Forest Change Detection Using Multi-temporal Remotely Sensed Data in Phu Luang Wildlife Sanctuary, Northeast Thailand.

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Abstract: The main functions of the Wildlife Sanctuary are to conserve forest ecology and to maintain a rich habitat wildlife species. Remotely sensed data provides the updated information on the change and dynamics of the Sanctuary. The objective of this study is to periodically monitor the forest change and to identify the plant community in the sanctuary. Aerial photo acquired in 1976, Landsat data in 1998 and 2005 were used to produce the land use patterns and its changes. The field investigation was conducted to verify the interpretation and to the inventory the plant community and sub community of forest types including its profile diagram. In addition the GIS database of land use pattern was established for the years 1976, 1998 and 2005. Further analysis was digitally performed to create the change detection maps. The results obtained indicate a significant change of forest acreage between 1976-1998 and 1998-2005. The forest types and the plant community were identified within intensive plot observation.
Keyword: Forest change detection, multi-temporal remotely sensed data

1. Introduction

Phu Luang Wild-life Sanctuary (PWLS) is among many sanctuaries, a form of maintaining forest reserves for wild-life habitat. The controlling and preventive measures are enforced rigidly to minimize the encroachment on forest reserves. On a regional basis, a remarkable change in forest land during the past 4 decades has been found. Thailand used to have abundant forest reserves which used extensively to increase cultivated areas and develop the country economy. The forest area has depleted rapidly from about 50% of the total land area in 1961 to 25% in 1998 (charuppat.1998). In 1990 the forest was in crisis the government terminated the forest concessions. The sixth national economic and social development plan called for developing forest resources with emphasis on conservation through preventive and controlling measures and encouraging economic use. (NESDB 1987). To minimize the forest crisis and conserve the resources, emphasis is currently placed upon the national parks and wild-life sanctuaries. With the preventive measures in the wildlife the forest area is still encroached upon and fired. In addition although reforestation has been on going, its overall result has been rather small. Prior to the establishment of the PLWS in 1974, the situation of forest within the area was in crisis and serious trouble with illegally loggings and fires. The wild-life habitat, inevitably encroached with accelerated rate. In addition the PLWS was considered as a largest source for all breeds of life with a diversity of ecosystems which make it unique in the areas. The previous study conducted by Wildlife division and Khon Kaen University revealed that the PLWS was rich with forestry resource and numerous Wild-life species (Wildlife Division and Khon Kaen University. 2000). There exists a number of endangered species of wildlife including birds and wild mammals. The habitat suitability for 9 wildlife species relevant to the PLWS was also identified using overlay analysis of forest type, topography, water resource, salt lick and distance from the human activity sites (wildlife division and Khon Kaen University 2000). These include Asian elephant, Sambar deer, Serow, Asiatic black bear, barking deer, red dog, white handed gibbon, silver pheasant and big-headed turtle.

The enforcement of law and the protection of forest is then promulgated at Cabinet level. To enhance the efficiency of the protection, regeneration and utilization of forest resources, the information about the change is still needed. These include an inventory, periodical monitoring and the causes of changes. With the advent of high resolution satellite data the updated and multi-temporal information to detect the changes can be obtained. Two approaches to land cover change detection have been reported. The first approach is that each-date imagery is separately classified into land cover class, subsequently the comparison of a result is made (Bordon, 1980; Millington et al, 1986).

The second applied mathematical transformation mainly image differencing and rationing to the raw coregistered images. This technique is reported to give slightly more accurate result. (Nelson 1982, Jenson and 1982). Bureau et al (1987) reported the application of multi-temporal satellite data by using interactive classification of each date imagery separately and each date imagery is subsequently compared. Sader (1988) utilized Landsat imagery of three dates, supplemented by aerial photograph, to study forest change dynamics in a tropical area. The information to be obtained can be used for the wildlife habitat protection, planning and long-term policy.

2. Objective

The purpose of this study is to monitor the forest change in the wild-life sanctuary and to inventory the plant community and sub-community of forest types.

3. Description of the Study Area

The study area, PLWS, is located in Loei Province NE Thailand. (Fig.1) and covers and area of about 100 km^2 with elevation differences between 400 m on the foot hills and 1600 m on its summit. It is characterized by a number of hills with a thick sequence of Mesozoic rock 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 varied from 1,200 – 1,400 m.m., with over 60% of the annual rainfall falls in August and September.

