50 years monitoring land cover and use of the Phu Wiang watershed, Thailand.

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ABSTRACT

The area of the Phu Wiang watershed is monitored for 50 years, with the help of aerial photographs and satellite images. Aerial photographs of 1954, 1976 and 1984 were interpreted. The resulting maps were digitised. Landsat TM image of 1988 and Aster image of 2004 were classified. Available forest plantation maps, including planting year and species, for both years was obtained from the watershed management unit. Field data was collected in 1989 to validate the 1988 classification. In 2004 field data was collected with handheld GIS and GPS for accuracy assessment of the 2004 classification. The land cover/use information of the different years were superimposed with GIS overlay to detect changes in land cover/use. Deforestation in the area was seen from 1954 till 1984. Protection and forest plantations started in 1981. Since then the forest area did not decrease. Upland crop has changed from 1988 to 2004 from cassava in to maize, depending on the market prizes.

1. INTRODUCTION

In 1989 geographical data from 4 different years the watershed area of Phu Wiang was collected for training in monitoring (Westinga, 1989). This material is used during training courses, organised by ITC. In 2004 the author had the opportunity to visit the area again, in order to collect field data. Since the earliest data were from 1954, geographical data over a period of 50 years would then be available.

As part of the UNDP/FAO regional project "Strengthening forest inventory capabilities for forest management in Asia and the Pacific" RAS/86/049 a course in remote sensing and mapping for forest management had to be organised in March 1989 at the faculty of forestry, Kasetsart University, Bangkok. For training purposes the project provided equipment, data and material in digital image processing and geographical information system to the Kasetsart University.

Course material on remote sensing and geographical information system had to be developed. This had to be on an area of interest to foresters and this area had to be relatively easy accessible from Bangkok for fieldwork during courses. The "Integrated Development of the Phu Wiang" UNDP/FAO project THA/84/002 had already much information available about the watershed available, a.o. landuse maps of 1976 and 1984. Also the project was willing to cooperate and to facilitate fieldwork.

The Phu Wiang watershed is located in the the Khon Kaen province in the North East region of Thailand. This area of about 300 km2 contains different types of forest and landuses. Extensive areas were reforested from 1984 onwards.

An Aster image 11 March 2004 was obtained, geo-coded and entered in a handheld GIS. With this in connection to a GPS, field data was collected efficiently in two days. From this a reliable classification was made and compared with the data of previous years.

2. METHODOLOGY

The aster of 11 March 2004 and the Landsat Thematic Mapper satellite data of 1988 was processed on land cover and land use. This procedure is further explained below in section 2.1.

The accuracies of the final results were assessed, by matching with the field data.

From aerial photographs of 1954, scale 1: 50 000, a photo interpretation was made in 1989. Classes were based on the land use map of 1976. The interpretation of 1954 was transferred to the

1969 topographical map, scale 1: 50 000, using a zoom transferoscope at the Kasetsart University. This resulting map was digitized.
The existing land use maps with scale 1: 50 000, based on interpretation of aerial photographs scale 1: 15 000 from 1976 and 1983-84 were also digitised. An existing map showing forest plantations from 1982 till 1989 was also digitised.
With GIS the different land use maps were compared by overlaying and changes map were derived.

