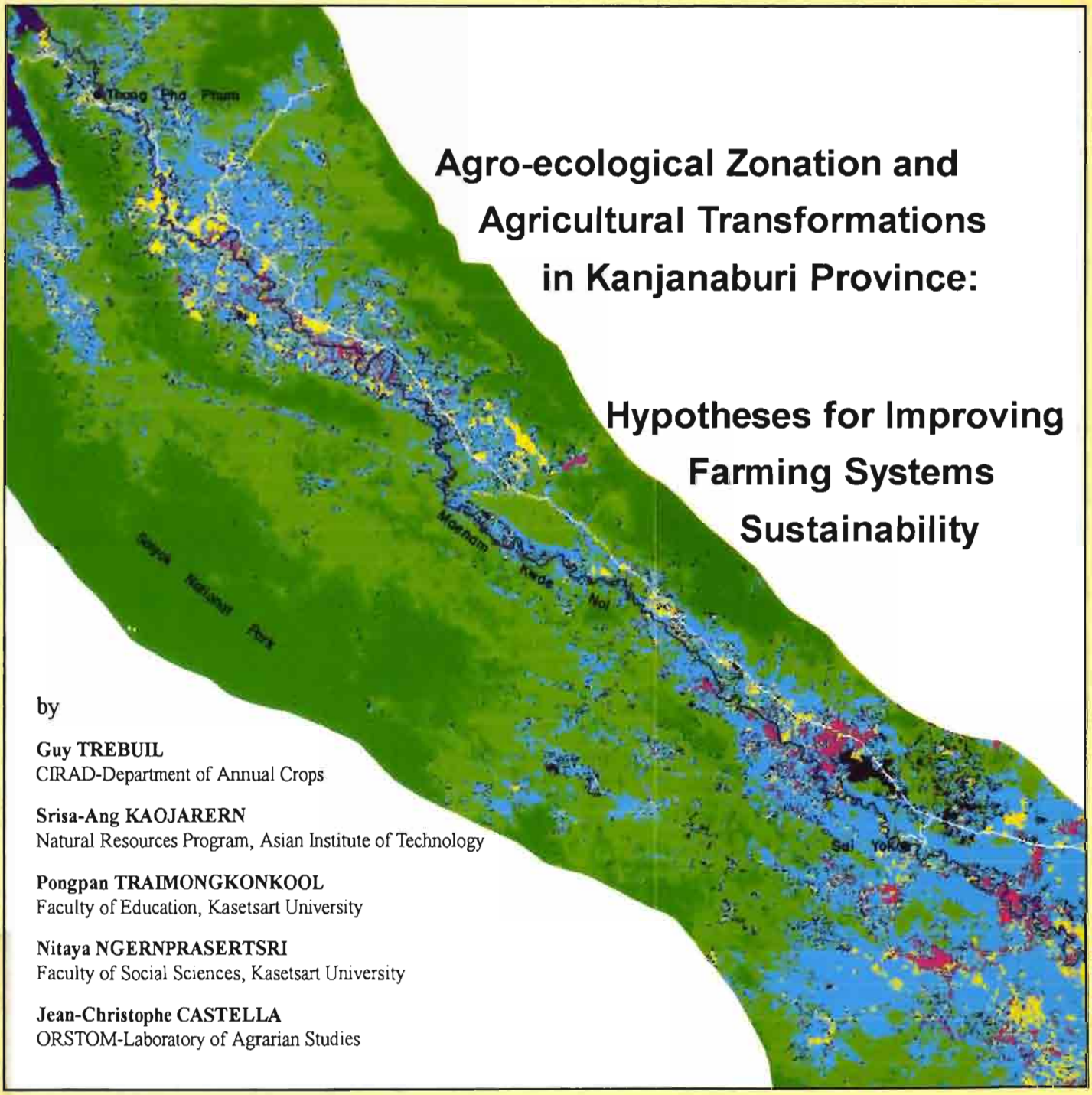
# DYNAMICS OF AGRARIAN LANDSCAPES IN WESTERN THAILAND




## Agro-ecological Zonation and Agricultural Transformations in Kanjanaburi Province:

## Hypotheses for Improving Farming Systems Sustainability

by

**Guy TREBUIL**
CIRAD-Department of Annual Crops

**Srisa-Ang KAOJARERN**
Natural Resources Program, Asian Institute of Technology

**Pongpan TRAIMONGKONKOOL**
Faculty of Education, Kasetsart University

**Nitaya NGERNPRASERTSRI**
Faculty of Social Sciences, Kasetsart University

**Jean-Christophe CASTELLA**
ORSTOM-Laboratory of Agrarian Studies

DORAS PROJECT
Central Laboratory
KASETSART UNIVERSITY
Kamphaengsaen Campus
NAKHON PATHOM 73140
THAILAND

NATURAL RESOURCES PROGRAM
THE SCHOOL OF ENVIRONMENT,
RESOURCES AND DEVELOPMENT
Asian Institute of Technology, G.P.O. Box 2754
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# FOREWORD

Considering agricultural development as the gradual changes occurring in the agricultural production processes that are assumed to be socially beneficial, the knowledge of these processes, their transformations in time as well as spatial adaptations is of paramount importance. This is because such a knowledge should be at the basis of any critical consideration or recommendation for action aimed at modifying the existing production processes and the on-going course of their changes in a given area.

The past failures of a large number of agricultural development policies, schemes, programmes or projects have often been attributed to initial misapprehensions of the actual agrarian realities in the target areas, leading to a lack of adaptation of the innovations proposed to farmers. Particularly, most of the time, bio-physical, agro-technical as well as social and economic heterogeneities have been largely ignored.

In the framework of the preliminary holistic diagnosis on regional agrarian systems (TREBUIL, 1988), and in conjunction with other methodological tools such as the agro-ecological zonation, the key determining factors and conditions explaining the existing differentiated farmer situations can rapidly be identified and understood by looking at the local history of agricultural transformations. This should be done as soon as the initial planning stage of a rural development project or programme.

This publication reports the findings of a case study carried out through collaborative research between the Development Oriented Research on Agrarian Systems Project (DORAS) at Kasetsart University and the Natural Resources Program of the Asian Institute of Technology (NRP/AIT). Despite each institution having different, but still complementary objectives, the interdisciplinary nature of the present study is underlined. This research was an activity among DORAS project diagnostic studies which preceded farming and cropping systems research activities to improve the sustainability and competitiveness of cotton-based production systems in Mae Nam Kwae Noi valley of Kanjanaburi province. Training of students in landscape analysis and application of remote sensing techniques to rural studies, as well as the evaluation of such techniques for the promotion of agricultural development at regional level were the main interests of the NRP/AIT team during the implementation of this joint survey.