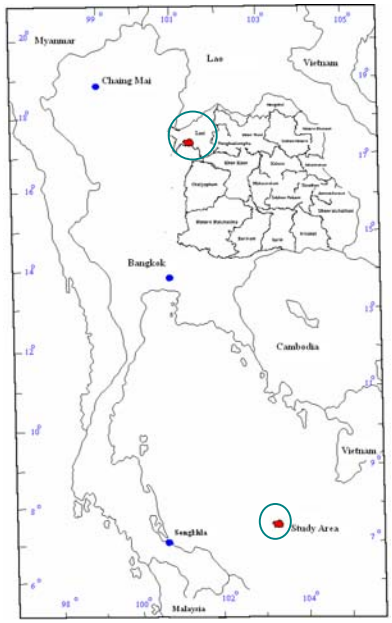


Fig.1 Study Area (Phu Luang Wildlife Sanctuary, NE Thailand)

4. Data sources

The change detection in the PWLS was derived from the following sources.

1) Aerial photo (1:50,000) acquired in 1976
2) Multi-temporal Landsat data acquired on March 17, 1998 and February 25,2005which corresponded to the dry season.
3) Topographic maps of the Royal Thai Survey Department at the scale 1:50,000 which were used for geo-referencing and supplement information

5. Methodology

The aerial photo and two Landsat TM data of different dates as mentioned above were coregistered to a 25 meter UTM projection resulting in a single image set. The visual interpretation was performed on the three dates data to identify the land use in areas. The result, obtained were digitally encoded in GIS database. The comparison of changes was processed by the overlay functions of GIS. The ground truth survey was also conducted to support the interpretation and to inventory the community plant and sub-community of forest types including its profile diagram. Details of methodology are described as the following steps.

5.1) Preprocessing of the imagery.

The two TM scene was georeferenced using the ground control points selected from the topographic map and a nearest neighbor interpolation algorithm was performed.

The aerial photos were converted into digital form by scanning with resolution of 200 dpi and was further coregistered to the TM images and resampled to 25m.

We used a color composite image of the 2 scenes which three bands which are TM4(red), TM5(green) and TM2(blue). The result image allows us to distinguish the areas with different land use patterns.

The geo-referenced aerial photo was mosaicked and digitally enhanced to provide a better discrimination.

5.2) Visual interpretation

The aerial photo and two scenes of TM imagery are visually interpreted and a hierarchical interpretative scheme is devised which consists of the following steps :

1) directly-observable features such as water bodies water channels, roads and community areas are identified;
2) Stratification of the target area, based on color, texture and pattern of the imagery is carried out and general features of the area being mapped are noted. Sampling sites for field survey are also identified at this stage;
3) Land use patterns are identified with particular reference to the classification schemes as used by Land Development Department. The additional features include the ground conditions and the heterogeneity of the area;
4) Field surveys, to sample and verify relationships between terrain-vegetation, are carried out. In addition the inventory of the community plant and sub-community of forest types including its profile diagram was conducted in a number of sampling sites.

5.3) Inventory and ground survey

The ground survey provided details of establishing the relationships between image feature and vegetation covers including site characteristics. To achieve the objective this approach used the stratified random sample method which the stratified random sample method which performed the stratification of the target area followed by sampling at different frequencies within each area. Twenty ground sites were chosen that encompassed 6 forest types with 3 replications. Observations recorded at each site included canopy and understory species type, percent, height and size of plant species and plant locations. Identification of plant species in the selected plots/sites was based on the individual expertises and experiences. Estimation and measurement of the characteristic recorded in each plot was carried out to ensure that observations were as representation as possible. Allocation of the test plots was based on GPS in combination with the satellite imagery and the initial land use developed.

5.4) Establishment of GIS database

1) Land use maps produced by manual method of the years 1976, 1998 and 2005 were prepared with references to the topographic maps at 1:50,000 scale.
2) Each of the maps and their associated attribute data were digitally encoded in a GIS database to eventually generate 3 land use layers. In addition, the geo-information forming the basis for the establishment of the land use map were digitized and encoded in the GIS database.

5.4) Change Analysis

The forest change procedure used involved a comparison of land use layers derived from different dates of remotely sensed data. This approach was digitally performed on an initial land use layers established and subsequently overlaid the land use layers. In this case, the comparison of the changes was carried out between the land use of the years 1976 and 1998, including the year 1998 and 2005.

