and their composition, topography and land types as related to image elements. The obtained map was checked against the ground-truth data and a confusion matrix [11] was applied to validate the obtained results.

To analyze the encroachment of agriculture on forest reserve area, a comparison of a pair of landuse maps between the year 1994 and 1998, 1998 and 2001, 2001 and 2005, and 2005 and 2010 was carried out to obtain the landuse change maps [12]. The statistics of the changed class were calculated. The intention of this study was to monitor the change of forest and agricultural classes.

5. Results and Discussion

The landuse maps and the acreage of the PLWS for the years 1994, 1998, 2001, 2005, 2010, based on the multi-temporal data of Landsat TM and THEOS, are shown in Fig. 3 and Table 1. The encroachment of agricultural areas on the forest areas in the PLWS had greatly increased from about 30.22% in 1994 to 36.77% in 2010, representing agricultural areas in the PLWS of about 32,986 ha for the year 2010. The total forest areas in the PLWS accounted for 68.08%, 64.60%, 63.27%, 61.89% and 61.12 % for the years 1994, 1998, 2001, 2005 and 2010 respectively. The obtained results indicate that the majority of the forest type was restricted to hill evergreen and dry evergreen forests, with over 70% of the total forest area. To date, in the PLWS the forest cover represents about 61.12%. The depletion in forest areas by type was 1.51%, 2.85% and 1% for hill evergreen, dry evergreen and dry dipterocarp forests respectively (Fig. 4 and Table 2). The rate of forest change in the PLWS for the periods 1994-1998, 1998-2001, 2001-2005 and 2005-2010 accounted for -3.48%, -1.33%, -1.38% and -0.77% respectively, with an overall depletion rate (1994-2010) of 6.96% (Table 2). Significant changes were found during the period 1994-1998 with a progressive decrease in changes after 1998, during which the preventive