Landscape analysis is a powerful tool for training of agriculturalists and natural resources specialists because it stimulates personal thinking through patient observation, promotes the integration of various aspects of agrarian realities, allows the critical confrontation and interpretation of different sources of information, and leads to the elaboration of comprehensive and pertinent syntheses to explain the genesis of the diversity of current on-farm circumstances.

At the same time, according to certain authors, a successful application of remote sensing techniques presupposes an *a priori* knowledge of the phenomena to be displayed, but also an *a priori* knowledge of the type of information we are looking for and this is not exactly the same thing! Indeed, it is also necessary to understand why this kind of information we are looking for is interesting; finally it is necessary to *need* such information (POUPARD, 1987). This is the reason why information users (DORAS project here) are potentially the best placed to extract data side by side with image processing specialists (from NRP/AIT).

The main results of the joint efforts of both teams are presented here. This research report should be considered as a contribution to the analysis of forest dominated agrarian systems in tropical areas for the identification of more sustainable and equitable land use systems when the current main trend is dominated by a rapidly advancing cultivated frontier.

## SUMMARY

The spatial and chronological agro-ecological zonation is a key tool used to achieve the main objectives attributed to the initial diagnostic phase of the so-called Development-Oriented Research on Agrarian Systems (DORAS) approach, which are:

(i) to *identify* and *prioritize* factors and conditions (bio-physical as well as social and economic ones) that are *determining the choice and evolution* of various types of family-based Agricultural Production Systems (APS) in the area...

(ii) to understand how these factors and conditions are involved in the recent and current agro-technical *transformations* of the regional agrarian system (AS) landscapes,

(iii) to reveal the extent of the process of socio-economic *differentiation* among the local APS and understand its origin and mechanisms.

Establishing such a diagnosis is not only a matter of identifying constraints and potentialities for a series of homogeneous zones that will be based, as it is usually done, on a description of the, mainly bio-physical, conditions. At the end of a DORAS diagnosis, one should also *be able to explain how to intervene* on these different key factors and conditions in order to steer the agricultural development process in a more sustainable and less unequal way.

Understanding the dynamics of the transformations which are currently at work is then essential. A pertinent zonation must elucidate the functioning of the AS, which is a product of the recent agrarian history.

This paper presents the results of such a spatial/historical analysis carried out in 1991/2 in Western Thailand by an interdisciplinary team of agronomists, remote sensing and social scientists.

Two main transitional phases between three kinds of AS were identified and analyzed along the rapidly advancing cultivated frontier in Kanjanaburi province. A first major change occurred from a post-second world war system, still dominated by forest ecosystems because of low population and difficult access, to a second type of AS system based on the production of annual cash crops which is still dominating since the early seventies. Later, the recent appearance of a third type of AS in which perennial crops will play a major role was also diagnosed. In the near future, this could lead to the domination of a new AS, in which cultivated trees and animal husbandry would play more important functions.

Elucidating these transitional phases of the regional agriculture led to the understanding of the extent, origins and mechanisms of the farmer differentiation process in the area under study. Such prior scientific knowledge on regional agrarian realities was used to implement on-farm research and development activities at farm and plot levels.

## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AIT | Asian Institute of Technology, Rangsit, Bangkok |
| BAAC | Bank for Agriculture and Agricultural Cooperatives |
| CIRAD | Centre de Coopération Internationale en Recherche Agronomique pour le Développement |
| DOA | Department of Agriculture, Ministry of Agriculture and Cooperatives |
| DOAE | Department of Agricultural Extension, Ministry of Agriculture and Cooperatives |
| DORAS | Development-Oriented Research on Agrarian Systems |
| EGAT | Electricity Generation Authority of Thailand |
| FCC | False Color Composite |
| GIS | Geographic Information System |
| IRCT | Institut de Recherches sur le Coton et les Textiles Exotiques (a former department of CIRAD) |
| KU | Kasetsart University |
| LANDSAT | U.S. Earth Resources Satellite |
| LANDSAT TM | LANDSAT Thematic Mapper |
| RFD | Royal Forestry Department |
| SPOT | French Earth Resources Satellite |

# INTRODUCTION

To carry out a research on the dynamics of land use patterns, the suitability of the "small regional scale" (usually from one sub-district to one district in the Thai context, according to the local degree of heterogeneity in bio-physical and socio-economic conditions) is based on the fact that it constitutes a unity, historically built on intense and long lasting relations between natural resources and rural communities, that led to a complementary functioning system. This facilitates the delimitation of the boundaries of the local agrarian system (AS, see definition in the glossary at the end of this report).

When thinking about zonation, one should begin with the definition of what kind of pertinent classes must be mapped, as well as what are their operational significance in the analysis of the agricultural development process? This is why the objectives and function of the agro-ecological zonation tool in the diagnostic phase of the so-called Development-Oriented Research on Agrarian Systems (DORAS) approach (NARITOOM et al., 1990; SRIJANTR et al., 1990) must first be briefly presented. The full iterative process of the DORAS approach used by the project is shown in Appendix 1.

## 1. DIAGNOSIS ON AGRARIAN SYSTEMS FOR DEVELOPMENT: OBJECTIVES AND COMPLEMENTARY ROLES OF AGRO-ECOLOGICAL ZONATION AND ANALYSIS OF RECENT AGRICULTURAL TRANSFORMATIONS

### 1.1. Objectives of the preliminary holistic diagnosis prior to intervention: assessment of farming system diversity and its origin

The main objectives attributed to the phase of preliminary diagnosis of the DORAS approach are as follows:

(i) to *identify* and *prioritize* factors and conditions (bio-physical as well as social and economic) which are determining the choice and evolution of the various existing types of family-based Agricultural Production Systems (APS) in the area,

(ii) to understand how these factors and conditions are actually involved in the recent and current agro-technical *transformations* of the agrarian system (AS) landscapes,

(iii) to reveal the extent of the process of socio-economic *differentiation* among the local APS and understand its origin and key mechanisms.

Establishing such a diagnosis is not only a matter of identifying constraints and potentialities for each rather homogeneous zone. At the end of the diagnosis, one should also be able to explain *how to intervene on these different key factors and conditions in order to steer the agricultural development process in a way which would be more suitable for the common good.*

Toward such an end, understanding farmers' differentiated social and economic objectives and subsequent strategies is a prerequisite because they regulate their technico-economic decision-making processes. Relevant research and development activities to support trends that are found favourable for the majority of the local community can then be planned and their potential impact predicted.

In Thailand, development-oriented research activities which were conducted for the past ten years at three complementary sites (a coastal rainfed area in Sathing Phra district of Songkhla province, a partly-irrigated rice-growing alluvial plain in Khao Chaison district of Patthalung province, an irrigated low terrace in Kamphaengsaen district of Nakhon Pathom province), have shown that regional agricultural development means how to improve the economic sustainability of a majority (approximately 60% of the total number of APS at each site) of small APS which are facing elimination due to their past and/or current poor resource base and related economic performances (TREBUIL 1988, 1993).