The statistics of the changed class were also calculated. The intention of this study was not placed on the monitoring the change of specific class. The change of any class of land use for the entire study area is the main interest and concern.

6. Result and Discussions

6.1) Land use and its changes

The land use in the PLWS of the years 1976, 1998 and 2005 is presented in fig.2, fig.3 and fig.4 respectively. The area occupied by each class of land use types in the PLWS and its 5 Kms buffer around the sanctuary is shown in Table 1, Table 2 and Table 3 for the year 1976, 1998 and 2005 respectively. In the year 1976 or 2 years after the establishment of the PLWS, the majority of the area was restricted to Dry evergreen forest which covered approximately 42% of the total area. The hill evergreen, dry dipterocarp, mixed deciduous and pine forests accounted for 33.09%, 4.47%, 2.94% and 0.73% respectively, while the agricultural areas covered an area of about 15.16%. Twenty two years later or in 1998 there existed 28.39%, 20.82%, 2.32%, 3.1% and 0.73% for dry evergreen, hill evergreen, dry dipterocarp, mixed deciduous and pine forests respectively. The land use of the year 2005 as shown in the table 3 indicates that the hill evergreen, dry evergreen mixed deciduous and dry dipterocarp forests cover areas of 27.44%, 20.75%, 3.098% and 1.96% respectively.

Table 1 Landuse in the Wildlife Sanctuary and its 5 km buffer 1976

Number	Landuse	Area of Landuse in Wildlife Sanctuary and its buffer		Area of Landuse in Wildlife Sanctuary	
		Area (Hectare)	Percentage	Area (Hectare)	Percentage
1	Hill evergreen forest	34,016	18.535	29,682	33.093
2	Pine forest	665	0.362	655	0.730
3	Dry or semi-evergreen	52,961	28.858	38,468	42.887
4	Mixed deciduous forest	3,174	1.730	2,633	2.935
5	Dry dipterocarp forest	30,761	16.761	4,006	4.466
6	Range land	397	0.216	391	0.436
7	Outcrops	224	0.122	221	0.247
8	Agriculture	61,087	33.285	13,605	15.168
9	Community	238	0.130	33	0.037
10	Water body	3	0.002	1	0.001
	Total	183,527	100.000	89,695	100.000

Table 2 Landuse in the Wildlife Sanctuary and its 5 km buffer 1998

Number	Landuse	Area of Landuse in Wildlife Sanctuary and its buffer		Area of Landuse in Wildlife Sanctuary	
		Area (Hectare)	Percentage	Area (Hectare)	Percentage
1	Hill evergreen forest	26,816	14.611	25,466	28.392
2	Pine forest	665	0.362	655	0.730
3	Dry or semi-evergreen	19,038	10.373	18,682	20.828
4	Mixed deciduous forest	3,436	1.872	2,813	3.136
5	Dry dipterocarp forest	9,721	5.297	2,089	2.329
6	Bamboo forest	1,316	0.717	1,004	1.120
7	Plantation	9,738	5.306	7,234	8.065
8	Range land	1,130	0.616	1,114	1.242
9	Outcrops	224	0.122	221	0.247
10	Agriculture	109,703	59.775	30,193	33.662
11	Community	1,272	0.693	210	0.234
12	Water body	469	0.255	14	0.016
	Total	183,527	100.000	89,695	100.000

Table 3 Landuse in the Wildlife Sanctuary and its 5 km buffer 2005

Number	Landuse	Area of Landuse in Wildlife Sanctuary and its buffer		Area of Landuse in Wildlife Sanctuary	
		Area (Hectare)	Percentage	Area (Hectare)	Percentage
1	Hill evergreen forest	25,942	14.135	24,616	27.445
2	Pine forest	733	0.399	722	0.805
3	Dry or semi-evergreen	18,949	10.325	18,612	20.750
4	Mixed deciduous forest	3,377	1.840	2,779	3.098
5	Dry dipterocarp forest	9,165	4.994	1,765	1.968
6	Bamboo forest	1,532	0.835	1,180	1.315
7	Plantation	8,095	4.411	5,923	6.603
8	Range land	1,337	0.728	1,314	1.465
9	Outcrops	224	0.122	221	0.247
10	Agriculture	112,277	61.177	32,292	36.003
11	Community	1,381	0.753	239	0.267
12	Water body	514	0.280	31	0.035
Total		183,527	100.000	89,695	100.000