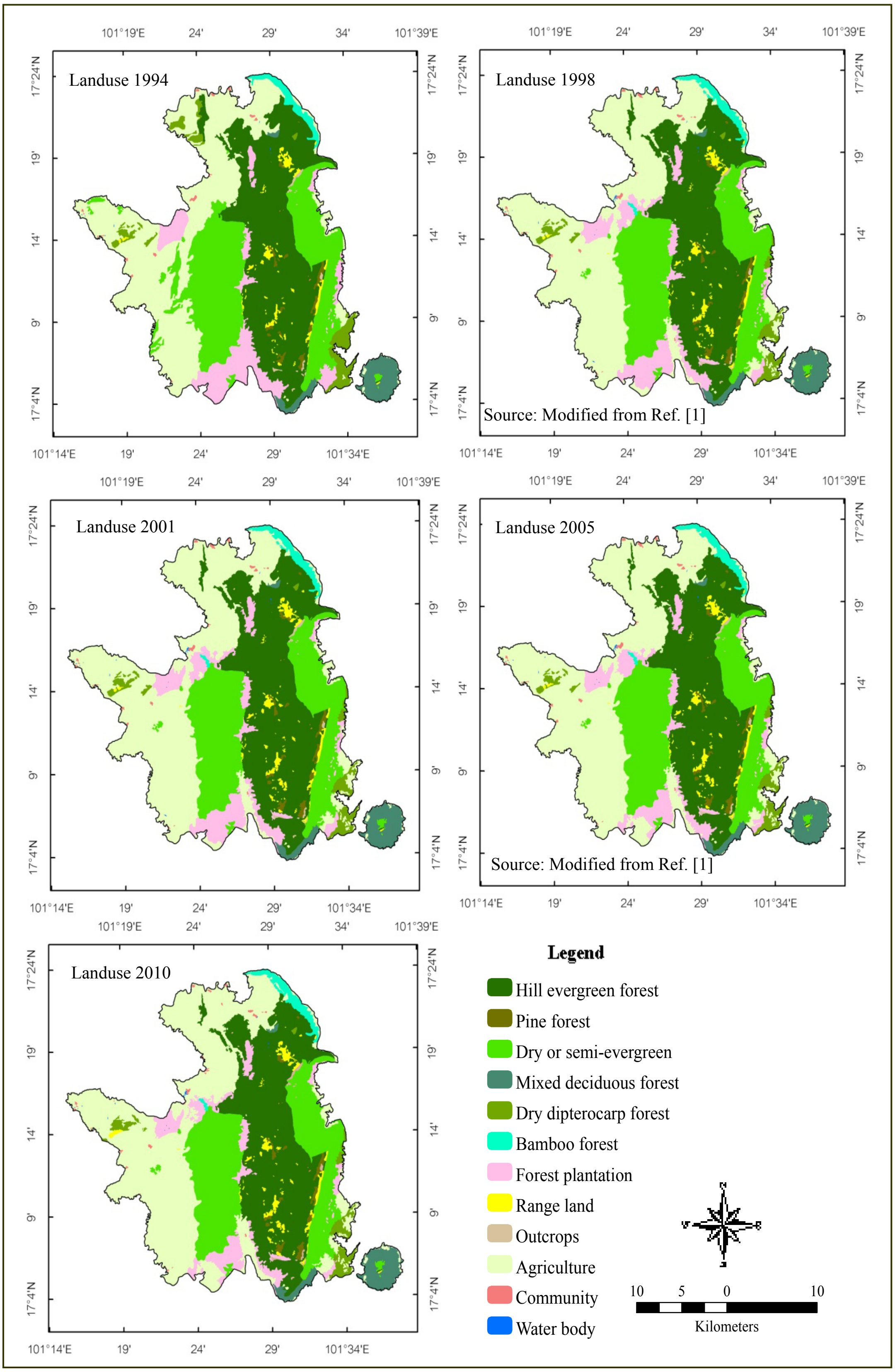

Fig. 3 Landuse maps of PLWS from 1994 to 2010.

Table 1 Statistical data of each landuse type in PLWS from 1994 to 2010.

Landuse type	Area of landuse in wildlife sanctuary									
	1994		1998		2001		2005		2010	
	ha	%	ha	%	ha	%	ha	%	ha	%
Forest	61,069	68.08	57,953	64.60	56,755	63.27	55,508	61.89	54,822	61.12
-Hill evergreen forest	25,739	28.70	25,466	28.38	24,984	27.85	24,626	27.45	24,392	27.19
-Pine forest	650	0.72	665	0.74	726	0.81	722	0.80	752	0.84
-Dry or semi-evergreen	21,139	23.56	18,682	20.83	18,707	20.85	18,629	20.77	18,578	20.71
-Mixed deciduous forest	2,725	3.04	2,813	3.14	2,687	3.00	2,725	3.04	2,717	3.03
-Dry dipterocarp forest	2,646	2.95	2,089	2.33	1,799	2.01	1,724	1.93	1,749	1.95
-Bamboo forest	1,083	1.21	1,004	1.12	1,192	1.33	1,223	1.36	1,252	1.40
-Forest plantation	7,087	7.90	7,234	8.06	6,660	7.42	5,859	6.54	5,382	6.00
Range land	1,077	1.20	1,104	1.23	1,287	1.43	1,314	1.46	1,382	1.54
Outcrops	221	0.25	221	0.25	221	0.25	222	0.25	221	0.25
Agriculture	27,107	30.22	30,193	33.66	31,166	34.75	32,373	36.09	32,986	36.77
Community	208	0.23	211	0.24	234	0.26	246	0.27	252	0.28
Water body	15	0.02	15	0.02	34	0.04	34	0.04	34	0.04
Total	89,697	100.00	89,697	100.00	89,697	100.00	89,697	100.00	89,697	100.00

Source: Data in year 1998 and 2005 modified from Ref. [1].

Table 2 Landuse change in PLWS from 1994 to 2010.

Landuse type	Area of landuse change in wildlife sanctuary									
	1994-1998		1998-2001		2001-2005		2005-2010		1994-2010	
	ha	%	ha	%	ha	%	ha	%	ha	%
Forest	-3,116	-3.48	-1,198	-1.33	-1,247	-1.38	-686	-0.77	-6,247	-6.96
-Hill evergreen forest	-273	-0.32	-482	-0.53	-358	-0.40	-234	-0.26	-1,347	-1.51
-Pine forest	15	0.02	61	0.07	-4	-0.01	30	0.04	102	0.12
-Dry or semi-evergreen	-2,457	-2.73	25	0.02	-78	-0.08	-51	-0.06	-2,561	-2.85
-Mixed deciduous forest	88	0.10	-126	-0.14	38	0.04	-8	-0.01	-8	-0.01
-Dry dipterocarp forest	-557	-0.62	-290	-0.32	-75	-0.08	25	0.02	-897	-1.00
-Bamboo forest	-79	-0.09	188	0.21	31	0.03	29	0.04	169	0.19
-Forest plantation	147	0.16	-574	-0.64	-801	-0.88	-477	-0.54	-1,705	-1.90
Range land	27	0.03	183	0.20	27	0.03	68	0.08	305	0.34
Outcrops	-	-	-	-	-	-	-	-	-	-
Agriculture	3,086	3.44	973	1.09	1,207	1.34	613	0.68	5,879	6.55
Community	3	0.01	23	0.02	12	0.01	6	0.01	44	0.05
Water body	-	-	19	0.02	-	-	-	-	19	0.02

measures were rigidly enforced. The encroachment on the forest reserves resulted in a substantial expansion of agriculture covering an area of about 5,779 ha (6.44%) from 1994-2010.