To such an end, the analysis of agrarian landscapes can be used to identify the diversity of on-farm situations and build hypotheses to explain such differences.

### 1.2. Function of agrarian landscape analysis complementary to remote sensing techniques

In the recent past and in a wide diversity of situations, located both in developing as well as industrialized countries, the analysis of the dynamics of agrarian landscapes has proved to be a powerful tool to understand and assess recent, rapid and often brutal agrarian transformations leading in a number of cases to uncontrolled consequences (Lizet et al., 1987). Considered as an historical product, the agrarian landscape provides abundance of significant information about the diversity of technical, social and cultural aspects of man-made agro-ecosystems. Of special importance here is the fact that *landscape analysis can help to elucidate relations between agricultural practices and social relations* in the countryside. Because it introduces the observer to the particularities of a given geographical environment, landscape analysis is a key tool in the field of comparative agriculture and agronomy in a broad sense.

The agrarian landscape being a mirror of past and current relations of rural communities with their natural environment, it has a story to tell, or at least it invites us to restore it on the basis of various pieces of (visual, written or oral) information that reached us. It has also been found that landscape analysis can usefully be used to evaluate the state of relations between man and his surrounding natural resources. Quite often outputs underline doubts and question marks concerning the sustainability of current trends in rural societies. Main trends affecting the studied area and related problems dealing with the sustainability of artificialized agroecosystems can then be detected, understood, and addressed in a relevant manner.

Based on series of visual observations at different scales (first from high grounds, then along well-selected line-transects, etc), landscape analysis is a complementary tool in remote sensing studies applied to agricultural production. Digital data processing of imagery only cannot replace direct visual landscape observations that improve map legends. From them specific phenomena are identified and located, constraints and needs are expressed and problems can be set in pertinent ways. Both tools are very complementary and were used simultaneously in this case study.

### 1.3. Importance of spatial zonation: identification of phenomena and delimitation of their extent

The agro-ecological zonation is a preliminary step of the diagnostic-analysis on the evolution and differentiation of agrarian systems. Previous experiences at other above-mentioned research sites have shown the necessity to undertake this kind of activity before launching investigations at the household-based APS and plot levels (NARITOOM et al., 1990; SRIJANTR et al., 1990). Indeed, the agro-ecological zonation of the target area facilitates the well-thought selection of relevant sites for following in-depth studies or testing of innovative activities. After their completion, the zonation is used again to delineate the extrapolation domain of a given promising technical recommendation.

To be useful in an agricultural development perspective, a pertinent agro-ecological zonation should first *divide the area into homogeneous zones presenting different key questions for agricultural development. Such issues are inherited from the recent past action of farmers on their environment*. A relevant zonation cannot be derived from a classic collection of academic, descriptive and structural criteria (usually exclusively or mainly bio-physical ones) leading to the delimitation of the so-called "land suitability" units and maps. Because of their lack of understanding and consideration for the diversity of current on-farm realities and dynamics of existing situations,

the operational character of such documents is seriously questioned. To guide agricultural development interventions, more dynamic types of zonation are needed that can be used to prepare *functioning typologies* and not only structural descriptions of farm environments.

Accordingly, each of the agro-ecological zones to be considered here should be characterized by:

(i) similar recent transformations of the agricultural production processes,

(ii) a set of specific agro-ecological and socio-economic potentialities and constraints to local agricultural development.

As a consequence, such a classification leads *to the characterization and location of several main technical systems used by farmers in the process of artificialization and exploitation of the various local agroecosystems*. Some are recent ones, other older, only a simultaneous historical analysis can help to explain their origins as well as past and current distributions.

### 1.4. Necessity for a complementary historical survey to verify, understand and interpret key land use changes

Agricultural Development is here considered as the process of gradual changes occurring in agricultural production processes that are assumed to be socially beneficial. Such changes aim at improving the cultivated environment, tools, crops varieties and breeds of domestic animals to satisfy the changing social needs. Thus, *a detailed knowledge of these processes of agricultural production, of their transformations in time as well as spatial variations, adaptations or differentiation, is of paramount importance*. Furthermore, a pertinent understanding of the existing conditions of these transformations and variations should be at the basis of any critical consideration or recommendation for research or development interventions aiming to modify the existing agricultural production processes and the on-going course of their changes in a given area (MAZOYER, 1985; TREBUIL, 1989).

Considering the multiplicity of factors and conditions which are interfering in the evolution of the local APS making them more and more diverse, it is important to understand rapidly what are the dominating mechanisms that are logically leading farmers to implement different kinds of APS. *Such knowledge of main trends and mechanisms is necessary to guide the selection of pertinent classes for land use mapping in an agricultural development perspective that emphasize recent changes.*

Here, recourse to *the historical analysis is necessary* to elucidate the causal relations in the sequence of phenomena that are at the origin of changes in agricultural production processes, of the subsequent differentiation among the local APS, as well as to assess their future direction. Over the recent history, because they were evolving in different ecological as well as economic conditions, the various categories of farmers could not accumulate similar levels of means of production. In the Thai context, this process of, both intra- and inter-regional differentiation among farms has proved to be exceptionally rapid for the past thirty years (TREBUIL, 1993).

The objectives of the agrarian historical analysis are as follows:

(i) To distinguish and characterize the main changes of state of the agricultural production processes in the area over time and their relations with the evolution of the local social as well as economic conditions.

(ii) To understand the social and economic implications of these past ecological and technical changes in order to identify the origins and causes of the increasing differentiation among farmers and their APS.

