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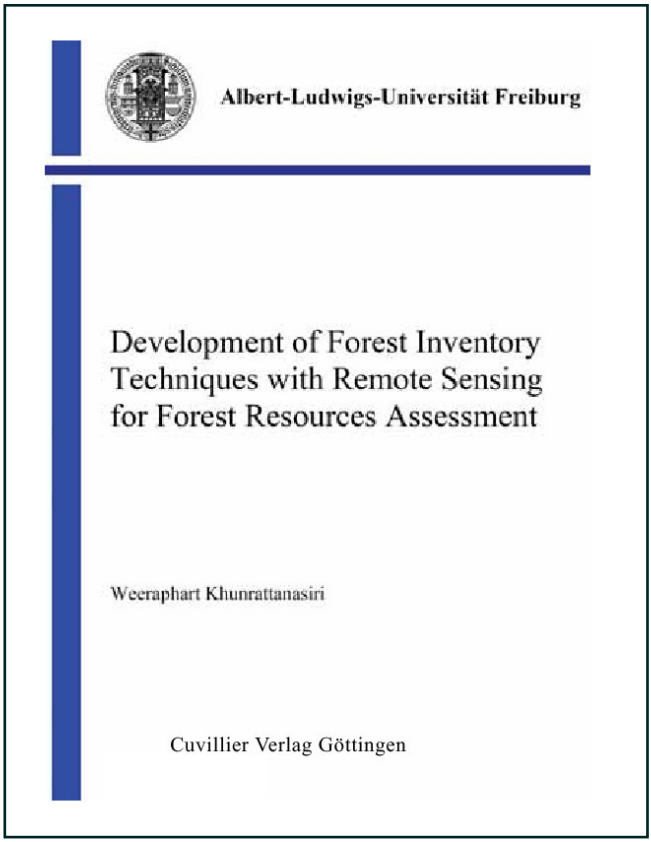
# Development of Forest Inventory Techniques with Remote Sensing for Forest Resources Assessment

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# 1. Introduction

Forests are an indispensable foundation of life for humans. They fulfil multiple functions in a single area: they are a source of income to many; they provide wood, an environmentally compatible, renewable resource, as well as foodstuffs and many other basic commodities; they protect the soils from erosion and stabilise the water table; they stabilise the climate on a regional and global level and they offer humans numerous opportunities for recreation and relaxation. These functions have different levels of significance in the various regions of the earth. For the past twenty years, increases in the produce and income generated in Thailand resulted from the increase of the agricultural area rather than that of products per unit area due to the high rate of population growth correlated with a limited area of land available for cropping and housing. Situations such as poverty and a scarcity of food have forced villagers to migrate into the forest reserves, where they subsequently destroy the forests through shifting cultivation, especially in the watershed areas in the northern part of Thailand. During the period 1961-1985 the forest area decreased at an average rate of 0.5 million hectares annually. Among the major causes of forest depletion were illegal logging, cultivated area expansion, and slash and burn activities. In 2003, the National Park, Wildlife and Plant Conservation Department declared the forest area of Thailand to be only 170,110.8 $km^2$ or 33.15% of the country's total area.

In the past, the method of forest inventory used in Thailand was systematic or non-random sampling. During the period 1955-1960 the 'camp-unit system' was used in regional forest inventories in northern Thailand by Loetsch (Loetsch, 1957a), after which the Royal Forest Department started applying the same system, referring to it as the 'modified camp-unit system'. This forest inventory technique was the main one used between 1969-1976 and 1977-1981 (Wacharakitti, 1982). In certain areas the 'line-plot system' and 'point sampling' were used extensively in later years. In 2000, with the support of the International Tropical Timber Organization (ITTO), Project PD 2/99 Rev. 2 (F) saw the implementation of preparatory studies in Thailand, including an operational pilot, the purpose of which was to install a national forest resource monitoring system using sampling techniques based on the integration of a permanent sample plot and temporary sample plots. However, all forest inventory techniques applied in Thailand to date have been labour intensive, expensive and the time required for field data measurements was long. The protected forest areas, in particular, require the development of more rapid forest inventory methods in order for the national forest planning efforts to reflect accurately the rapidly changing forest parameters, the patterns of land-use and shifting cultivation.

