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Analysis of Land Cover Change Detection Using Satellite Images in Paukkaung Township Area

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Abstract

The Global Forest Resources Assessment 2010 (FRA-2010) report identified Myanmar as one of the 10 countries with the largest annual net loss of forest area between 1990 and 2010, indicating the need to analyze changes in forest cover patterns at the township level to implement sustainable forest management schemes. Forest monitoring is an important tool for evaluation of the state of forest resources, carbon sequestration, and forest management programs. The remote sensing technique using satellite imagery has been recognized as an effective and powerful tool in monitoring and detecting land use and land cover changes. In this research, remote sensing technique using Landsat-5, Landsat-7, and Landsat-8 images collected during the same season was used to study the land cover change in Paukkaung Township. The land cover types were grouped into 6 classes such as closed forest, open forest, shrubs, agriculture, water, and others. Fieldwork was conducted to collect reference data. Land cover maps of 1999, 2003, 2006, 2009, and 2013 were produced using a supervised image classification technique. Post-classification change detection method was used to detect alterations in land cover at each interval. The results showed that during 14 years period, between 1999 and 2013, the total forest area of closed forest, open forest and shrubs decreased from 59.05% to 43.85% of the total land area, i.e. on the average 1,667 ha of forest area had disappeared annually from the existing 112,950 ha, resulting in an annual deforestation rate of 1.47%. There was not only deforestation but forest degradation also. Over time, closed and open forest areas have changed mostly to shrubs which again changed to agricultural land. Agricultural land increased from 33.95% to 45.54%, implying a decrease in vegetation as a result of anthropogenic activities, mainly agricultural expansion, in the study area.

Keywords: Land Cover Classification, Landsat, Remote Sensing

Contents

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1. Introduction

Forests constitute one of the most important and valuable natural resources that play a vital role in establishing global ecological balance (Ali *et al*., 2011). Deforestation strongly influences the occurrence of global warming and also leads to a reduction in biodiversity, disturbances in water regulation, and destruction of the livelihood of farmers (Doug *et al.*, 2011; Haughton, 2005). Reducing deforestation would not only reduce GHG emissions, but would also provide additional benefits to the climate (Ecorys *et al*., 2010). Programs that aim to reduce the emissions from deforestation and forest degradation are being considered as a cost-effective way to mitigate anthropogenic GHG emissions (Werf *et al*., 2009). For this purpose, forest monitoring is an important tool for evaluation of the state of forest resources, carbon sequestration, and forest management programs. It can also help decrease the incidence of illegal logging and facilitate the monitoring of forest fires, generate early warnings against forest degradation, reduce deforestation, and improve forest quality. The remote sensing (RS) technique using satellite imagery has been recognized as an effective and powerful tool in monitoring and detecting land use and land cover changes (Duong, 2004; Pol and Marvine, 1996; Sader *et al*., 2001). By using satellite image data, the geographic information system (GIS) and RS technique comprise a valuable tool for the detection and prediction of changes in forest cover and the identification of areas under risk of invasion (Adubofour, 2011). RS data have recently been of immense help in monitoring changes in the pattern of forest cover (Park *et al*., 2011). These data also allow quantification of changes in land cover patterns in the area, demonstration of the potential of multi-temporal satellite data for mapping, and analysis of the changes in land cover in a spatiotemporal framework, which can be used as inputs for land management and policy decisions with regard to varied themes associated with space such as urbanization, water management, deforestation, and land degradation (Eric *et al*., 2012).

Myanmar has retained much of its forest cover, but its forests have declined by 0.3% annually from 1990 and 2000 (Peter *et al*., 2005). However, FAO estimated that Myanmar lost its forest cover at a rate of 1.17% per year in 1990–2000 and 0.93% per year in 2000–2010; the country was thus identified as one of the ten countries with the largest annual net loss of forest area in 1990–2010 (FAO, FRA-2010). According to the 2010 Forest Resources Assessment (FRA 2010) report, Myanmar is included in the list of ten countries with the largest annual net loss of forest area between 1990 and 2010 (Table 1). Although Myanmar has established >30,000 hectares of various types of forest plantations and has conducted forest conservation operations (Yu *et al*., 2011), it is needed to make the assessment of forest cover changes at the township level. Therefore, the objective of the present study was to assess the loss and gain of forest cover and to detect how it changed in the Paukkaung township area from 1999 to 2013 by using RS and GIS technology.

