RUBBER TREE EXPANSION IN FOREST RESERVE AND PADDY FIELD ACROSS THE GREATER MEKONG SUB-REGION, NORTHEAST THAILAND BASED ON REMOTELY SENSED IMAGERY

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Abstract: Agricultural land use of the Greater Mekong Sub-region (GMS) is being rapidly reshaped by expansion of rubber tree plantation. This occurrence, which has been progressed at an increasing rate in the last three decades, has had consequences for surface water hydrology, degraded ecosystems and loss of paddy land, and has accelerated the processes of drought and flooding. The ensuing scarcity of land has led to the plantation encroachment on legal forest reserve and paddy land marginally unsuitable for rubber tree. The study aims to address the encroachment areas of the rubber tree plantation on the forest reserve of government land and on the paddy field. The study area, a portion of northeast Thailand in the GMS, covers an area of approximately 1.7 million ha and is characterized by gently undulating topography .The methodology procedure comprised an analysis of imagery for land cover/land use(LCLU),a comparison of LCLU changes and spatial and quantitative identification of the expansion of the rubber tree plantation. The 2002 aerial orthophotography and 2011 THAICHOTE imagery were used to derive LCLU on which the changes and expansion areas were analyzed. Spatial and quantitative information on the rubber tree expansion areas and its change rate was derived from an overlay of the conservation forest (CF) and paddy field layers on the 2002 and 2011 LCLU maps. The total plantation area increased from 42,411.75 ha in 2002 to 288,550 ha in 2011 with its average expansion rate of 27,348.694 ha/annum (155.08%). Of the total plantation area, the plantation encroachment on the legal forest reserve shared about 2.23 % (947.60 ha) in 2002 and 4.77% (10,835.17 ha) in 2011. Moreover, the expansion in the paddy land, which is marginally suitable for rubber tree, covered 3,424.72 ha in 2002 and 42,231.35 ha in 2011, representing 8.07% and 14.63 % of the plantation areas respectively. Our study provided geo-spatial information on the plantation distribution and the expansion areas in the forest reserve and the paddy land as well.

INTRODUCTION

LCLU in the GMS, northeast Thailand is rapidly reshaped by expansion of rubber tree plantation as a result of increasing demand for rubber over the past two decades (Fox et al, 2012).The rubber tree plantation covers extensively in southern Thailand and has been extended to the northeast where the tree was not historically planted (Mongkolsawat et al, 2010). The rubber tree plantation has replaced traditional crops (cassava, sugar-cane and rice) and brings about a decline in the cropping areas of those crops. In 2011 the tatal rubber tree planted areas amounted to 100,291.04, 21,773.29 and 29,074 ha in Bueng Khan , Muk Dahan and Nakhon Phanom provinces respectively (Office of Agricultural Economics, 2011). Since the tree requires high amount of rainfall, well drained and deep soils (Department of Agriculture, 2005; Land Development Department, 2005; Watson, 1989) land areas in the provinces along the Mekong then meet these requirements. The rapidly increasing expansion causes competition for the upland in these provinces. Attempts to seek the scarcity of upland lead to the encroachment on the government conservation forest and low land paddy field marginally suitable for the tree. The ensuing expansion has significant consequences on regional ecosystem by altering surface water hydrology, soil erosion, biodiversity, connectivity of forest patches ,carbon flux and etc. If these consequences left untackled it may have serious effects on the region ecosystem and the ways of living. With the advent of high resolution satellites, information about the LCLU and the rubber tree expansion could be derived with high accuracy. Li et al (2011) reported the successful use of Landsat 5 TM to estimate the areas of mature and middle-age rubber stands using a Mahalanobis typicality method while accuracy for young rubber stands should be improved. This study did not provide spatial accuracy test the map obtained against the ground truth for the post classification. Another study conducted by Mongkolsawat et al (2010) indicated that young rubber tree plantation could be resolved using THEOS panchromatic data through spatial pattern of the planting space of 4*6-5*7 m.In addition ,the plantation area for mature and middle age tree produced from the integration of SPOT 4-5 HRV and physical land data performed very well with the ground truth. Resolving the perennial plants and forest from mature and middle-age trees is difficult, due to ambiguity in reflectance characteristics .To obtain the reliable expansion areas in this study

we therefore examined on screen digitizing method considering color and pattern in combination with land types, including a number of ground truths. This method is time-consuming and requires the experiences in land ecosystem in the study areas. This study thus used high resolution satellite data to provide spatial and quantitative information with higher accuracy. The objective of this study is to address the encroachment areas of rubber tree plantation on legal forest reserves and lowland paddy field. The results obtained could be applied for further empirical study on the consequences.