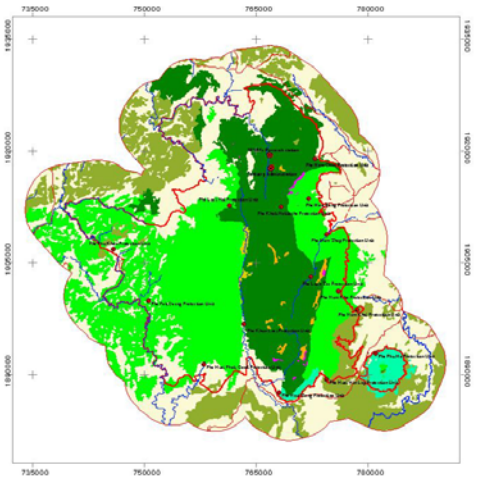


Fig.2 Landuse in PLWS and its buffer 1976

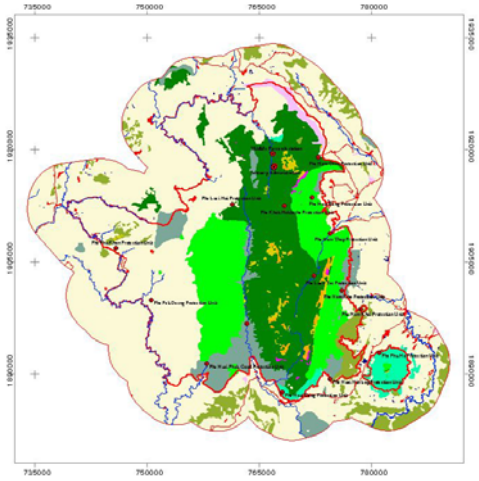


Fig.3 Landuse in PLWS and its buffer 1998

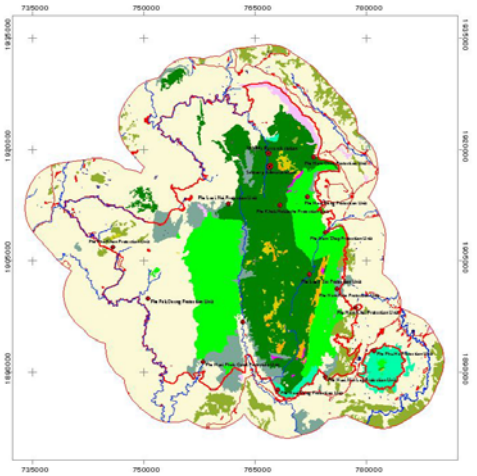
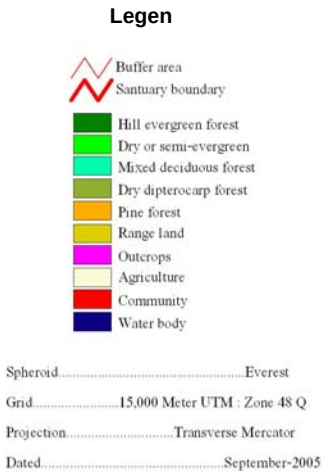


Fig.4 Landuse in PLWS and its buffer 2005



The results obtained indicate a significant change of forest acreage between 1976-1998. The depletion in forest area by type from 1976 to 1998 was 14.20%, 51.43% and 47.85% for hill evergreen, dry evergreen and dry dipterocarp forests respectively. (table 4). The landuse change (1976-1998) map is shown Fig.5 which distinguish changes in all kinds of landuse. The depletion of forest by type between 1998-2005 is not significant in relation to 1976-1998. The decrease in forest area by type (1998-2005) is 3.34%, 0.37%, 1.21% and 15.51% for hill evergreen, dry evergreen, mixed deciduous forests respectively. The total reduction of forest area by type since the establishment of the PWLS (1974) to date is approximately 17.07%, 51.62% and 55.94% for hill evergreen, dry evergreen and dry dipterocarp forests respectively. It should be noted that 30 years after the establishment of the sanctuary the depletetion of forest area is relatively significant . The reasons behind the cause of forest degradation include the demand of land for cultivation, wood and firewood needs and community expansion. The vast extent of the PLWS and a limited number of protection officials my have significant effects on the decrease of the forest area and wildlife species as well.