2.1 Image processing of the ASTER and Landsat TM data.
First step is geo-coding the images. The TM image was geo-coded, using ground control points from the topographical map. Together with the ASTER image GCP points are obtained. These were used to geo-code the ASTER image. After geo-coding a shift in X and Y was made to exactly fit the other image and maps. Nearest Neighbour was used for re-sampling both images.
For ground truth observation of the 1988 image, fieldwork was carried out in four days in July 1989. Aerial Photographs of 1984 1:15,000 were used for exact location. Field data of the observation areas were recorded on paper. The areas visited during the fieldwork were digitised on the screen with the TM image on the background. This resulted in a map of small patches scattered over the entire with land use derived from the ground. This was used for assessment of classification accuracy.
On 21 and 22 July 2004 field data was collected with a handheld GIS, connected to a GPS. This data was used for the accuracy assessment of the ASTER image of 11 March 2004. The first day was entirely spent on calibrating. The second day field data was collected.
With the selection of training areas for classification it was tried as much as possible to choose areas with little variation in band values. This is to avoid confusion between classes. Some classes have different appearances on the image. These are first separately classified and after classification combined.
Best classification results were obtained with maximum likelihood. The thermal bands were not included in the classification. Only six classes were used for the 1988 image, two forest types, upland crops, paddy field, sugarcane and water. In 2004 all upland crops were sugarcane. And therefore only 5 classes were used.
In order to get a comparable level of information as obtained from the aerial photo interpretations, the classification was smoothed with a 3 X 3 majority filter. The result was filtered again and also this result was filtered. This 3 consecutive times filtering is needed to get rid of single isolated pixels. Using a bigger size of filter would result in enormous change in shape of the objects.
Only 6 classes were distinguished with the classification of 1988 and only 5 with the classification of 2004. Villages, large water bodies, rock outcrops and forest plantation was obtained from other sources and super imposed on the classification.
Classification of these objects would lead to enormous errors. Villages are a combination of fruit trees, houses and roads. In the large water bodies water hyacint and floating plants lead to a similar signature as other vegetations. Rock outcrops are similar to bare rice fields or upland crops.
Plantation areas appear in different colors, because they are in different stages of development. Trying to classify this would cause a lot of confusion. Their location is already known from existing plantation maps, including precise information on species and planting date. The plantation map was not geometrically correct. On the TM image although plantation is not to be classified, the shape of boundaries were detectable. Plantation was therefore edited in ARC/INFO with the TM classification in the background, in order to fit on the image.
For the 1988 classification the forest map, villages from 1984 and water bodies from 1984 were superimposed on the classification. The rock outcrops of 1984 were not geometrically matching. Probably 1984 map was not geometrically sound on sloping areas. Therefore interpretation on the screen for rock outcrops was made based on 1954 and 1976 maps. And this was superimposed on the classification.

The very small areas cloud and shadow were digitised on the screen and the most likely class assigned.
Some areas on steep slopes were classified as rice field, which was not possible due to the slope. Therefore a simple terrain map was generalised from the digitised contours from the topographical maps, indicating almost flat and sloping terrain. Rice field in sloping terrain was recoded to upland crops.
In 2004 the forest plantations had dense tree canopies and could be classified as forest. Villages and large water bodies were digitized. This and rock outcrops from 1988 were superimposed on the classification.
Areas in on steeper slopes and classified as sugarcane, were visually inspected on the screen and interpreted as deciduous forest. These areas were recoded as such.

2.2 GIS overlay

The final classification was transferred from Erdas to an ARC/INFO file. In order to make this map comparable with the landuse maps of scale 1:50,000, the areas smaller than the smallest mappable unit (5x5 mm on the map) were eliminated. That means that from areas smaller than 62500 m2 the longest boundary was erased and the label deleted. In other words these small polygons were assigned to its neighbour polygon. Only small polygons on the outer boundary were maintained in order to keep the watershed boundary the same for all maps.
The 1984 and 1988 landuse covers contained too many areas smaller than smallest mappable unit (= 39.02 rai on 1: 50 000 scale). Therefore these data were first generalised. That means that small adjacent polygons of different forest types were merged. The same for agricultural classes. Area smaller than 39.02 rai were eliminated except for swidden areas in 1984, because our interest goes exactly to these areas. This eliminating of small areas had some effect on area total for different classes, similar to the majority filtering on classification.
When the four land use maps were superimposed it was apparent that the 1976 map was geometrically displaced. This could be clearly seen from the position of the villages and water bodies. With gisedit this was corrected visually, with the land use map of 1984 on the background, only for the area with villages.
The 2004 classification was not converted to vector.

3. RESULT

The accuracy matrix of the 1988 image with the 1989 field data is presented in Table 1. The overall accuracy is 85%. The result looks pretty accurate, except for the dry dipterocarp forest. Not of very importance is the misclassifying between the two forest types. If needed the delineations between the two forest classes can be taken from the 1984 map. If we group the two forest types and forest plantation in one class forest, the overall accuracy is 89%.

