LAND USE/LAND COVER CHANGE DETECTION OF TONLE SAP WATERSHED, CAMBODIA

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KEY WORDS: Land cover/Land use, Tonle Sap, Change detection, ALOS AVNIR-2, Landsat

ABSTRACT: Tonle Sap, the largest freshwater lake in Southeast Asia, lies in the center of Cambodia and its watershed covers an area of about 60,000 km^2 which constitutes about 32% of the total land area of the country. In recent years, natural and human induced activities contribute to the degradation of natural resources including forest cover in Tonle Sap watershed. Usage of the land use also changed with the increase of population exceeding the carrying capacity of land. The objective of this study was to investigate land cover/land use changes of Tonle Sap watershed in last 20 years that could help to identify land degradation process in this important watershed.

Land cover/land use changes were analysed over the period of 1990-2009 using Landsat TM data (1989 and1990) and ALOS AVNIR-2 data (2007-2009) by image classification techniques. A classification scheme was developed with 8 land cover/land use classes based on the field visit data and prior knowledge of the study area.

The results indicate that during the period of 1990-2009, Forest cover has been decreased by 43% (from 20170 km^2 to 11436 km^2) while Agriculture has been increased by 34% (from 14076 km^2 to 18858 km^2). There was a decrease in Water bodies by 26% and built up areas have been expanded by 188% showing the large growth inurban areas.

1. INTRODUCTION

Tonle sap lake, (also known as the Great lake) is situated in the central plains of Cambodia and has enormous significance for Cambodians. The unique hydrological system of Tonle Sap Lake is characterized by an annual inflow of Mekong waters into the lake during the wet season, when the water levels in the Mekong rise. At the end of the wet season, the flow reverses and the lake empties again. This hydrological cycle supports and maintains high biodiversity and productivity, particularly fishand plant communities, and wildlife, which are the resource base for the national economy of Cambodia. Nearly half of the Cambodian population depends on the Lake's resources, about one million of which is fish dependent community.

Economy of the Tonle Sap region has declined to very basic subsistence farming andfishery. Illegal activities, largely based on destructive exploitation ofnatural resources are expanding. Most prominent example is illegal logging in which the country loses 3%of its forests each year(Varis,2003). In addition to logging, main factors that contribute to the reduction of forest cover in Cambodia are; expansion of agriculture land, tree felling and burning during war, fuel

wood collection, shifting cultivation, mining in Battambang province, shrimp farming and commercialization of forestry products (Rot,2001, Keskinen et al.,2002).

Given these prominent changes in the use of land, accurate land cover/ land use of the watershed has become necessary in order to monitor these changes.Therefore, this study was carried out to identify changes occurred in land cover/land use of Tonle Sap watershed during last 20 years (1990-2009) using Landsat TM and ALOS AVNIR-2 data.

2. STUDY AREA

Watershed of Tonle Sap was delineated by performing GIS operations on 30m ASTER GDEM datausing "Arc Hydro" toolbox in ArcGIS (Figure 1).Resulted watershed was 56924 km^2in area which is about 31.4% of total area of the country. Study area covers 8 provinces; Kampong Chhnang,Kampong Thom, Siem Reap, Banteay Meanchey,Battambang, Pailin, Pursat and part of the Preah Vihear.