Table 4 Landuse in The PLWS. 1976, 1998 and 2005 and its changes

Number	Landuse type	Area (%)			Change (%)		
		1976	1998	2005	1976-1998	1998-2005	1976-2005
1	Hill evergreen forest	33.093	28.392	27.445	-14.20	-3.34	-17.07
2	Pine forest	0.730	0.730	0.805	0.00	10.23	10.23
3	Dry or semi-evergreen	42.887	20.828	20.750	-51.43	-0.37	-51.62
4	Mixed deciduous forest	2.935	3.136	3.098	6.84	-1.21	5.55
5	Dry dipterocarp forest	4.466	2.329	1.968	-47.85	-15.51	-55.94
6	Bamboo forest	-	1.120	1.315	-	17.53	-
7	Plantation	-	8.065	6.603	-	-18.12	-
8	Range land	0.436	1.242	1.465	184.91	17.95	236.06
9	Outcrops	0.247	0.247	0.247	0.00	0.00	0.00
10	Agriculture	15.168	33.662	36.003	121.93	6.95	137.35
11	Community	0.037	0.234	0.267	-	-	-
12	Water body	0.001	0.016	0.035	-	-	-

Total area of the PLWS. = 89,695 ha.

Fig.5 and Fig.6 show the land use change in terms of locational extent between 1976-1998 and 1998-2005 respectively. It should be noted that the map legends have only shown the change of the forests by type which are significant distinctive. The forest areas were mainly transformed into range land and cultivated areas.