6. Conclusions

Using multi-temporal satellite data the periodical monitoring and management of the PLW can be effectively carried out. A significant decrease of the rate in which forest encroached upon has been seen over the past five years. Continuing control and preventive measures to protect the forest should be made, employing spatial information acquired from periodical satellite data.

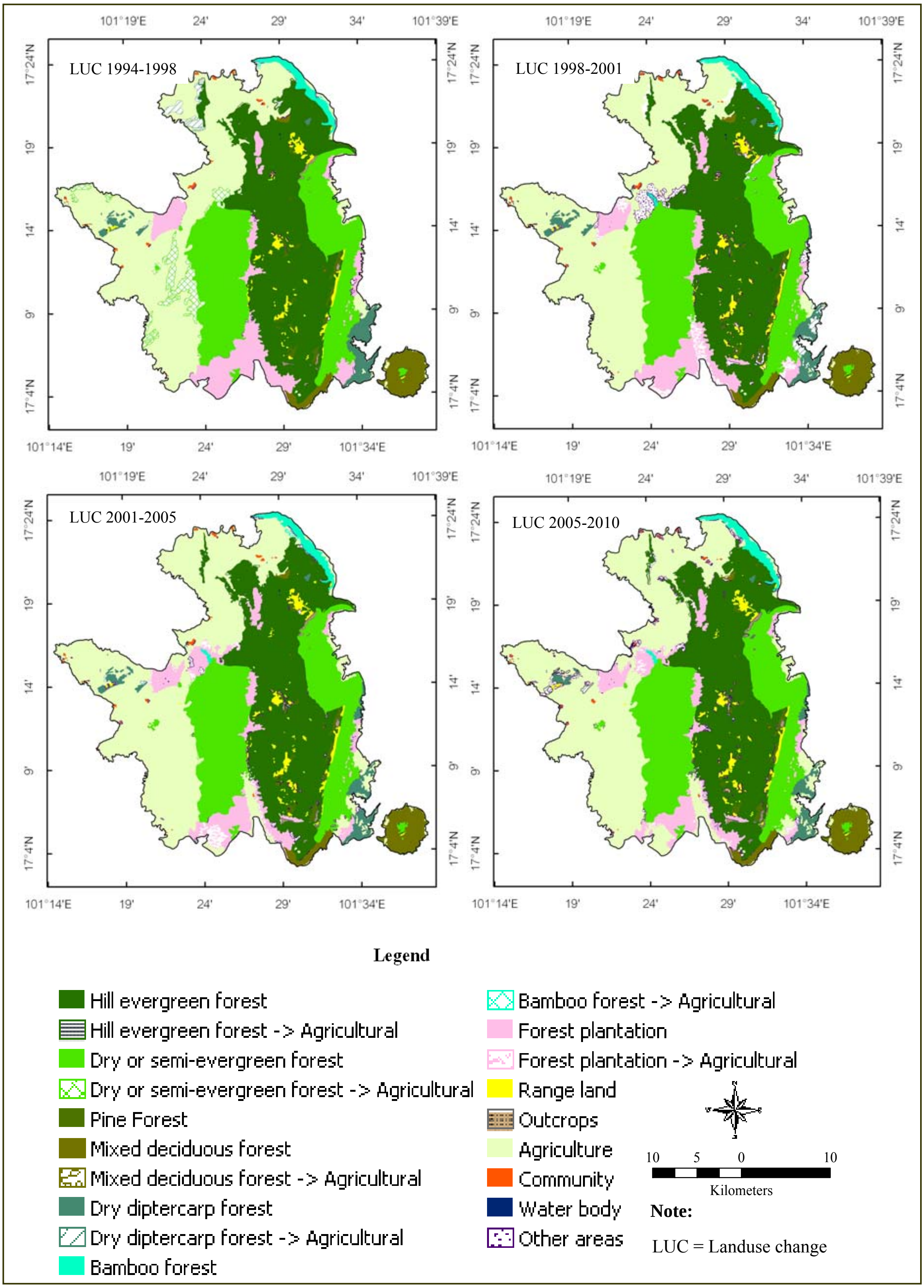

Fig. 4 Landuse change map of PLWS from 1994 to 2010.

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