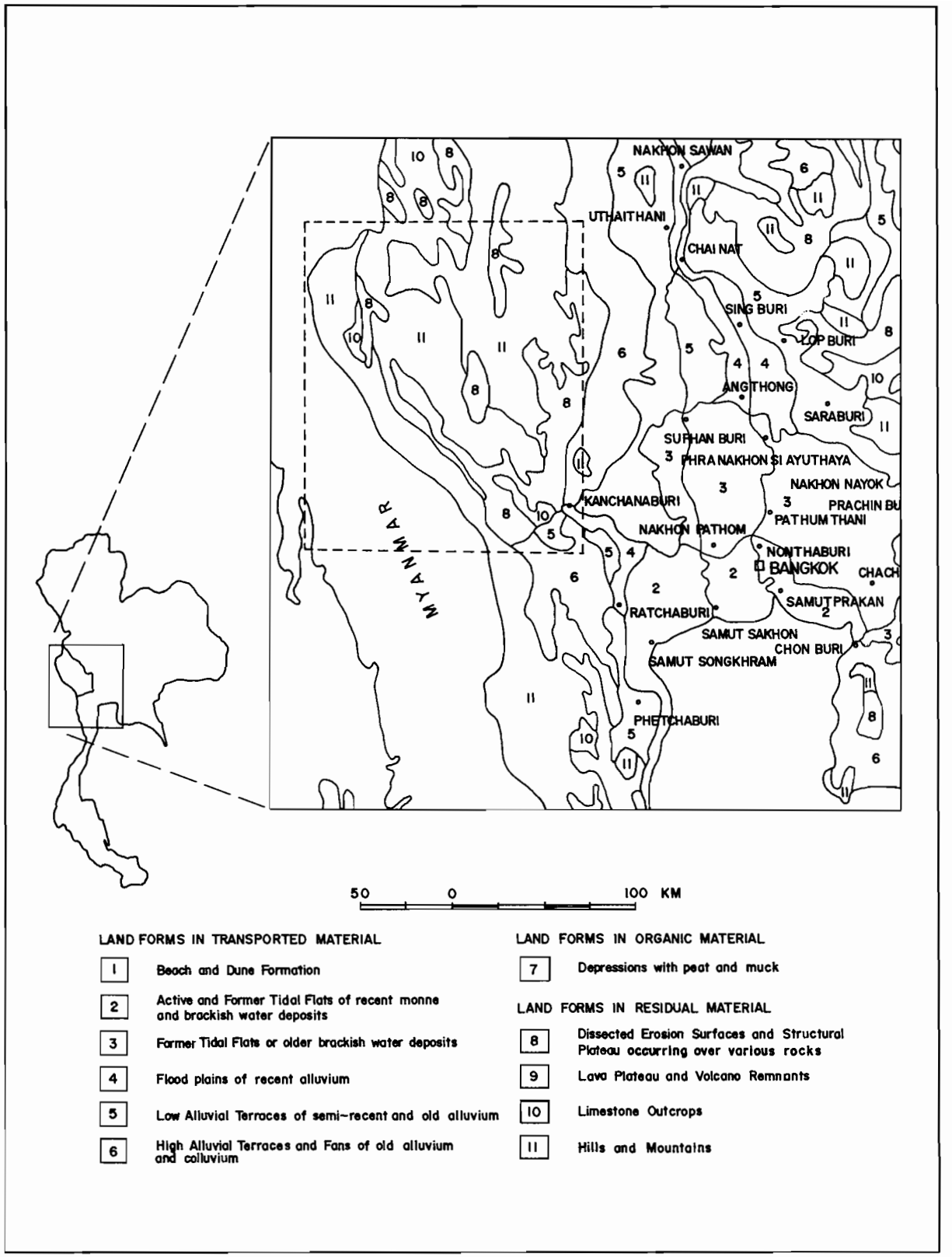
(iii) To identify the origin and follow up the development of any "new agricultural order", while monitoring the recession of the ancient organization of agriculture that it is replacing. To be able to forecast the evolution of the local agrarian system if the past and/or current trends goes on, in order to point to the non-desirable effects of such an evolution that will have to be corrected to improve productivity, sustainability and equity in the target area.

(iv) To determine the existing conditions for such a change: particularly the economic, political and socio-cultural conditions at that time which permit, accelerate or slow-down such a change.

(v) On the other hand, to discern the obstacles and restraining factors which forbid or hamper the change towards such a new agricultural order.

Figure 1 shows such complementarity between spatial and historical zonation for the assessment and understanding of farmer differentiation process.

It was with such objectives in mind, that a spatial/historical zonation was undertaken in 1991/92 in the central part of the Mae Nam Kwae Noi valley, covering part of Saiyok and Thongphaphum districts in Kanjanaburi province, west of Thailand central plain (see map 1).




**Map 1.** Location of Kanjanaburi province and main land forms in western Thailand.

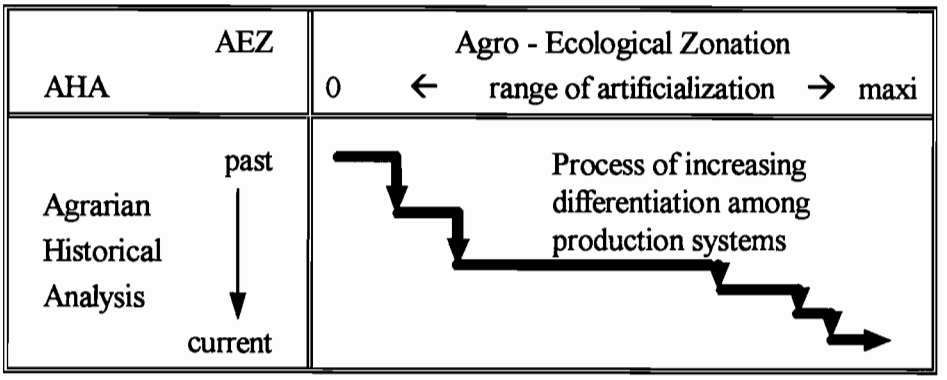



**Figure 1.** Complementarity of agro-ecological zonation and agrarian historical analysis to understand the process of farmer differentiation