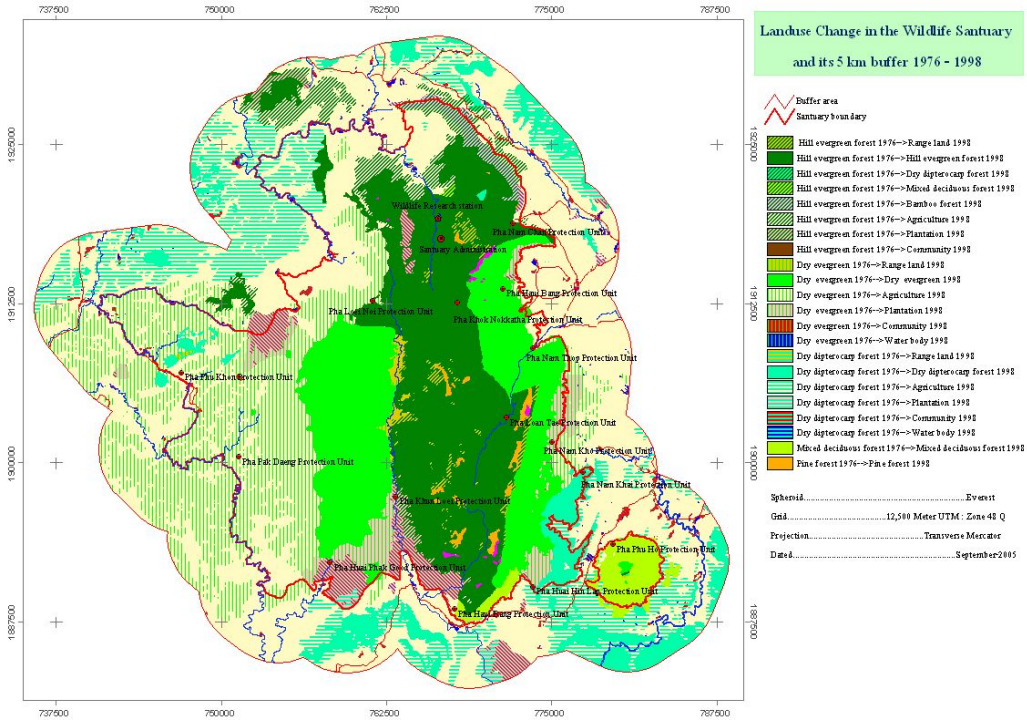


Fig.5 Landuse change in the PLWS 1976-1998

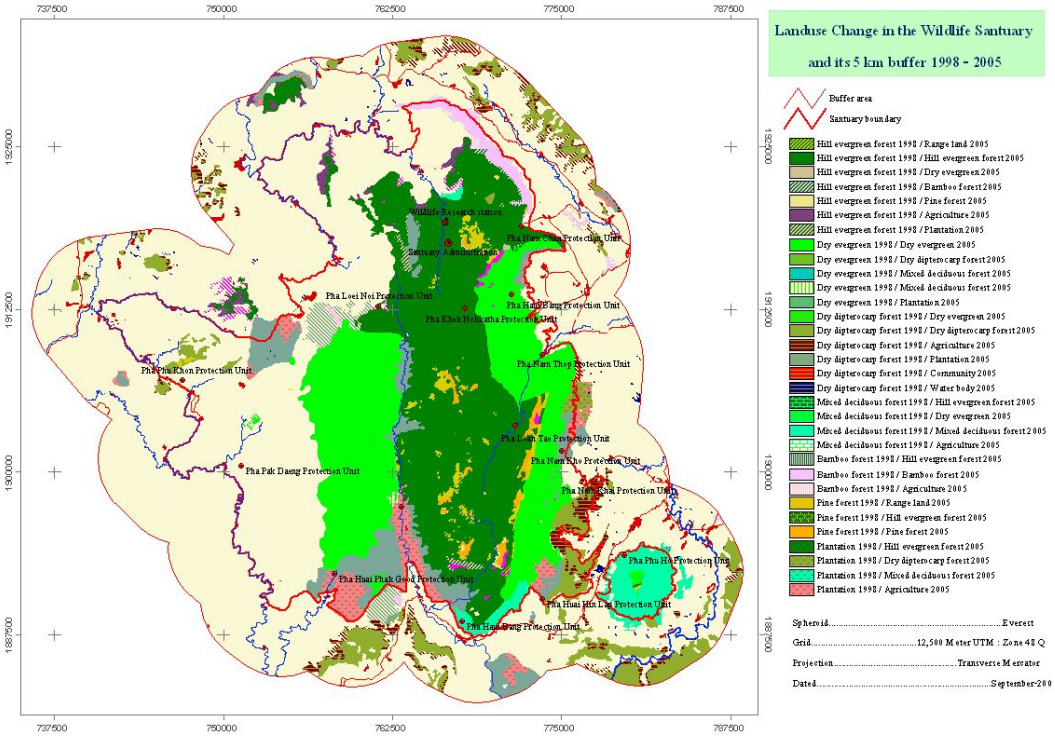


Fig.6 Landuse change in the PLWS 1998-2005

6.2) Forest types and plant-community

The sub-community or dominant species by forest types in relation to main species, canopy density height and site elevation was shown in table 5. It should be clarified that there existed more than some hundreds of tree species for the evergreen and deciduous forests in the PLWS. The presentation of those in table 5 is only some main example species.

Table 5 Forest type and its sub-community in the PLWS

Forest types	Forest class	Sub- community Dominant species	Description			
			Elevation (msl)	Example of Main	percent of canopy density	Tree height (m)
Evergreen Forest [F1]	Hill Evergreen	Lower Montane Oak	1,100	*Lithocarpus trachycarpus, Eugenia cumini, Castanopsis tribuides*	80	20
		Hill Evergreen Forest (*Dacrydium elatum*)	1,400	*Dacrydium elatum, Calocedrus macrolepis*	70	18
		Lower Montane Rain Forest	1,450	*Lyonia foliosa, Lithocarpus recurvatus*	<50	3 to 5
	Coniferous forest	Merkus Pine forest	1,200	*Pinus merkusii*	50	30
		Kesiya Pine forest	1,250	*Pinus kesiya*	40	15
		Merkus and Kesiya Pine forest	1,250	*Pinus merkusii, Pinus kesiya*	50	24
	Dry Evergreen	Dry Evergreen (Lythraceae)	850	*Lagerstroemia calyculata, Shorea guiso, Eugenia cumini, Hopea odorata*	70	30
		Dry Evergreen Forest (Fagaceae)	800	*Eugenia aquea, Shorea guiso, Bischofia javanica*	60	24
		Dry Evergreen Forest (Dipterocapaceae)	800	*Shorea guiso*	50	30
Evergreen Forest [F1]				*Schima wallichii, Anisoptera costata*		
Deciduous Forest	Mixed Deciduous	Deciduous- Bamboo Forest	500	*Lagerstroemia calyculata, Dalbergia nigrescens, Shorea guiso, Aphanamixis polystachya*	60	10
	Dry Dipterocarp	Deciduous Dipterocarp Forest	300	*Shorea obtuse, Shorea siammensis, Pterocarpus macrocarpus*	50	10
		Deciduous Dipterocarp-Dipterocapaceae Forest	800	*Dipterocarpus obtusifolius, Anogeissus acuminata*	60	12
		Deciduous Dipterocarp-Fagaceae Forest	700	*Dipterocarpus turbinatus, Shorea siammensis, Quercus ramsbottomii, Pterpcarpus macrocapus*	60	15