Remote sensing using satellites can make a significant contribution to regional and global forest cover assessment. Satellite images permit the observation of large geographical areas, can be repeated at short time intervals and the costs are reasonable. The basic forest cover information that can be obtained from satellite images at different spatial resolutions relates to the area and spatial distribution of broad forest cover types, to the degree of canopy fragmentation and to the forest cover changes occurring. Over the last few years it has been possible to obtain satellite images with very high spatial resolution. With the main aim of forest inventory being to define potential areas of the forest for future development, remote sensing can reduce the costs of forest inventory and monitoring. Recent papers show that remotely sensed data are well correlated with forest stand parameters such as diameter at breast height (DBH), percent crown cover, tree age class, tree height, basal area and volume. The most frequently used remote sensing products continue to be from optical sensors with a moderate spatial resolution (10–120 m). Examples include Landsat Multi-Spectral Sensor (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+), and SPOT High Resolution Visible (HRV), which are all multispectral sensors with three to seven broad spectral bands. In this study, Landsat-5 Thematic Mapper (TM) imagery with 30 m resolution was used as an example.

Khao Ang Runai is one of fifty five wildlife sanctuaries, and was the location for all of the data collected for this study. The sanctuary is the last of the very large forest areas in the eastern part of the country and it covers an area of 107,896 ha. There are no people living within the sanctuary other than sanctuary staff and their families. One of the main characteristics distinguishing this sanctuary from others is the rising pressure placed on the sanctuary by the densely populated villages around its edges resulting in forest degradation through hunting, timber collection, fire and other agricultural or gathering activities. Up to date information on the forest status in this area is of great importance in order for the government agencies to focus and plan preventive measures for the protection of the area. Currently the paucity of information pertaining to the sanctuary makes it difficult to develop specific courses of action.

The development of forest inventory techniques using remote sensing for forest resource assessment should be established in Khao Ang Runai Wildlife Sanctuary. The application in the national forest policy and in forest management plans of new forest inventory techniques contributing remote sensing data obtained from a high resolution satellite is necessary for the planning and greater efficiency of sustainable forest management.

# 2. Objectives

The first objective of the study presented is to develop a sampling model for monitoring tropical forests and using remote sensing for measuring and assessing forest characteristics. The methods are based on the measurement of ordinary forest characteristics complemented with additional measurements and information pertaining to microsite variations.

The second objective is to estimate forest variables using satellite imagery provided by the Landsat-5 Thematic Mapper and compare the sample plot size and arrangement of present forest inventory techniques in Thailand with the new techniques derived from the study.

The third objective is to develop a new model of forest resource assessment by using new forest inventory techniques and remote sensing in order to better understand and improve the management of the forest area in the future.

# 3. Materials and methods

## 3.1 Khao Ang Runai Wildlife Sanctuary

### 3.1.1 General information

Thailand is situated in the heart of the Southeast Asian mainland, covering an area of 513,115 $km^2$, extending about 1,620 kilometres from north to south and 775 kilometres from east to west. Thailand borders on Laos People's Democratic Republic and the Union of Myanmar (Burma) to the north, the Kingdom of Cambodia and the Gulf of Thailand to the east, the Union of Myanmar and the Indian Ocean to the west, and Malaysia to the south.

Thailand has a variety of vegetation types ranging from tropical evergreen rainforest to dry deciduous forest and savannah forest that reflect a wide range of ecological and climatic conditions. At present, it is estimated that 33.15% of the land is under forest cover, including forest plantations (rubber plantations and orchards excluded) (National Park, Wildlife and Plant Conservation Department, 2003). Kutintara (1998) described vegetation types in Thailand according to the following categories: mangrove forest, swamp forest, beach forest, lower tropical rain forest, upper tropical rain forest, dry evergreen forest, coniferous forest or pine forest, evergreen hill forest, moist upper mixed deciduous forest, dry upper mixed deciduous forest, lower mixed deciduous forest, deciduous dipterocarp forest, savannah and tropical grassland.