Table 1. Ten countries with largest annual net loss of forest area, 1990-2010

Country	Annual change 1990-2000		Country	Annual change 2000-2010	
	×1000 ha/yr	%		×1000 ha/yr	%
Brazil	-2890	-0.51	Brazil	-2641	-0.49
Indonesia	-1914	-1.75	Australia	-562	-0.37
Sudan	-589	-0.80	Indonesia	-498	-0.51
Myanmar	-435	-1.17	Nigeria	-410	-3.67
Nigeria	-410	-2.68	Tanzania	-403	-1.13
Tanzania	-403	-1.02	Zimbabwe	-327	-1.88
Mexico	-354	-0.52	Congo	-311	-0.20
Zimbabwe	-327	-1.58	Myanmar	-310	-0.93
Congo	-311	-0.20	Bolivia	-290	-0.49
Argentina	-293	-0.88	Venezuela	-288	-0.60

Source: FAO, 2010. Forest Resources Assessment

2. Materials and Methods

2.1. Study area description

The study area, Paukkaung Township, is a severely deforested township in Myanmar. The area of the township is about 190,000 ha, of which 60,000 ha is demarcated as reserved forest area. It is located approximately 200 miles away from Yangon, the former capital city of Myanmar. Its total population is approximately 100,000 and many rural people depend on the forest for their livelihood. There are two big water reservoirs at the upland of the population area. These two reservoirs play vital roles in farm and paddy field irrigation in the township; however, there is also the risk of flooding of rural areas due to annual sedimentation of the reservoirs, causing the dam to break down. The watershed areas of the reservoirs are legally demarcated as reserved forests and are included in forest conservation efforts. A reserved forest is a specific term for designating forests and other natural areas that enjoy judicial and/or constitutional protection under the legal systems of many countries (Wikipedia encyclopedia). However, forest areas are continuously lost each year due to various factors.