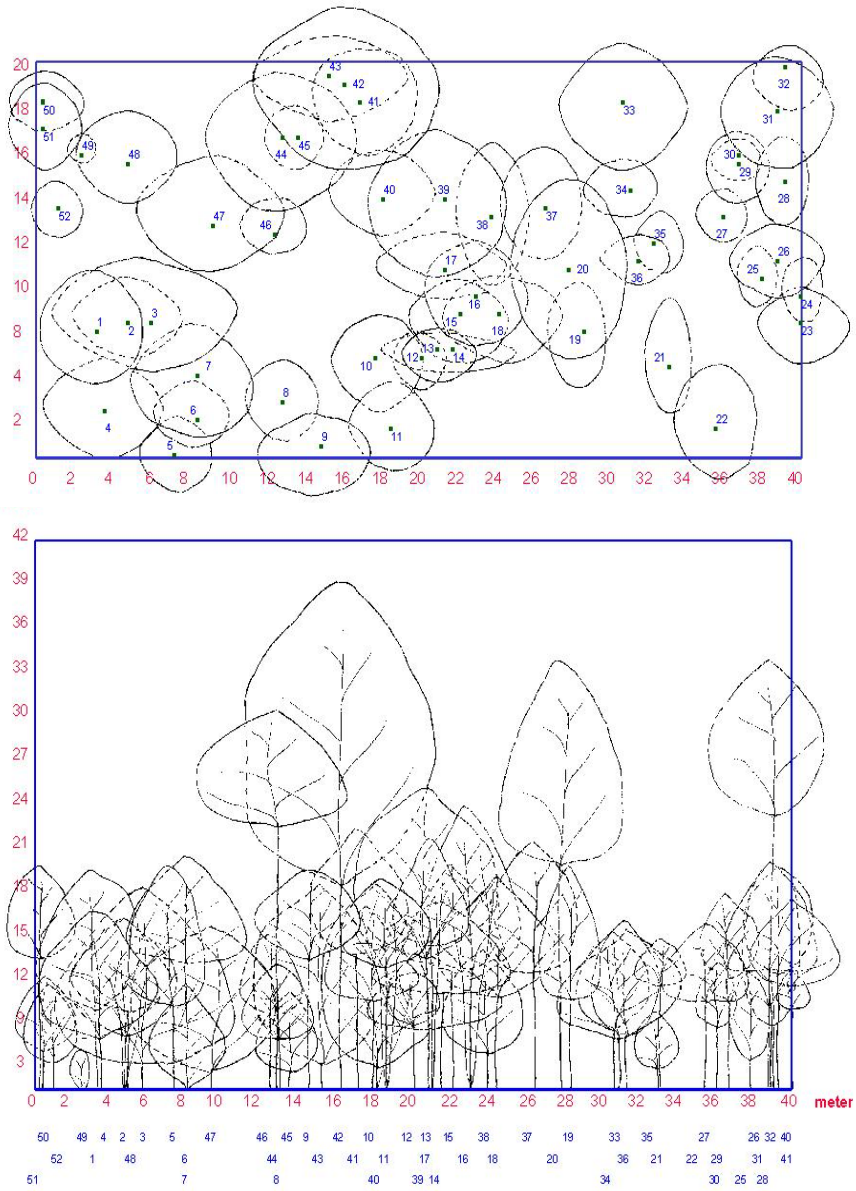


Fig. 7 Profile diagram of dry evergreen forest in the PLWS

Fig.7 shows a profile diagram of the dry evergreen forest structure in the PLWS. This study conducted over 50 plots of 20x40 m. covering all kind of forest type and its sub community. In the finding there still exists a diversity of plant species in each forest types. The spatial arrangement of the vegetation is seen in the profile diagram and described in terms of canopy density.

In conclusion, with the remotely sensed data the periodical monitoring in the conservative area can be effectively undertaken. The significant changes in the evergreen forest since the establishment of the PLWS have been found. The PLWS management should be carried out on a sustainable basis using appropriate and effective measures in accordance with present ecological knowledge. Computer-based GIS with updated satellite data offers the spatial information relevant to the effective measures.

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