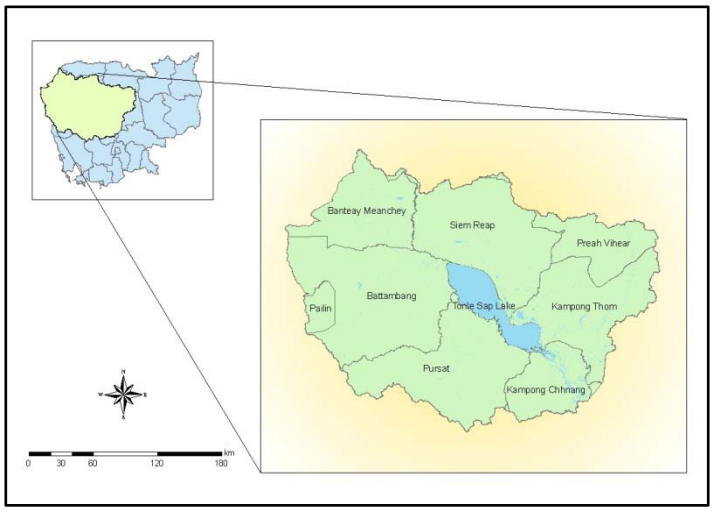

Figure 1. Study Area

3. DATA

30 scenes of ALOS/AVNIR-2 and 8 scenes of Landsat TM were used for the study. Several factors had to be considered in selecting satellite images, one of which the main factors were cloud cover and acquisitiondate.Images were chosen keeping the maximum cloud cover at 2% or less. When there were no images in archives which satisfy the search criteria, images that available were chosen.

Since the available data which acquired on the same date was not enough to cover the whole study area, images taken on different dates were used, ensuring they were taken on the same time period in both years. In this study, all Landsat and ALOS/AVNIR-2 images were chosen between December–April, which is the dry season where water level of the Tonle Sap is at minimum. Landsat 5 TM data of Global Land Survey in 1990 were downloaded from Global Land Cover Facility website (ftp://ftp.glcf.umiacs.umd.edu/glcf/Landsat/) including 3 Scenes from year 1989 and 5 scenes from year 1990.5 ALOS/AVNIR-2 scenes from year 2007, 3 scenes from year 2008 and 22 scenes from year 2009 were provided by JAXA (Japan Aerospace Exploration Agency).

4. METHODOLOGY

4.1 development of Land cover/Land use classification system

Initially, existing land cover maps of Cambodia andother classification systems were referred. Based on that8 major land cover classes (Level 1) were identified in Tonle sap watershed (Table 1).After examining Landsat and ALOS AVNIR-2 data, several subclasses were identified and added to the classification system (Level2).

Level 1	Level2
Agriculture	Harvested rice fields
	Vegetative stage rice fields
	Other agriculture
Forest	Evergreen forest
	Mixed forest
Water body	Lake
	River
	Other water bodies
Shrubs	
Other vegetation	
Wetland	
Builtup areas	
Bare soil	

Table 1.Developed land cover/land use classification system

4.2 Classification

During the field visit, 86 ground truth points were collected in Tonle Sap watershed.Half of the ground truth data were used as training samples for supervised classification and other half was used for accuracy assessment.

First, two mosaics were created using Landsat TM and ALOS/AVNIR-2 scenes.Taking Landsat dataset as the reference, ALOS AVNIR-2 mosaic was georeferenced using image to image technique. The method was quite accurate because Global Land Survey (GLS) Landsat data offers better geometric accuracy (~18 m). Ground control points (GCPs) obtained during the process had been used in a later part of the methodology. To maintain the accuracy, images acquired on the same date were mosaicked first. Then training samples were collected using ground truth data, Google Earth imagery and prior knowledge of the study area. All scenes were then classified using supervised classification method and maximum likelihood technique. Finally,classified images were mosaicked to obtain the final classification result. Initially 13 classes(level 2 in the classification system) were used for the classificationto achievea better separation between land cover/land use classes. Later it was reduced to 8 major land cover/land use classes(level 1 in the classification system) by combining similar classes according to the classification scheme. For example, ‘Evergreen forest’ and ‘Mixed forest’ subclasses were combined together to obtain a single ‘Forest’ land cover class.Classified image of 2009 was georeferenced using GCPs obtained in the earlier step. Then,change detection analysis was performed on 1990 and 2009 land use/ land cover maps. Figure 2 shows Land cover/Land use maps of years 1990 and 2009.