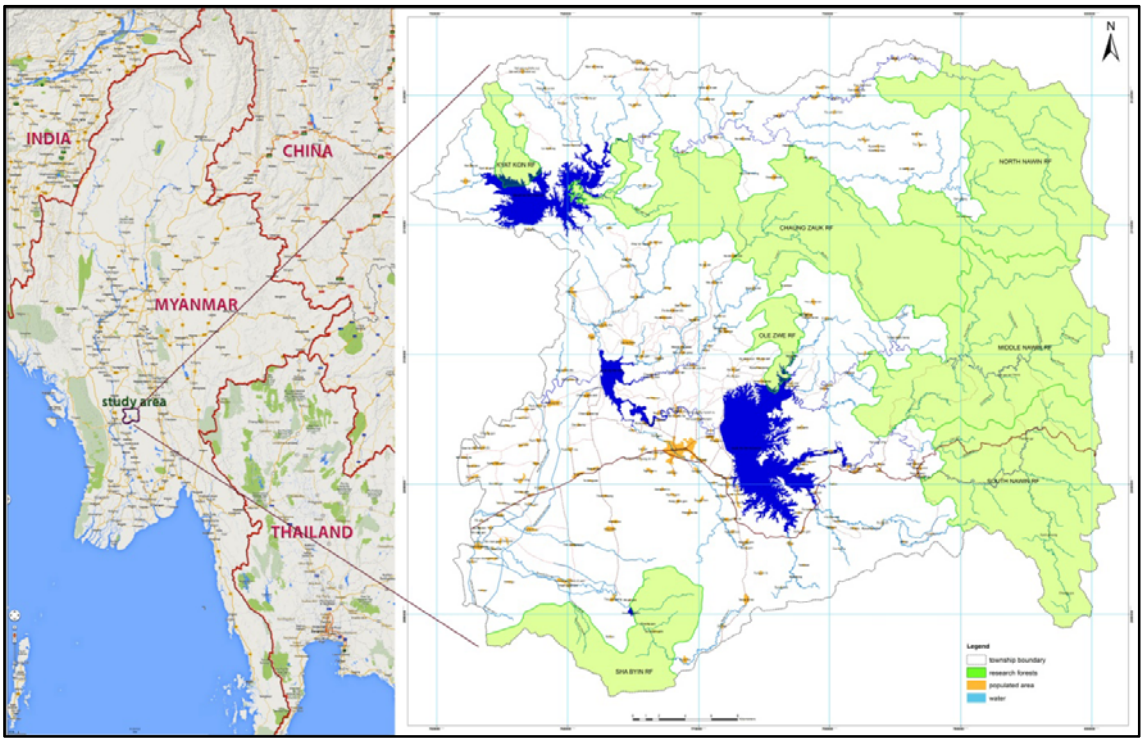

Figure 1. Map showing study area

2.2. Data collection and analysis

Clear, cloud-free Landsat images obtained in December 30, 1999, January 23 2003, January 15, 2006, January 15, 2009 and December 12, 2013 were selected to classify the area. The satellite image data type and sources are listed in Table 2.

Table 2. Satellite image data sources list

Image data	Path/ row	Acquisition date	Source
Landsat7_ ETM$^+$	133/47	Dec 30,1999	Earth explorer [http://earthexplorer.usgs.gov/]
Landsat7_ ETM$^+$	133/47	Jan 23, 2003	Earth explorer [http://earthexplorer.usgs.gov/]
Landsat7_ ETM$^+$	133/47	Jan 15, 2006	GLCF [http://glcfapp.glcf.umd.edu:8080/esdi/]
Landsat5_TM	133/47	Jan 15, 2009	Earth explorer [http://earthexplorer.usgs.gov/]
Landsat8_ OLI & TIRS	133/47	Dec 12, 2013	Earth explorer [http://earthexplorer.usgs.gov/]
TM = Thematic Mapper, ETM$^+$ = Enhanced Thematic Mapper Plus OLI = Landsat 8 Operational Land Imager, TIRS = Thermal Infrared Sensor			

Paukkaung Township is entirely contained within the Landsat path 133, row 47. All images were already rectified to UTM zone 46 N using WGS84 datum which showed that there was no need to conduct further pre-processing tasks. A supervised classification using the maximum likelihood classification technique was performed to produce land cover

classes. The land cover types were grouped into 6 classes: closed forest, open forest, shrubs and re-growth, agricultural land, water, and others. Open forest pertains to land areas of >0.5 ha with tree heights of >5 m and canopy cover ranging from 10% to 40%. Closed forest indicates land areas of >0.5 ha with tree heights of >5 m and canopy cover > 40%. Shrubs include land that covers young trees, shrubs, herbs, and bushes with heights of <5 m and fallow lands. Agricultural land is that used for planting agricultural crops. Water pertains to water bodies and others indicate types that were not included in the above mentioned classes. Urban area, villages, roads, wet lands, and bare lands are included in others.

Land cover maps derived from RS data inevitably contain errors of various types and degrees; it is therefore very important to determine the nature of these errors (Lunetta *et al*,. 1991; Giles, 2001). The measurement of accuracy is expressed as "user's accuracy," "producer's accuracy," and "overall accuracy" through the use of percentages (Muller *et al*., 1998). Producer's accuracy refers to the probability that a certain land cover of an area on the ground is classified as such, whereas user's accuracy refers to the probability that a pixel labeled as a certain land cover class in the map is really of this class (Congalton, 1991). Kappa analysis serves as another measure of accuracy or agreement (Jenness and Wynne, 2005). Kappa values range from 0 to 1 and those > 0.75 indicate strong agreement, values between 0.70 and 0.79 indicate fair to good agreement, and those < 0.40 indicate poor agreement (John *et al*., 2002). For this research, accuracy assessment was conducted for each classified map by using 200 random assessment points, at a minimum of 30 points per class. For change detection, a post-classification comparison method was employed. Of the various methods that are available for change detection (i.e., image overlay, change vector analysis, and image rationing), in the post-classification comparison method, images of different dates were initially classified and individually labeled. Then, the classified images were compared and the data on the changed areas were extracted (Eric and Adubofour, 2012; Serra *et al*., 2002).