STUDY AREA

The study area, a portion of the GMS covering three provinces of northeast Thailand along the Mekong river (Figure 1), encompasses 1.7 million ha and is characterized by flat to gently undulating topography. Most of the areas are drained eastward by Song Kram river and a number of tributaries to The Mekong. Traditional agricultures are cassava, sugar cane and orchards for upland well drained and rice for flat lowland. Rubber tree was not historically planted in this region. The region used to have abundant forest area. Dry Dipterocarp, Mixed Deciduous and Evergreen forest types, range land and isolated patches of remnant forest, fragmenting the areas characterize the natural vegetation. Mean annual rainfall ranges from 1400-2500 mm. with an overall average of 1500 mm. Soils are inherently low in fertility, have coarse-medium texture and were formed from alluvium with high proportion of sandy materials. Most of the soils comprise Typic Ustifluvents, Aeric Kandiaquults, Plinthic Paleaquults and Typic Plinthustults.

Figure 1: Study area

METHODS

Information in this study was derived from the 2002 aerial orthophotography (scale 1:4000), THAICHOTE panchromatic imagery (2m.resolution) acquired in December 2011 and national forest reserve area (1:50000) available from Royal forest department. The Thaichote images were geo-metrically corrected using the aerial orthophotography and the nearest neighbor resampling method.

On screen digitizing method of the aerial orthophotography and the Thaichote images was used to identify the LCLU and rubber tree plantation in the study area. Directly observable features of the high resolution images provide identification the LCLU and rubber tree growth with different ages rubber tree. The mature and middle ages rubber tree could be discriminated by the difference in plant canopy and pattern. The young rubber tree plantation could be resolved through a pattern of planting space of 4*6-5*7m. The young rubber tree plantation is mostly composed of the mixed pixels of bare ground, grass, weeds, small shrub and the young rubber trees. The ensuing mixtures pose a difficulty in resolving the young rubber tree when using digital classification method.

Over 98 training sites of different classes and tree ages were investigated to establish the ground truth of the covers and site characteristics. To ensure the observation, estimate and measurement of the tree stands was carried out. The obtained information was checked against the classified images. Kappa coefficient was calculated to validate the resulted maps.

To address the expansion areas of rubber tree in conservation forest (CF) and paddy land. The 2002 LCLU layer was overlaid with the 2011 LCLU layer, yielding the rubber tree encroachment on paddy land. The encroachment of the plantation on conservation forest was performed by overlay the2011 LCLU layer with the conservation area.

RESULTS

The plantation areas and its distribution, based on the 2002 aerial orthophotography and the 2011 Thaichote imagery are shown in Table1 and Figure 2 and 3. The rubber tree planted area increased from 42,411.75 ha. in 2002 to 288,550.00 ha. in 2011, representing 2.49% to 16.94% of the study area respectively. Among the study provinces, the Bueng Khan plantation area covers the largest proportion with substantial expansion. LCLU shown in Table 2 provides information about the LCLUC between 2002-2011. Results indicate that the area of rubber tree increases at high rate with a decline of over 50% of range land and traditional field crops. The rubber tree requires the upland well drained, similar to that of the traditional crops. Competition for the upland between the rubber tree

and the field crops is very high and demand for the rubber tree growth is greater than the land resources available. Increasing demand for rubber over the past three decades with the promise of a high economic return, has been a significant driving force for the expansion of rubber tree plantation.

Table 1: Rubber tree plantation by province in 2002 and 2011

Province	2002		2011		Area change by province	
	ha	% of total	ha	% of total	ha	%
Bueng Kan	31,612.75	1.86	186,596.66	10.95	+154,983.91	+490.26
Nakhon Phanom	6,072.01	0.36	59,352.62	3.48	+53,280.61	+877.48
Mukdahan	4,726.99	0.28	42,600.73	2.50	+37,873.74	+801.22
Other	1,661,188.25	97.51	1,415,050.00	83.06	-246,138.25	-14.82
Total rubber plantation	**42,411.75**	**2.49**	**288,550.00**	**16.94**	**+246,138.25**	**+580.35**
Total	**1,703,600.00**	**100.00**	**1,703,600.00**	**100.00**		

Table 2: LCLU in 2002 and 2011

LCLU	Area				Change by class (%)
	2002		2011		
	ha	% of total	ha	% of total	
Forest	517,093.17	30.35	420,315.39	24.67	-18.72
Paddy field	635,257.07	37.29	618,833.25	36.33	-2.59
Field crop	225,075.31	13.21	109,651.20	6.44	-51.28
Rubber tree	42,411.75	2.49	288,550.00	16.94	+580.35
Perennial tree	60,392.87	3.55	91,838.44	5.39	+52.07
Range land	115,080.90	6.76	46,174.33	2.71	-59.88
Water body	70,414.94	4.13	71,991.54	4.23	+2.24
Community/Infrastructure	37,873.97	2.22	56,245.85	3.30	+48.51
Total	**1,703,600.00**	**100.00**	**1,703,600.00**	**100.00**	