The Eastern Forest covers parts of five provinces, namely Cha Choeng Sao, Chanthaburi, Chon Buri, Rayong and Sa Kaew. Another name for the Eastern Forest is therefore the ‘Contiguous Forest Connecting Five Eastern Provinces’. The area of the Eastern Forest has decreased rapidly in recent times, especially during the last decade. Areas of encroachment into the forest were found both along the forest border and even within areas of dense forest. The fact that Khao Ang Runai, the largest forest area in the region, hosts many villages along its boundary is the main reason why the government must seek to find a way to protect this area. Khao Ang Runai Wildlife Sanctuary, in which all of the data referred to within this research study was collected, is located in eastern Thailand ($13^{o}$ 00' 00" - $13^{o}$ 30' 00" N and $101^{o}$ 35' 00" - $102^{o}$ 05' 00" E) (Figure 1). The total area of the wildlife sanctuary is 107,896 ha (nine 1:50,000 topographic map sheets).


Figure 1: Map of Thailand and Khao Ang Runai Wildlife Sanctuary

Khao Ang Runai in the Chachoengsao province was declared a wildlife sanctuary on the 11th of October 1977, and is the thirteenth wildlife sanctuary in Thailand. It adjoins Khao Soi Dao Wildlife Sanctuary in Chanthaburi and Khao Chamao-Khao Wong National Park in Rayong. Initially, the sanctuary covered an area of 10,810 ha, with the area extended to 107,986 ha by the government on the 30th of December 1992, covering five provinces. The main physical feature of the north and central area is a plain, with a moderate slope. There are mountains to the southwest, southeast and northeast. The elevation ranges from 30 to 763 m above sea level and the highest mountain is Khao Ta Krub (763 m) to the northeast. Parts of the Khao Bun Thad and Chanthaburi mountain ranges are located within the sanctuary boundaries to the south. The land use patterns were classified by the Forest Research Center using the Landsat-5 Thematic Mapper acquired in 1990. Applying a visual interpretation technique they found three main patterns: forest area (94.73%), old paddy field and grassland (5.16%) and water reservoirs (0.11%). In 1995, there were 35,511 people living in 24 villages around the boundary of sanctuary (Forest Research Center, 1999).

### 3.1.2 Climate

The study area is located in a monsoon region with high precipitation caused by the Khao Bun Thad and Chanthaburi mountain ranges to the south of the area. Therefore, rainfall is higher to the south than to the north. The climate is savannah to the north and tropical monsoon to the south, due to the influence of monsoon and the sea. This variation has an important role in the high level of biodiversity of flora and fauna. The plant community especially exhibits the distribution of the two regions Indo-China and Indo-Malaya. The meteorology data from 1956 to 1985 show that the average annual rainfall, yearly temperature and average humidity are 1,891.4 mm, 26.7 $^{O}$C and 75.6% respectively.

### 3.1.3 Forest types

The high level of biodiversity is another major reason highlighting the importance of the area for conservation purposes. Three forest types can be distinguished:

**Dry evergreen forests** are found in most areas of the sanctuary. The main commercial trees are *Dipterocarpus turbinatus*, *Anisoptera costata*, *Shorea hypochra*, and *Hopea odorata*. The vertical structure characteristics of this forest type can be divided into three categories:

1) Upper layer (20-45 m): the main dominant trees are *Lagerstroemia calyculata* and *Irvingia malayana*. Some tree species occupy only small areas, such as *Dipterocarpus turbinatus*, *Hopea odorata*, *Pterocymbium javanicum* and *Tetrameles nudiflora*;
2) Middle layer (15-20 m): some tree species such as *Aglaia pirifera*, *Aphanamixis polystachya*, *Pterospermum diversifolium*, *Sandoricum koetjape*, *Nephelium hypoleucum*, *Litchi chinensis* and *Carallia brachiata* are present;
3) Lower layer (6-15 m): tree species such as *Murraya paniculata*, *Excoecaria oppositifolia*, *Diospyros castanea*, *Aglaia palembanica*, *Diospyros ferrea*, *Sageraea elliptica*, *Mansonia gagei*, *Diospyros buxifolia* and *Dendrocnide stimulans* are present.