	Field data 1989									
	evergreen	deciduous	for plant	sugarcane	upland	rice field	water	rock	village	totals
evergreen	1644	87	2	15						1748
deciduous	110	1712	31	38	309	19		5		2224
for plant		31	353							384
sugarcane				108						108
upland		1	154	26	608	22		5		816
rice field			11		55	630	3			699
water							38			38
rock								107		107
village									75	75
totals	1754	1831	551	187	972	671	41	117	75	6199
		correctly classified		5275						
		overall performance		85%						

Table 1. Accuracy matrix 1988 classification with 1989 field data.

	evergreen	deciduous	sugarcane	paddy	water	rock	village	totals
evergreen	187	0	0	0	0	0	0	187
deciduous	543	619	20	191	10	0	46	1429
sugarcane	0	0	61	5	0	0	8	74
paddy	0	9	45	1872	0	0	0	1926
water	0	0	0	0	158	0	0	158
rock	0	0	0	0	0	0	0	0
village	0	0	0	3	0	0	2123	2126
totals	730	628	126	2071	168	0	2177	5900
		correctly classified		5020				
		overall performance		85 %				

Table 2. Accuracy matrix of 2004 classification with 2004 field data.

The accuracy matrix of the March 2004 classification with the July 2004 field data is presented in Table 2. Again an enormous misclassifying is observed between the two forest types. If we group them in one class the overall accuracy becomes 99%.
The maps and classification results are presented in figure 1. Clearly a decline in forest cover is observed from 1954 to 1976 and to 1984. In 1988 it stabilizes and even increases if the forest plantation is added.
In table 3 the area of land uses in % for each year is presented. The classes of the different years were not exactly the same. When grouped in main classes the comparison over the years is more clear. In table 4 the detailed classes are combined in main classes.

Code	**Landuse**	**1954**	**1976**	**1984**	**1988**	**2004**
1012	Villages	1.33	1.4	1.74	1.75	1.74
2000	Agriculture	8.47	24.32			
2100	Upland crops	1.8		8.94	6.94	
2302	Sugarcane				0.09	1.86
2411	Rainfed rice			15.42	14.96	10.94
2602	Swidden		3.99	12.48	2.75	
3112	Dry evergreen forest	52.73	47.69	43.2	33.7	35.25
3220	Dry dipterocarp forest	34.7	21.41	17.25	34.26	49.53
3540	Forest plantation				4.63	
4001	Water	0.4	0.48	0.38	0.54	0.3
5000	Bare soil			0.27		
5003	Rock outcrop	0.57	0.71	0.32	0.38	0.38
	Total	100	100	100	100	100

Table 3. The area covered by the different detailed classes of land uses in % of the total area for each year.

It can be observed that the forest cover is returning in the area to almost the cover of 1954.

Main Landuse	**1954**	**1976**	**1984**	**1988**	**2004**
Villages	1.33	1.4	1.74	1.75	1.74
Agriculture	10.27	28.31	36.84	24.74	12.8
Forest	87.43	69.1	60.45	72.59	84.78
Water	0.4	0.48	0.38	0.54	0.3
Bare	0.57	0.71	0.59	0.38	0.38
Total	100	100	100	100	100

Table 4. The area covered by the different main land uses in % of the total area for each year.

Different maps were overlayed and forest change maps constructed. In figure 2 forest change maps from 1954 to 1984, 1954 to 2004 and 1984 to 2004 are presented.