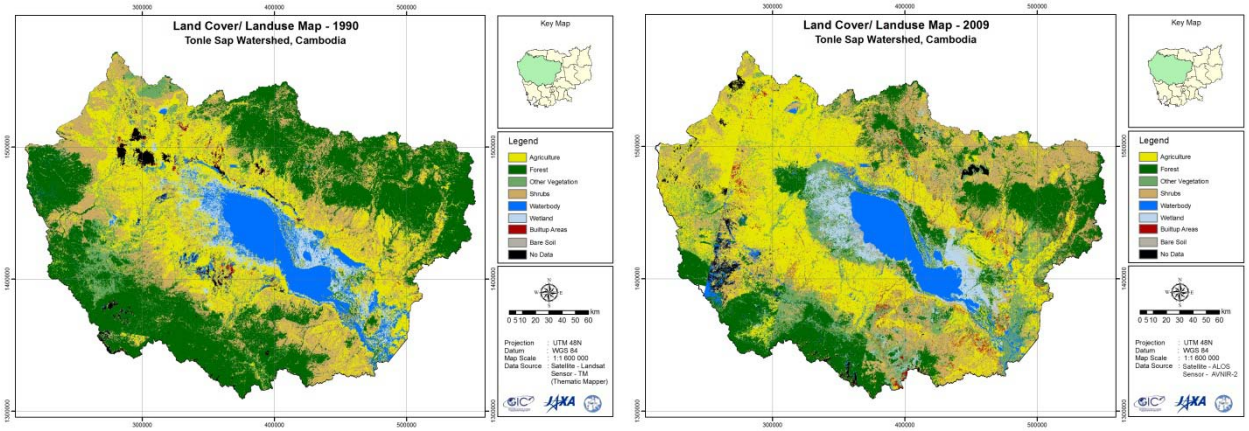

Figure 2. Land cover/Land use maps of years 1990 and 2009

5. RESULTS AND DISCUSSION

An accuracy assessment wasdone for ALOS AVNIR-2 classification (2009 Land cover classification) using ground truth points collected during the field visit and Google Earth imagery. Overall accuracy was 81.2% and Kappa coefficient was 0.77 which we believe is an acceptable accuracy. (Kappa coefficient >0.8: High accuracy, 0.4-0.8: Moderateaccuracy, <0.4: Poor accuracy)(Congalton, 1999).

Class	Producer's Accuracy (%)	User's Accuracy (%)
Built up areas	47.09	52.26
Agriculture	79.59	87.99
Forest	98.48	92.48
Other Vegetation	73.56	29.13
Shrubs	80.52	94.69
Wetland	45.64	100
Water bodies	100	98.59

Table 2.Producer's accuracy and User's accuracy for ALOS AVNIR-2 classification

Considering Producer's accuracy and User's accuracy for each class (Table 2), some of the classes (Built up areas, Other vegetation and Wetland) have less accuracieswhileother classes have accuracies more than 80%. Therefore it can be assumed thatclasses with high accuraciescould providemore reliable results in change detectionstatisticscompared to classes with less accuracy. Bare soil class had to be omitted from the accuracy assessment because it had only one ground truth data which was not enough for an accuracy assessment.

Landsat TM classification has taken as it is for the change detection analysis since there were no ground truth data in 1990 to perform an accuracy assessment.

Results of change detection analysis are shown in Table 2 and Table 3.

LU/LC Class	Area in 1990 (km^2)	Percent of Total watershed	Area in 2009(km^2)	Percent of Total watershed	Change Compared to Total watershed (%)	Change Compared to initial state (%)
Agriculture	14076	25	18858	33	8	34
Forest	20170	35	11436	20	-15	-43
Shrubs	11344	20	11674	21	1	3
Water Bodies	5290	9	3940	7	-2	-26
Wetland	2319	4	2896	5	1	25
Other Vegetation	2635	5	5721	10	5	117
Built up Areas	351	1	1011	2	1	188
Bare Soil	70	0	619	1	1	782
No data	668	1	724	1	0	8
Total	61878	100	65496	100		