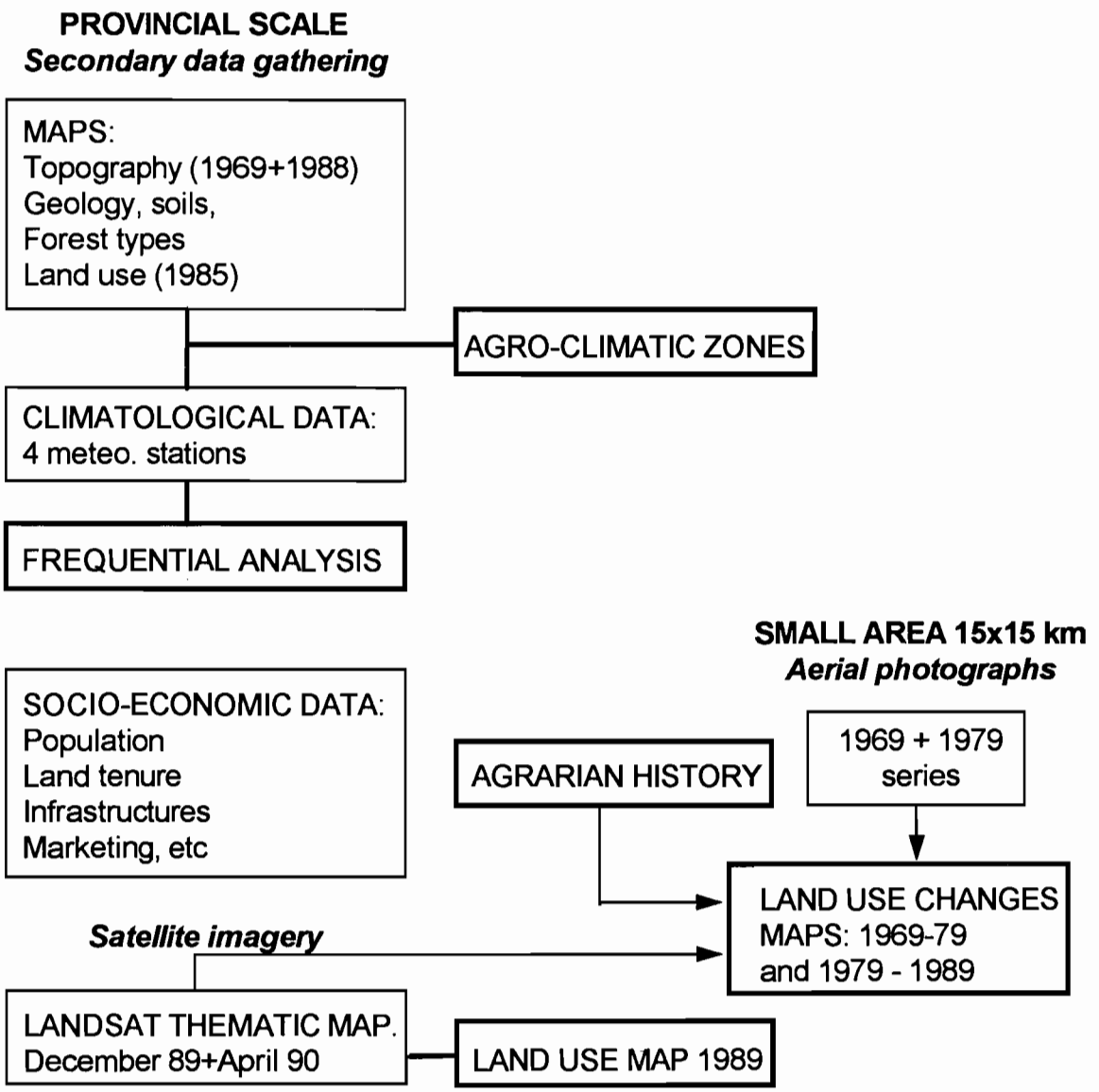



**Figure 2.** Flow chart showing the process of preparation of the agro-ecological zonation

# 2. MATERIALS AND METHODS

## 2.1. Review of secondary data and elaboration of preliminary hypotheses

A review of the available secondary information (geology, topography, soils, climatology, hydrology and related infrastructures, demography, forest types and land use maps, etc) was first carried out and synthesized into a set of sketch maps and overlays for Kanjanaburi area.

While keeping in mind that these secondary data were not necessarily collected for agricultural development purposes, they were also used to generate hypotheses for the following step of the analysis. A critical analysis of the available reports, statistics, maps and imagery was done to prepare a set of hypotheses about the existing sources of heterogeneity and diversity of farmer situations across the province.

Figure 2 displays the process of generation of the agro-ecological zonation from secondary data and remote sensing imagery that was used in this case study.

## 2.2. Analysis of spatial zonation and land use changes using a combination of visual interpretation and digital processing of available remote sensing imagery

### *2.2.1. Background on remote sensing and data processing*

Remote sensing imagery is the information obtained about the earth's surface by acquisition and interpretation of spectral measurements made at a distant location. This information can be gathered from instruments mounted on board satellites or aircraft or from hand-held instruments. The large volume of information or spatial data will be transformed into usable form. The methods used for data processing are visual interpretation and digital image processing. Visual interpretation involves examining data using various viewing and interpretation devices to analyze pictorial data, whereas digital image processing is used to analyze numerical sensor data. Recognition of objects not only from spectral responses but also from shape, texture, pattern, size, landscape structure, etc. is a distinctive advantage of visual interpretation. Digital image processing classifies objects based upon spectral ranges of different land use/cover types. These spectral ranges are treated as training samples and input into the computer. The training samples were inventoried, selected, characterized and confirmed by ground surveying. The design and procedures of data processing depend upon the existence of spatial data handling and processing systems.

### 2.2.2. *Methodology of visual observation and analysis of agrarian landscapes*

#### *2.2.2.1. Identification of main units from high grounds and selection of several transects*

"Look and discover" can summarize the first step of landscape analysis. General landscape observation was first carried out from high grounds, with existing imagery and maps in hand to confront the information displayed with direct up-to-date visual observations. Identification and global description of main units (see the landscape data recording sheet in appendix 2) was made, as well as the selection of the most suitable (i.e., diverse) areas for further investigations along transect runs.

#### *2.2.2.2. Principles of transect analysis*

Later, this was complemented by runs of several well-selected and complementary line-transects. They were chosen so as to cut a maximum number of heterogeneities identified during the previous step in a minimum length and so field work time. Two very complementary kinds of transect can be distinguished:

- primary transects cutting heterogeneities born from bio-physical parameters (man response to different natural environments), and
- secondary transects which look at the diversity of socio-economic origin within a rather homogeneous ecological zone (various farming system adaptations to a given bio-physical environment).

A detailed description of each rather homogeneous zone was prepared before continuing with the next one. These transect runs enable previously established key questions on the origins of the variability observed in the field situations to be complemented, refined and ranked.

Complementary information on annual cropping patterns was gathered during the 1991 and 1992 rainy seasons at various DORAS project experimental and surveys sites, which were mainly located in the medium part of the valley. This relatively long period of field work allowed a back and forth process between landscape analysis and exchanges of views with local people, and a continuous fruitful confrontation between both sources of information.

Putting identification of on-farm diversity first, whatever its origin, provides also a first assessment of farming system differentiation in the area and stimulates comparisons between

locations. This step led to the elaboration of a list of key questions to be asked to local informants during the almost simultaneous historical survey.

### 2.2.3. Assessment of available remote sensing imagery and production of land use/cover maps

As mentioned in 2.2.2. visual observation and analysis of agrarian landscapes was confirmed by digital image classification for the Mae Nam Kwae Noi valley. The land use/cover classification map of this valley was produced based upon Landsat TM data taken on December 21, 1989 (see details on the supervised classification procedures in appendix 3). As map 15 shows, there is a large area of degraded forest. What has happened to this area can be seen from a detailed analysis of the evolution of land uses in a selected small area, which is located in the northern part of the valley and situated between latitude 14 33'-14 48' N and longitude 98 35'-98 45'E. There, the study of chronological land use/cover changes over a 20 year period from 1969 to 1989 has been carried out to assess the dynamics of changes in agrarian landscapes in one of the most diversified parts of the valley for which chronological series of aerial photographs were also available.

Three land use/cover maps for 1967-70, 1979, and 1989 were produced and were superimposed to display changes by using manual GIS techniques. Classification (choice of map legend) for these three land use/cover maps had been designed to be make them comparable for the assessment of land use changes (see details in 2.2.4).

The first land use/cover map for 1967-70 was produced by interpreting aerial photographs taken in October 1967, January 1968 and 1970. This is due to the fact that no complete set was available at a single date. Since the photographs were taken on different years, slight differences in scale (photos taken in 1970 having a larger scale than those in 1967) and other distortions during flying missions occurred. Corrections were made by adjusting the documents through careful reduction or enlargement photocopying onto a 1:50,000 based map.