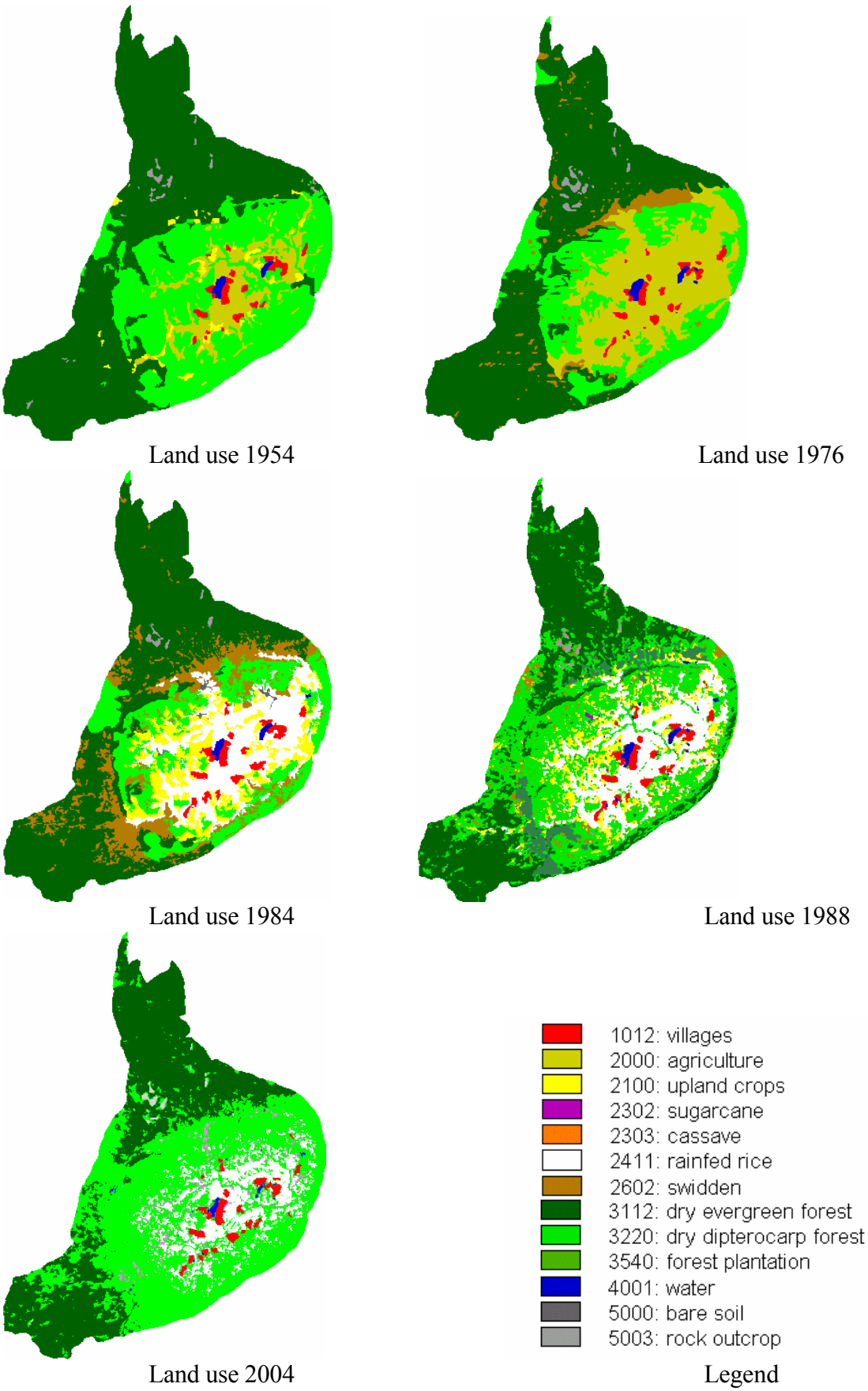

Figure 1. The use maps and classifications of the different years.