**Mixed deciduous forests** are found on limestone mountains, restricted to small areas with poor soils and where forest fire has occurred at some time in the past. Certain bamboo species can be found such as *Thyrsostachys siamensis* and *Bambusa arundinacea*. The vertical structure characteristics of the mixed deciduous forests can be divided into three categories:

1) Upper layer (20-30 m): some tree species such as *Terminalia bellerica*, *Pterocarpus macrocarpus*, *Bombax anceps*, *Albizia odoratissima* and *Schleichera oleosa* are present;
2) Middle layer (10-25 m): some trees species such as *Vitex pinnata*, *Markhamia stipulata*, *Terminalia nigrovenulosa*, *Cratoxylum formosum*, *Harpullia arborea*, *Semecarpus cochinchiensis* and *Spondias pinnata* are present;
3) Lower layer (6-15 m): characterised by *Litsea glutinosa*, *Antidesma ghaesembilla*, *Writhia tomentosa*, *Acronychia pedunculata* and *Bridelia ovata*.

**Deciduous dry dipterocarp forests** occur on the smallest area and are found where there is lateritic soil. The vertical structure can be divided into two categories:

1) Upper layer (10-20 m): some trees species such as *Dipterocarpus intricatus*, *Careya arborea* and *Dillenia obovata* are present;
2) Lower layer (3-10 m): characterised by *Strychnos nux-vomica*, *Dipterocarpus tuberculatus*, *Cratoxylum formosum*, *Phyllanthus emblica*, *Gardenia obtusifolia* and *Randia oocarpa*.

### 3.1.4 Wildlife

The wildlife species encountered in the study area can classified according to six categories:

1) Mammal (64 species from 50 genera in 23 families)
2) Bird (246 species from 160 genera in 64 families)
3) Reptile (53 species from 40 genera in 16 families)
4) Amphibian (18 species from 9 genera in 5 families)
5) Insect (106 species from 76 genera in 12 families)
6) Fresh water fish

The endangered species are the crowned gibbon (*Hylobates pileatus*), cloud leopard (*Neofelis nebulosa*), leopard (*Panthera pardus*), tiger (*Panthera tigris*), asiatic elephant (*Elephas maximus*), woolly-necked stork (*Ciconia eqiscopus*), lesser adjutant (*Leptoptilos javanicus*), Siamese fireback (*Lophura diardi*) and Siamese crocodile (*Crocodylus siamensis*) (Forest Research Center, 1999).

## 3.2 Forest inventory and sampling designs used in Thailand

A forest inventory is the procedure used to obtain information on the quantity and quality of the forest resource and many of the characteristics of the land on which the trees are growing (Husch et al., 1982). A forest inventory is a description of the quantity and quality of trees and other organisms that live in the forest and the characteristics of the land on which the forest grows (Shiver and Borders, 1996). The main goal is to report on the status of the forest, the area, and the volume and volume distribution in terms of size classes, but also on the expected changes (growth, vitality, mortality) (Laar and Akca, 1997).

In Thailand the process of forest inventorying was started in 1953 by Mr. Gongryp. Gongryp was the FAO expert who suggested the application of the ‘profile sample plot method’ to various locations in Thailand. However, his work was not recorded and eventually disappeared (Soravisuitra, 1994). In 1955, Dr. F. Loetsch, a German expert from the FAO revised the method of forest inventory, basing it upon statistical methods and testing various systems suitable for implementation in Thailand. He concluded that the ‘camp-unit system’ is the most suitable forest inventory method for use in the tropical zone. In subsequent years, the camp-unit system was applied as the forest inventory method used in five northern teak bearing provinces of Thailand. From 1961 to 1962, Mr. E.J.G. Gartner, another German expert from the FAO,