Table 3.Basic statistics of Change Detection

According to the results shown in Tables 3 and 4, major changes have been occurred in Forest and Agriculture land cover classes. During the period of 1990-2009, forest cover has been reduced by 43% (from 20170 km^2 to 11436 km^2) which accounts for 15% change in total area of the watershed. 21% and 17% of the total forest cover has been converted into Shrubs and Agriculture respectively. Referring to the forest data published by United Nations Food and Agriculture Organization (FAO), annual deforestation rate for Cambodia between 1990-2005 was 1.28%. Results from this study show that annual deforestation rate in Tonle sap watershed (2.26%) even worse than the other areas of the country.

	1990									
	Builtup areas	Agriculture	Forest	Other vegetation	Shrubs	Wetland	Water body	Nodata	Bare Soil	Class Total
Builtup areas	7	6	3	4	7	1	1	2	9	100
Agriculture	74	59	17	47	43	10	16	59	71	100
Forest	2	8	44	12	9	24	7	21	2	100
Othervegetation	6	8	10	11	11	14	6	5	5	100
Shrubs	5	12	21	18	25	7	3	6	7	100
Water body	4	3	1	4	1	9	58	4	2	100
Wetland	0	3	2	1	1	32	8	1	0	100
Bare Soil	1	1	0	0	1	3	1	1	4	100
No data	0	0	2	4	1	0	0	2	0	100
Class Total	100	100	100	100	100	100	100	100	100	0
Class Changes	93	41	56	89	75	68	42	98	96	0

Table 4.Detailed statistics of Change Detection

There was a 30% growth in Agriculture (from 14076 km^2 to 18858 km^2). 3588 km^2 of forest and 3653km^2 of shrubs have become agriculture during the period. The expansion of rice area was largely achieved by gradually bringing abandoned or idle farm lands back into production, while small amounts of forested land was also converted into agriculture by farmers in upland areas (U.S. Department of Agriculture). Even though the expansion of Shrub was 3%, changes within the class were about 75% which can be clearly seen on the map. Shrubs in West and South west of the watershed (43%) have been converted in to Agriculture while Forest (21%) in North East part has become Shrubs.

Water bodies also show a significant decrease of 26% from its initial state (from 5290 km^2 to 3940 km^2).The reason might be the seasonal change of water level because images of Tonle sap lake were taken on different months (1990 Landsat scene-December,1990 and ALOS AVNIR-2 scene-April,2007). Generally, water level of Tonle Sap is higher in December than that of the April.

Built up areas were expanded by 188% showing the development occurred around cities.

According to the results of the study, most prominent land cover/land use changes were deforestation and growth of the agricultural area. Main reasons for deforestation are demand of the land for fast growing agriculture sector and illegal logging. Deforestation in the flood forests around the lake has destroyed extensivetracks of wet-season fish habitat. Logging in upper watersheds sends silt downstreamclogging the mouth of the lakecan be resulted in downstream floods.

6. CONCLUSION

Tonle Sap Lake, being the largest freshwater lake in Southeast Asia and having a great impact on socio economic development in Cambodia, this study has helped in detecting changes in the land cover and Land use over past 20 years of the watershed. Deforestation and large agricultural growth were recognized as most important land cover changes occurred which could affect biosphere of the watershed. According to the results, if the deforestation continue at current rate (2.26% per year), total forest cover will be destroyed in another 25 years. Thus, it is suggested to take immediate measures to restore forest cover for the protection of Tonle sap lake and its watershed.
Since ALOS AVNIR-2 data provide acceptable accuracy, it is recommended to use ALOS AVNIR-2 data for land cover/land use applications.

ACKNOWLEDGEMENTS

Authors express their gratitude to Japan Aerospace Exploration Agency (JAXA) for providing ALOS AVNIR-2 data and financial supportthrough the Mini Projects.

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