3. Results and Discussion

The land cover maps for each year were prepared by supervised classification. The total forest area of 112,950 ha (59.05% of total land area) including closed forest, open forest and shrubs in 1999 had reduced to 89,609 ha (46.85%) in 2013, i.e. about 23,341 ha of forest area were lost in 14 years. On the average 1,667 ha of forest (or 1.47%) had disappeared annually. This deforestation rate was too high compared to the national deforestation rate of 0.093% in 1990-2000 and the global deforestation rate of 0.14% in 2005-2010. The closed forest area of 5,789 ha (3.03%) and open forest area of 38,374 ha (20.06%) in 1999 had declined to 2,364 ha (1.24%) and 14,685 ha (7.68%) respectively in 2013. The agricultural land occupying 64,938 ha in1999 (33.96% of total area) had increased to 87,116 ha (45.54%) in 2013. The result shows that both deforestation and forest degradation had happened between 1999 and 2013. Statistics of the classification results are summarized in Table 3 and shown in Figure 2.

Table 3. Summary of classification statistics for 1999, 2003, 2006, 2009 and 2013

Class	1999	2003	2006	2009	2013
Closed forest (ha)	5,789	4,665	3,316	2,998	2,364
Closed forest percent	3.03	2.44	1.73	1.57	1.24
Open forest (ha)	38,374	30,017	22,645	17,091	14,685
Open forest percent	20.06	15.69	11.84	8.93	7.68
Shrubs (ha)	68,787	73,166	74,636	69,143	72,560
Shrubs percent	35.96	38.25	39.01	36.14	37.93
Agriculture (ha)	64,938	69,244	75,066	83,120	87,116
Agriculture percent	33.95	36.20	39.24	43.45	45.54
Other (ha)	6,559	6,746	8,583	10,272	7,369
Other percent	3.43	3.53	4.49	5.37	3.85
Water (ha)	6,855	4,464	7,055	8,680	7,208
Water percent	3.58	3.90	3.69	4.54	3.77