Overlay the 1954 with 1984 and 2004

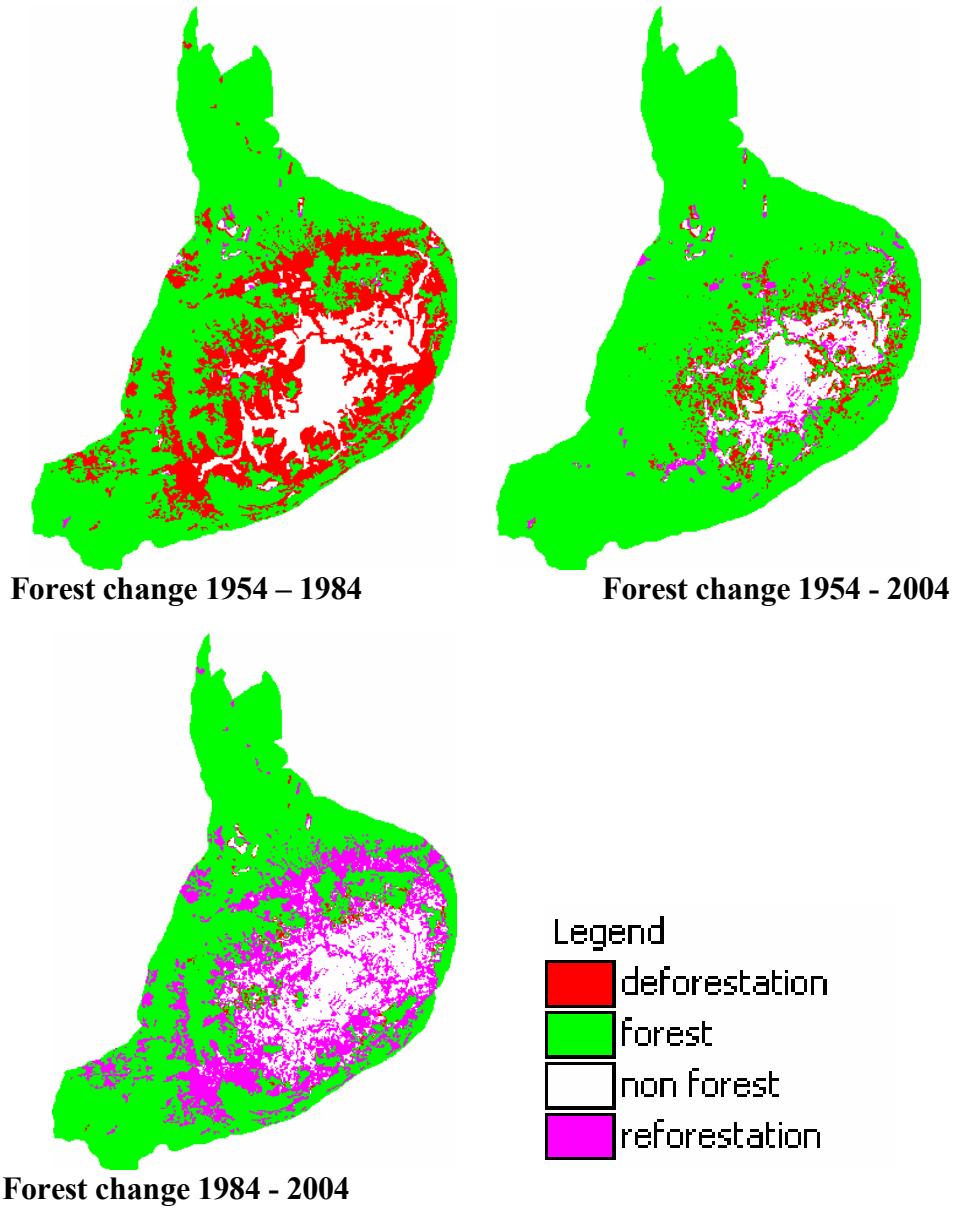

Figure 2. Forest change maps from 1954 to 1984, 1954 to 2004 and 1984 to 2004.

4. CONCLUSIONS

The degradation of the forest is clear from 1954 to 1984. In 2004 the forest cover has been returned to almost the same cover as from 1954.
The reforestation and protection program of the forest in the Phu Wiang area looks successful.
Upland crop has changed from 1988 to 2004 from cassava in to maize, depending on the market prizes.
Satellite data proves to be a usefull tool for change detection of forest cover.
Handheld GIS in connection with GPS speeds up field data collection considerably.

5. LITERATURE

Westinga E., 1989. Application of geographical information systems and remote sensing for monitoring landuse changes in the Phu Wiang watershed, Thailand. Proceedings of FRANCO-THAI workshop on remote sensing, nov 2-4, 1989, KhonKaen, Thailand.