The second land use/cover map in March 1979 was produced by the same procedure as of 1967-70. The original scale of 1:30,000 was adjusted to the 1:50,000 based map.

Advantages of using aerial photographs lie in their high spatial resolution and stereoscopic vision, while their spectral resolution is limited to visible bands (wavelengths ranging from 0.4-0.7 μm).

On the other hand, a third land use/cover map of the same area was produced from the interpretation of a cloud free 1:50,000 scale Landsat TM image acquired on December 21, 1989. The image was processed by a combination of band 4, 3, and 2 in red, green and blue respectively.

Advantages of such Landsat TM image are their spectral resolution, which covers infrared band (0.7-0.9 mm), and the combination of colours for a better discrimination of land use/cover types. Infrared wavelength proved to be effective for the detection of vegetation stages and land cover types. Disadvantages of Landsat TM imagery is its low spatial resolution, especially when compared to aerial photographs. This makes recognition of features not so easy and requires thorough field checking.

### *2.2.4. Mapping units and choice of classes*

Most of the available remotely sensed data were acquired either at the beginning (December and January) or at the end of the dry season (April). This did not allow for the full observation of vegetation stages for most of the crops. Figure 3 shows the main features of the local cropping calendar according to climatological conditions. The maize crop, which precedes cotton in the extensively practised relay cropping system, is grown from May to August and cannot be seen at all. The cotton, cassava and sugarcane crops could be partially seen at the harvesting stage in December and January. Some harvested plots displayed the same signatures as barren land. At many locations, it was therefore necessary to map the key annual crops and barren land together into the same class.

Mapping of orchards (mango, sweet tamarind and sugarapple mainly) in the dry season also proved to be difficult as their leaf coverage is often minimal at that time of the year. Most of the orchards are scattered small plots with mixed fruit species. On the Landsat TM image, mature orchards had similar signature as forest whereas young orchards looked similar to barren land or harvested upland crops. It was found that orchards and plantations occurred at specific locations, close to villages or where an easy access is provided by roads or rivers. Therefore, field checking played an important role for the mapping of this class, but its extent should still be considered as very underestimated on the final map.

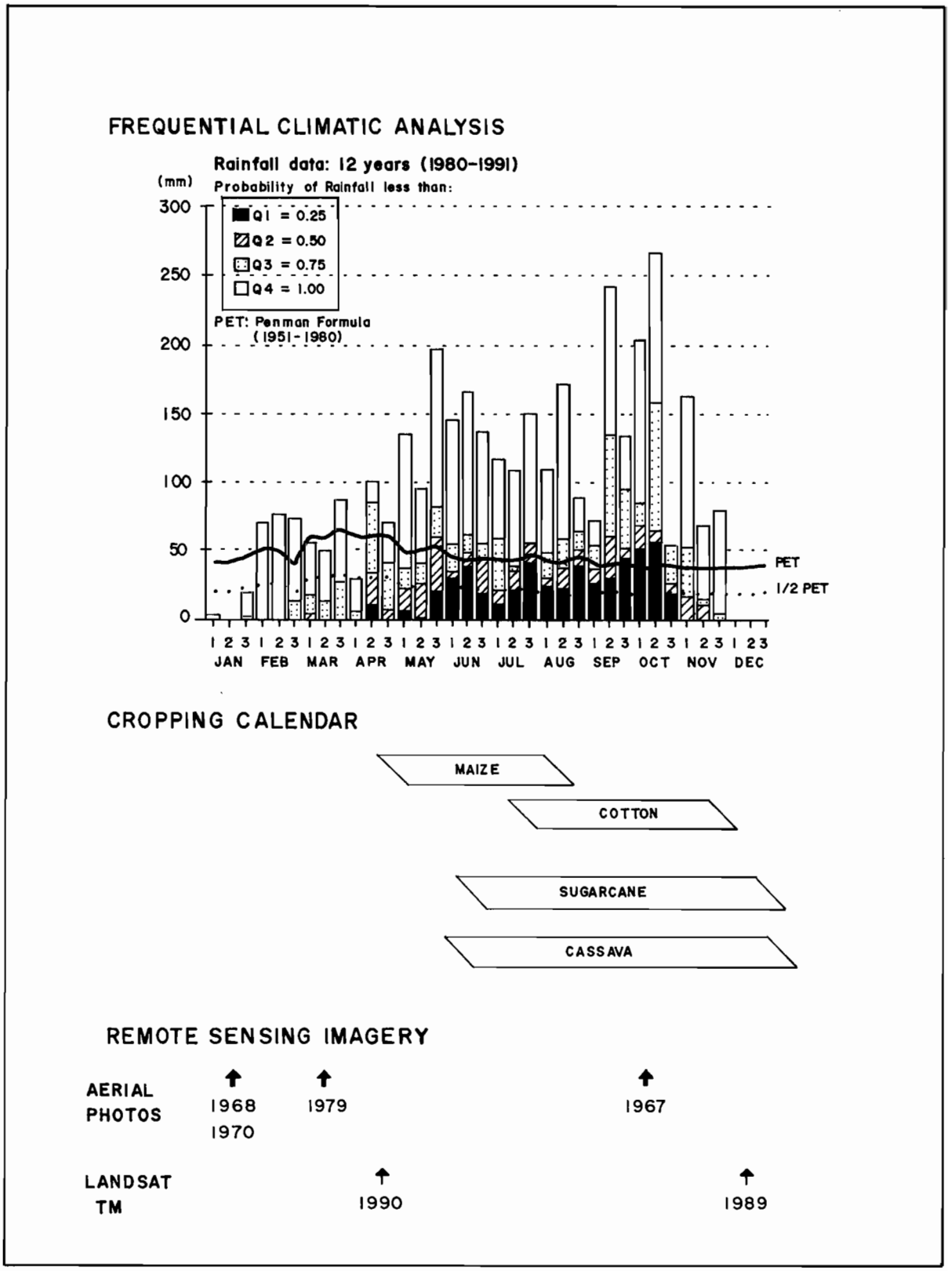



**Figure 3.** Date of acquisition of remotely sensed imagery according to climatic conditions and annual cropping calendar in Mae Nam Kwae Noi valley, Kanjanaburi province.

## 2.3. Recapitulation of the regional agricultural historical profile through informal interviews of selected key informants

Complementary to the agro-ecological zonation and as soon as the first key questions coming from landscape observations were available, studies were launched to introduce the historical approach and analyze the recent changes in the landscapes of a small zone in the medium part of the Mae Nam Kwae Noi valley. Tha Sao sub-district, north of Saiyok district, was selected *because of the extensive diversity of its production systems*. While the dominating mode of exploitation of the agro-ecosystem is based on the production of several key rainfed field crops (mainly maize- cotton relay cropping system), they are usually combined in family-based production systems with a number of other important production activities (orchards, vegetable crops, beef cattle rearing, silk production and off-farm jobs).