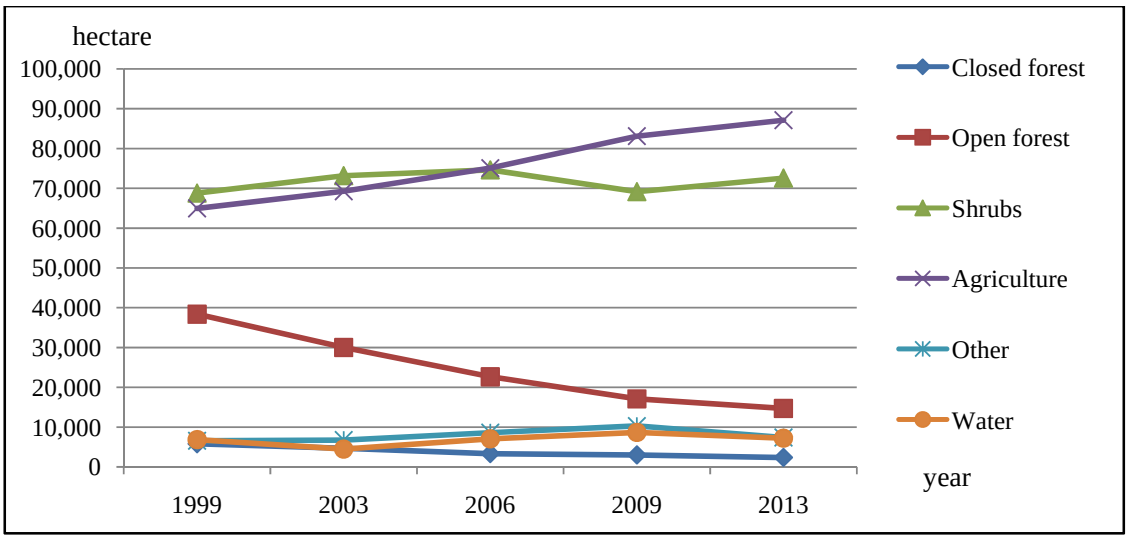

Figure 2. Chart showing land cover condition for 1999, 2003, 2006, 2009 and 2013

About 3.03%, 2.44%, 1.73%, 1.57%, and 1.24% of total area were under closed forest cover in 1999, 2003, 2006, 2009, and 2013, respectively. The open forest area covers about 20.06%, 15.69%, 11.84%, 8.93%, and 7.68% of the total land area in 1999, 2003, 2006, 2009, and 2013 respectively. The shrubs covered 35.96%, 38.25%, 39.01%, 36.14%, and 37.93% of the total area in 1999, 2003, 2006, 2009, and 2013 respectively. The agricultural land covered 33.95%, 36.20%, 39.24%, 43.45%, and 45.54% of the total land area in 1999, 2003, 2006, 2009, and 2013, respectively. The area of other land constituted 3.43%,3.53%, 4.49%, 5.37% and 3.87% of the total land area in 1999, 2003, 2006, 2009, and 2013, respectively, while water bodies occupied 3.58%, 3.90%, 3.69%, 4.54% and 3.77% of the total land area in 1999, 2003, 2006, 2009, and 2013, respectively.

Table 4. Summary of classification accuracy (%) and KAPPA statistics

Yr.	Accuracy	CF	OF	SH	AG	OT	WT	Overall accuracy	Kappa
1999	Producer's	90.48	70.23	75.00	80.43	88.00	96.77	82.00	0.783
	User's	63.33	85.29	71.05	97.37	73.33	100.0		
2003	Producer's	96.15	81.58	88.33	85.37	95.00	87.88	87.00	0.843
	User's	83.33	93.94	89.74	92.11	63.33	96.67		
2006	Producer's	86.21	87.50	80.49	79.55	84.62	96.43	85.00	0.819
	User's	83.33	87.50	86.84	92.11	70.97	87.10		
2009	Producer's	85.71	74.29	76.92	85.71	82.76	100.0	83.50	0.801
	User's	80.00	83.87	78.95	92.31	77.42	87.10		
2013	Producer's	67.86	76.00	83.33	91.53	83.33	100.0	84.50	0.806
	User's	95.00	73.08	76.92	93.10	68.18	100.0		

Note: CF = Closed forest, OF = Open forest, SH = Shrubs, AG = Agriculture, OT = Other, WT = Water

Error matrices were used to assess classification accuracy of the classified images, and they are summarized in Table 4. The overall classification accuracy for 1999, 2003, 2006, 2009, and 2013 were respectively, 82.0%, 87.0%, 85.0%, 83.5%, and 84.5%, with Kappa statistics of 0.7830, 0.8433, 0.8193, 0.8013 and 0.8062. User's and producer's accuracies of individual classes were consistently high. Multiplying the individual classification accuracies of each images give expected overall change detection accuracies as 71.34% for 1999-2003, 73.95% for 2003-2006, 70.97% for 2006-2009, and 70.55% for 2009-2013, respectively.

The change detection results (Table. 5) show that from 1999 to 2003, 14,886 ha of closed and open forests (2,405 ha of closed forest and 12,481 ha of open forest) had become shrubs, and 11,227 ha of shrubs had changed to agricultural land. Approximately 980 ha of closed forests and 6,561 ha of open forest were reforested from shrubs. From 2003 to 2006, 12,836 ha of closed and open forests (1,607 ha of closed forest and 11,229 ha of open forest) had degraded to shrubs, and 11,995 ha of shrubs had been converted to agricultural land. 1,555 ha of closed forests and 4,559 ha of open forests were reforested from shrubs. From 2006 to 2009, 11,101 ha of closed and open forests (2,835 ha of closed forest and 8,266 ha of open forest) had become shrubs, and 17,706 ha of shrubs were changed to agricultural land. Approximately 642 ha of closed forests and 3,783 ha of open forests were reforested from shrubs and 1,586 ha of agricultural land were reforested into open forests. From 2009 to 2013, 9,917 ha (864 ha of closed forest and 9,053 ha of open forest) changed into shrubs, and 14,544 ha of shrubs were converted to agricultural land. About 1,520 ha of closed forests and 6,197 ha of open forests were reforested from shrubs.