As the results, rubber tree encroachment on forest reserves of government land has intensified and spread throughout the area, reaching 10,835.17 ha. or 4.77% of the government conservation forest in 2011(Table 3). Due to rubber tree plantation in this region has been booming, including the extension program of Thai government, the farmers sought new marginal land for the plantation. With ensuing scarcity of upland, the plantation is then extended beyond the upland to lowland paddy field. The farmers shaped the lowland paddy field to provide the required gradient for draining excess water and constructed ridges and furrows. During the year 2002-2011, about 42,231.35 ha of the lowland paddy field, marginally suitable for the rubber tree has been converted to rubber tree plantation in the study area (Table 3).The map of the rubber tree expansion area in the conservation forest and paddy field, based on the overlay analysis is shown in Figure 4. Table 4 provides information about the comparison between the rubber tree plantation areas collected by the Rubber Research Institute of Thailand (RRIT) and analyzed using the THAICHOTE imagery. The results indicate that a significant difference in the plantation area analyzed by the THAICHOTE imagery and the RRIT data. The statistical data collected by the RRIT excluded the plantation area for those of non-registered farmers. The RRIT could not gather information about the plantation that extended into illegal use of the government land but emphasis has been placed on registered, grant-aid farmers.

Table 3: Rubber tree encroachment on conservation forest and paddy land in 2011

CF	2011 CF encroached		2002 Paddy land	2011 Paddy land encroached	
ha	ha	%	ha	ha	%
227,003.42	10,835.17	4.77	635,257.07	42,231.35	6.65

As the results the analyzed information is far greater than those of the RRIT. With 2 mm. resolution of THAICHOTE imagery, the plantation areas of different tree ages could be resolved through directly observable features of the imagery. Figure 5 illustrates the THAICHOTE features of different age trees in comparison to the training ground truths.