### *2.3.1. Principles of agrarian historical analysis*

Information gathering was based on informal interviews focusing on the identification of the date, nature, origin, causes, extent and consequences of the main recent agrarian changes. They were conducted with a series of local privileged witnesses of the recent agricultural transformations.

Interviews were conducted to understand how different kinds of farmers used to modify their cropping and animal rearing systems according to their respective access to capital and means of production and taking into account the framework of social relations in which they are operating (pricing system, land tenure, rural credit, etc). In this way, factors and conditions which used to determine the choice and evolution of the APS in the region were identified. Finally, it was possible to elucidate the *mechanisms of differentiated accumulation of fixed capital which are at the origin of specializations per zones and differences among APS.*

The historical approach also helped to elucidate the following topics to be investigated through subsequent analyses at the APS level:

(i) The extent of the recent (post second world war period) evolution and present state of differentiation and adaptation among the existing farmer production systems,

(ii) The identification of a set of hypotheses concerning the origins and causes (key factors and conditions, constraints or potentialities on which production is organized) of farmer

differentiation and, as a consequence, the identification of their main specific agricultural development problems in the area, and

(iii) Because key problems will be different among types of farmers, these hypotheses will point at the key information to be carefully collected later at the farm level in order to prepare a farmer typology based on the history and functioning of each category of household-based APS.

### 2.3.2. Selection of key informants and implementation of informal interviews

Interviews were carried out with a dozen local key informants (old farmers, middlemen, monks, village headmen, agricultural extension officers, field staff of agri-business companies, etc.) who were selected because of their in-depth knowledge of the recent evolution of agriculture in the area.

Broad subjects were introduced first in the conversation to give the informant the opportunity to guide the discussion towards what according to him was determining factors explaining the observed changes. Cross checking of the most important information between informants was done, and part of it being only of secondary interest was deleted before further analysis.

### 2.3.3. Steps in the analysis of historical data

Data analysis and reporting was carried out by using the concept of agrarian system and related theory on the evolution and differentiation of agrarian systems (MAZOYER, 1985). At this stage, the following four steps (one descriptive, one analytical and two interpretative) were followed:

(i) Recapitulation of a descriptive inventory of changes of various nature for each key component of the agrarian system: major ecological events, changes in means of production, technical practices and productions on the local APS; evolution of the farm social and economic conditions (demography, markets, credit, land tenure, labour, infrastructures and state interventions). This first output and organization of the complete set of information gathered is presented in Appendix 4, as well as the forms used for the subsequent steps of data analysis.

(ii) The second step aims at identifying causal relations between changes. According to the AS theory, the analysis is based on the assumption that transformations in the local socio-

economic conditions precede widespread changes in technical systems and production practices. The second output produced was displayed in a table establishing the chronological relations between the date, nature, origin, cause (internal as well as external to the local agrarian system), extent and consequences of the main recent transformations of the studied agrarian system. Changes observed for one agrarian system component are explained by looking at the transformations recorded for other components.

(iii) Based on the previous step, an agrarian historical profile diagram was prepared for the area that shows the determination of agro-ecological and technical changes by the transformations in socio-economic conditions along the recent agrarian history,

(iv) Finally, a chronological sequence of agrarian systems and transitional phases summarizing the local agricultural history and elucidating the extent of the farmer differentiation process was proposed.

## 3. RESULTS AND DISCUSSION

Before presenting the significant trends of the dynamics of agro-ecosystems that were identified in the Mae Nam Kwae Noi valley, it should be noticed that an interesting correspondence between the chronologies of main agrarian systems succession and date of imagery acquisition was obtained. This fact allows the presentation of the results by matching both sources of information for each main transformation or phase of the evolution of the local AS.

### 3.1. Original characteristics of the study area

#### *3.1.1. A loosely populated cultivated frontier system presenting very contrasted bio-physical conditions*

The bio-physical features of the Mae Nam Kwae Noi valley are characterize by their important variability:

- topography: elevation varies from less than 100 m amsl in the lower part of the valley to more than 1000 m amsl in the highest part of the mountainous highlands (Photo 1),
- geology and landform: from gently undulating dissected plateaux on metamorphic rocks to very steep limestone outcrops (Map 2),

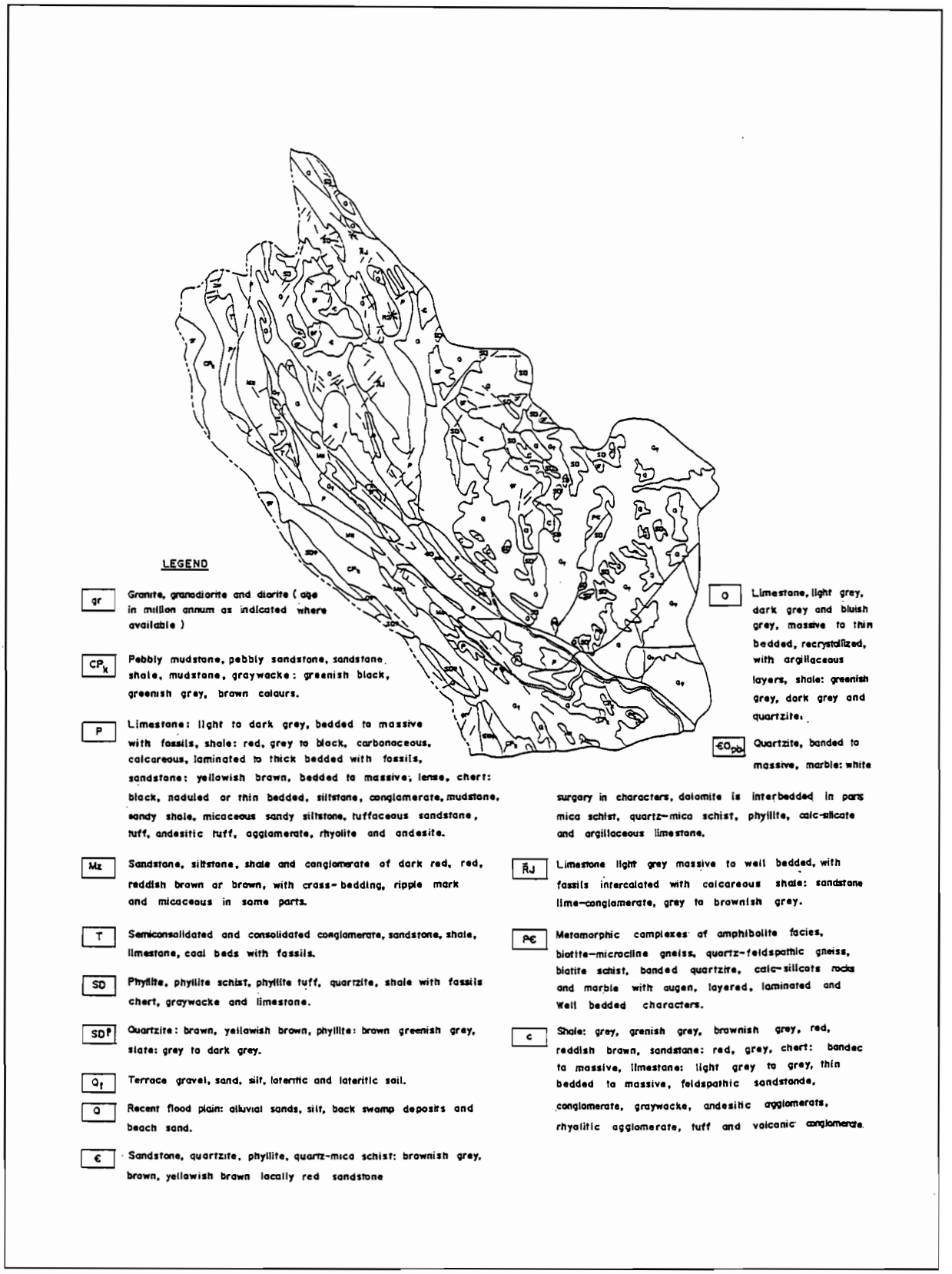
- soils: from skeletal sloping sandy soils to very deep and clayey ones on undulating terraces and banks (Map 3),
- hydrology: irrigated areas fed by two huge reservoirs, are limited to lower eastern part of the valley (Map 4) and
- rainfall conditions: from less some 1,000 mm to nearly 2,000 mm in total annual rainfall between the lower and upper part of the valley (Figures 4 and 5); when driving on the main road following the river one 100 mm isohyet is crossed every 20 km on the average (Map 5).