Table 5. Matrices of land cover changes (hectare) table

	2003							
1999	Class	Closed forest	Open forest	Shrubs	Agriculture	Other	Water	Total
	Closed	1,811	1,570	2,405	1	1	0	5,789
	Open	1,874	20,842	12,481	3,054	91	32	38,374
	Shrubs	980	6,561	49,184	11,227	710	126	68,788
	Agriculture	0	1,037	7,523	53,562	2,379	437	64,938
	Other	0	7	1,461	1,377	3,391	322	6,558
	Water	0	0	112	23	173	6,547	6,855
	Total	4,665	30,017	73,166	69,244	6,745	7,464	191,302
	2006							
2003	Class	Closed forest	Open forest	Shrubs	Agriculture	Other	Water	Total
	Closed	10,40	2,005	1,607	10	2	0	4,664
	Open	721	15,760	11,229	2,275	33	0	30,017
	Shrubs	1,555	4,559	53,099	11,995	1,880	78	73,166
	Agriculture	0	318	8,198	58,466	2,050	211	69,244
	Other	1	4	420	1,972	4,090	260	6,746
	Water	0	0	83	348	527	6,506	7,464
	Total	3,316	22,645	74,636	75,066	8,583	7,056	191,302
	2009							
2006	Class	Closed forest	Open forest	Shrubs	Agriculture	Other	Water	Total
	Closed	309	149	2,835	1	1	21	3,316
	Open	2,036	11,531	8,266	754	58	0	22,645
	Shrubs	642	3,783	49,624	17,706	2,619	262	74,636
	Agriculture	10	1,586	6,723	63,089	3,073	586	75,067
	Other	1	38	1,677	1,517	4,328	1,021	8,582
	Water	0	5	18	53	192	6,788	7,056
	Total	2,998	17,091	69,142	83,121	10,272	8,680	191,302
	2013							
2009	Class	Closed forest	Open forest	Shrubs	Agriculture	Other	Water	Total
	Closed	431	1,673	864	29	1	0	2,998
	Open	411	6,712	9,053	875	38	4	17,091
	Shrubs	1,520	6,197	45,628	14,544	1,136	116	69,142
	Agriculture	1	91	14,667	66,129	2,157	76	83,120
	Other	1	12	2,144	4,296	3,693	127	10,272
	Water	0	0	205	1,244	344	6,887	8,680
	Total	2,364	14,685	72,560	87,116	7,369	7,208	191,302
	2013							
1999	Class	Closed forest	Open forest	Shrubs	Agriculture	Other	Water	Total
	Closed	581	1,498	3,650	57	3	0	5,789
	Open	970	9,770	23,283	4,210	99	42	38,374
	Shrubs	808	3,268	39,094	24,359	1,056	203	68,787
	Agriculture	4	146	6,041	55,855	2,673	218	64,938
	Other	1	2	422	2,524	3,306	304	6,559
	Water	0	0	70	112	231	6,442	6,855
	Total	2,364	14,685	72,560	87,116	7,369	7,208	191,302