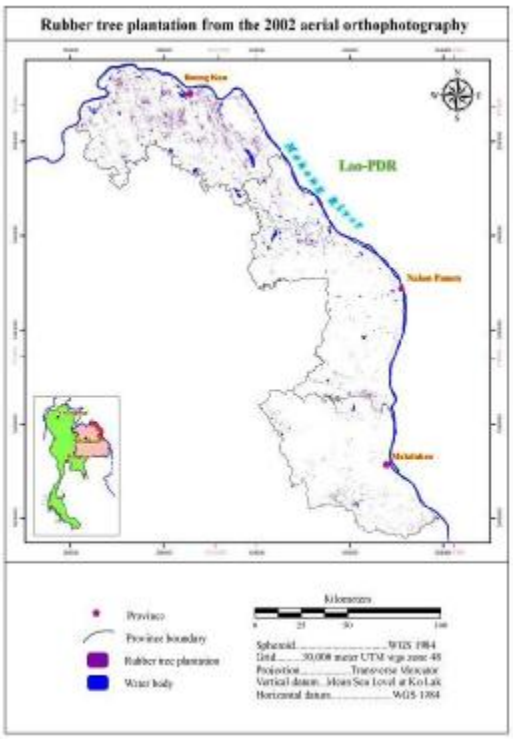

Figure 2: Rubber tree plantation analyzed by the 2002 aerial orthophotography

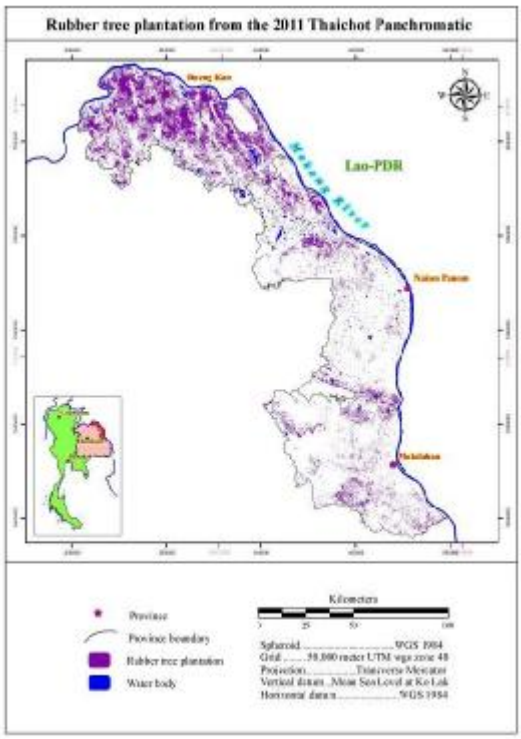

Figure 3: Rubber tree plantation analyzed by the 2011 Thaichote P band

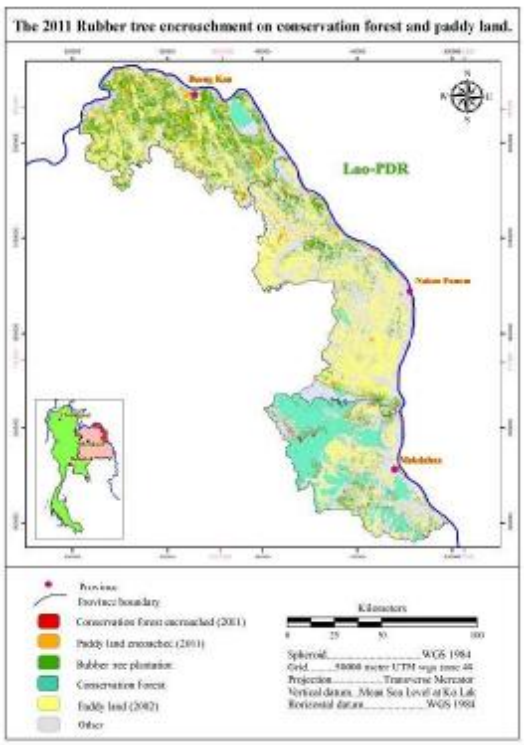

Figure 4: The 2011 Rubber tree encroachment on conservation forest and paddy land

Table 4: Comparison of the rubber tree plantation between statistics collected by the RRIT and the Thaichote P band analysis

Province	RRIT		Thaichote	
	ha	%	ha	%
Bueng kan	100,291.04	5.89	186,596.66	10.95
Nakhonhpanom	29,074.24	1.71	59,352.62	3.48
Mukdahan	21,773.28	1.28	42,600.73	2.50
Total	**151,138.56**	**8.87**	**288,550.00**	**16.94**

(a) Rubber tree < 5 years

(b) Rubber tree 5-10 years

(c) Rubber tree > 10 years

Figure 5: The 2011 Thaichote P band and the different ages of rubber stands

The THAICHOTE provides both update and spatial information with more reliability. Table 5 shows confusion matrix between ground truth of 98 locations and the classification based on the 2011 imagery. The Kappa coefficient of the results and ground truth is 0.87.

Table 5: Confusion between ground truths and the 2011 map obtained

Map	Ground truth									
	Paddy field	**Field crop**	**Perennial crop**	**Rubber tree**	**Forest**	**Range land**	**Community**	**Water body**	**Total**	**User's Accuracy (%)**
Paddy field	**22**	0	0	0	0	1	0	0	**23**	**95.65**
Field crop	0	**10**	1	0	0	1	0	0	**12**	**83.33**
Perennial crop	0	0	**6**	0	0	0	0	0	**6**	**60.00**
Rubber tree	0	1	1	**14**	0	0	0	0	**16**	**100.00**
Forest	0	1	0	0	**11**	2	0	0	**14**	**87.50**
Range land	0	0	2	0	1	**4**	0	0	**7**	**78.57**
Community	0	0	0	0	0	0	**11**	0	**11**	**100.00**
Water body	0	0	0	0	0	0	0	**9**	**9**	**100.00**
Total	**22**	**12**	**10**	**14**	**12**	**8**	**11**	**9**	**98**	
Producer's Accuracy(%)	**95.65**	**83.33**	**100.00**	**87.50**	**78.57**	**57.14**	**100.00**	**100.00**		

CONCLUSIONS & DISCUSSION

The THAICHOTE panchromatic imagery is able to resolve the different age rubber tree with higher accuracy through on screen digitizing method. The rubber tree encroachment on government forest land and lowland paddy field marginally suitable has intensified and is widespread throughout the region where the amount of rainfall is favorable for rubber tree growth. Rapidly increasing plantation area will lead to oversupply and lower price of rubber in the near future when the rubber tree could be tapped. With no update information of government agency, projecting rubber export policies and sustainable management could not be competitive. Moreover, when rubber trees replaced ecologically forest land and paddy land having earthen ridges ,it may have the negative consequences on the ecosystem by accelerating the process of soil erosion, flooding and drought , including loss of biodiversity and wildlife habitat, carbon fluxes and etc. Further empirical study to understand these consequences are urgently needed for protecting in advance the region ecosystem.

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