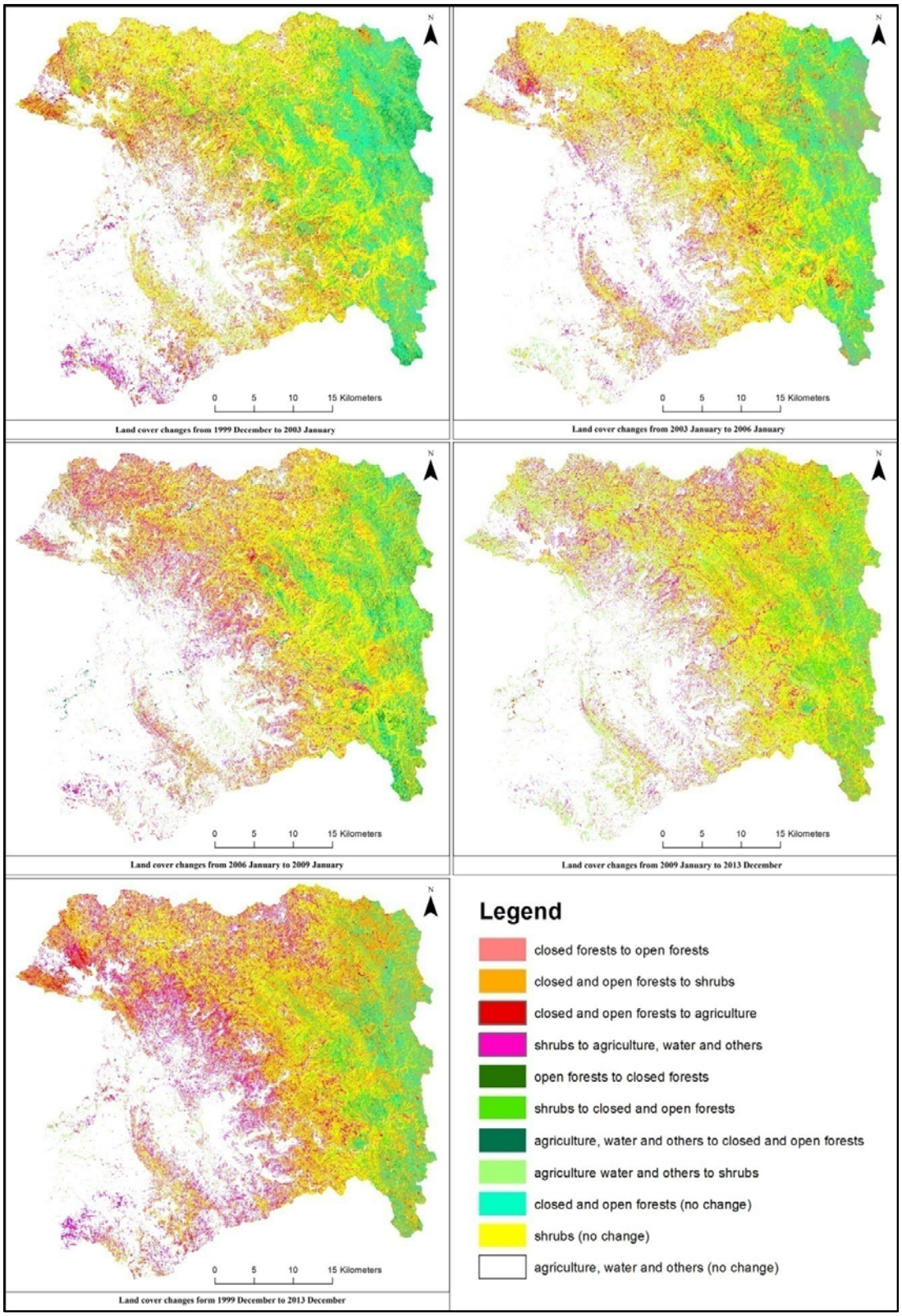

Figure 3. Land cover changes in Paukkaung Township area

The most obvious land cover change pattern is expressed by Figure 4. For the whole period, from 1999 to 2013, 3,650 ha of closed forest and 23,283 ha of open forest area had changed to shrubs, 24,359 ha of shrubs area to agriculture, and 6,041 ha of agriculture area were changed to shrub cover. Only 808 ha of closed forest and 3,268 ha of open forest could have been reclaimed from shrub land.

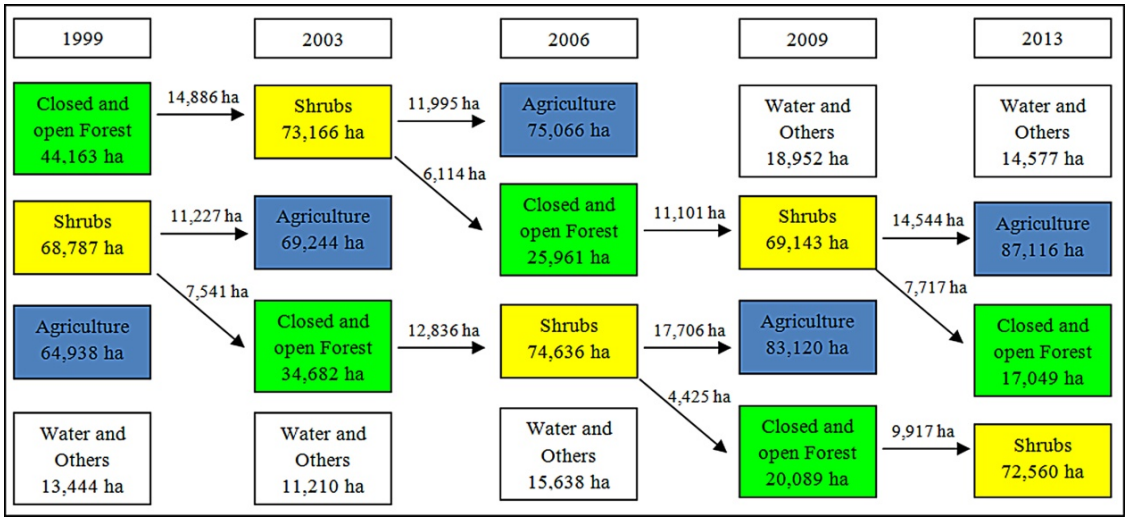

Figure 4. The most obvious land cover changes in Paukkaung Township area (unit: hectare)

By the land cover changes detection, it is obvious that closed and open forest areas were changing mostly to shrub cover type all the time and, the shrub cover again changed to agricultural land. Therefore, agricultural land had expanded every year mostly from shrub lands. It implies that vegetation had decreased as a result of anthropogenic activities in the study area. Agriculture is clearly the main culprit for deforestation, caused by clearing land to grow food, either for commercial or for subsistence purposes. It has been observed that during the study period, some agricultural lands have become shrubs and fallows, while some of the shrub lands have been rehabilitated to closed and open forests.

Table 6. Forest cover changes in Paukkaung Township area (hectare)

Change	Change classes	1999 -2003	2003 - 2006	2006 - 2009	2009 - 2013	1999 - 2013
Deforestation and degradation	CF to OF	1,570	2,005	149	1,673	1,498
	CF, OF to SH	14,887	12,836	11,101	9,917	26,933
	CF, OF to AG, OT, WT	3,180	2,321	836	945	4,411
	SH to AG, OT, WT	12,063	13,954	20,588	15,796	25,618
	Total	31,699	31,115	32,674	28,331	58,460
Reforestation	OF to CF	1,874	721	2,036	411	970
	SH to CF, OF	7,541	6,114	4,424	7,717	4,076
	AG, OT, WT to CF, OF	1,044	323	1,639	104	153
	AG, OT, WT to SH	9,096	8,701	8,417	17,015	6,533
	Total	19,554	15,858	16,517	25,247	11,733
No change	CF or OF no change	22,653	16,799	11,840	7,143	10,350
	SH no change	49,184	53,099	49,624	45,628	39,094
	AG, OT, WT no change	68,211	74,430	80,647	84,952	71,665
	Total	140,048	144,328	142,111	137,723	121,109

From the analysis of the above table (Table 6), it is found that deforestation and forest degradation had been more than reforestation in every period. The areas of forest degradation and deforestation in the periods 1999-2003, 2003-2006, 2006-2009, and 2009-2013 were 31,669 ha, 31,115 ha, 32,674 ha and 28,331 ha respectively. The areas of reforestation in the same periods were 19,554 ha, 15,858 ha, 16,517 ha and 25,247 ha respectively.

4. Conclusion

Land cover succession was analyzed by the remote sensing technology using Landsat satellite images. Over time, closed and open forest areas had changed mostly to the shrub land, whereas shrub land had changed to agricultural land. Therefore, the agricultural land area is expanding every year, mostly from shrub lands. This also implies a decrease in vegetation due to anthropogenic activities occurring in the study area. Some of the agricultural areas had become shrubs and some of the shrub areas were reforested into closed and open forests. However, out of the existing 5,789 ha of closed forest and 38,374 ha of open forest in 1999, only 2,364 ha of closed forest and 14,685 ha of open forest remained in 2013. During 14 years from 1999 to 2013 about 1,667 ha or 1.47% of forest had disappeared annually. Compared to the global and national deforestation rates this deforestation rate in the study area was too high. In this context, forest conservation and regeneration operations should be conducted more effectively in the Paukkaung Township to prevent further severe deforestation.

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