While there is a rapid decrease in population density per district area from the lower to medium (less than 10 inhabitants/km$^2$) and upper (less than 5 inhabitants/km$^2$) parts of the valley (Map 6), this trend is completely inverted when the number of inhabitants per km$^2$ of farm land is considered (Map 7).

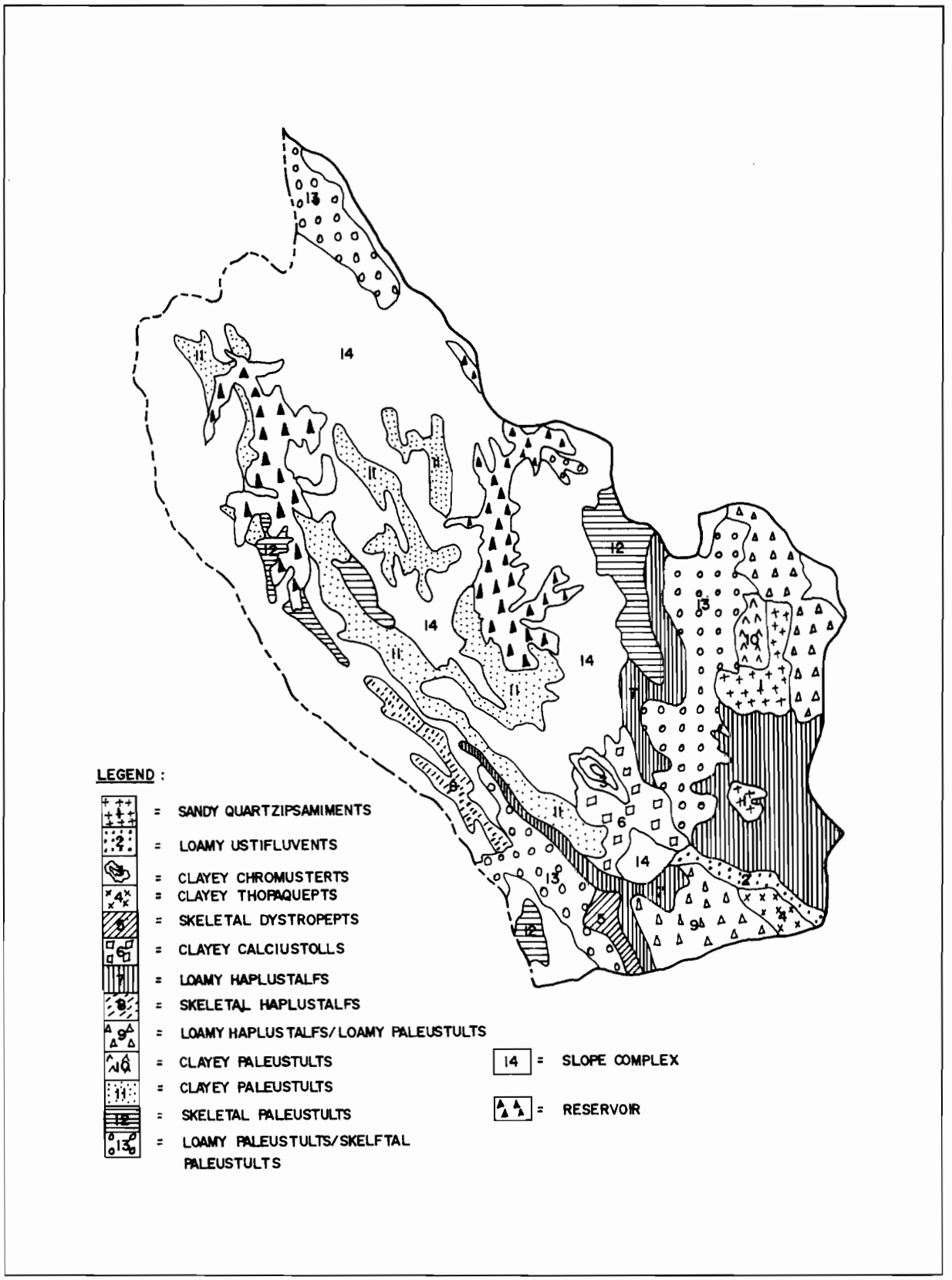
Indeed, figure 6 shows how fast the percentage of cultivated land decreases from the lower (40-60%) to the medium (around 10%) and upper (around 2-3%) parts of Mae Nam Kwae Noi valley. While paddies are occupying an important part of the agricultural land in the lower part of the valley, annual field crops dominate elsewhere (see their types and distribution in Figure 7 and their importance in the composition of the farm income in Figure 8), but perennial plantations are making a bigger share in the upper districts.

According to data from Saiyok district agricultural office, in 1990 the general landuse pattern in the medium part of the valley was made of some 68% of either reserved forest (41%) or national parks (27%) and only less than 15% was classified as farmland. The forest ecosystem is still dominating and the expansion of the agricultural land is being limited by:

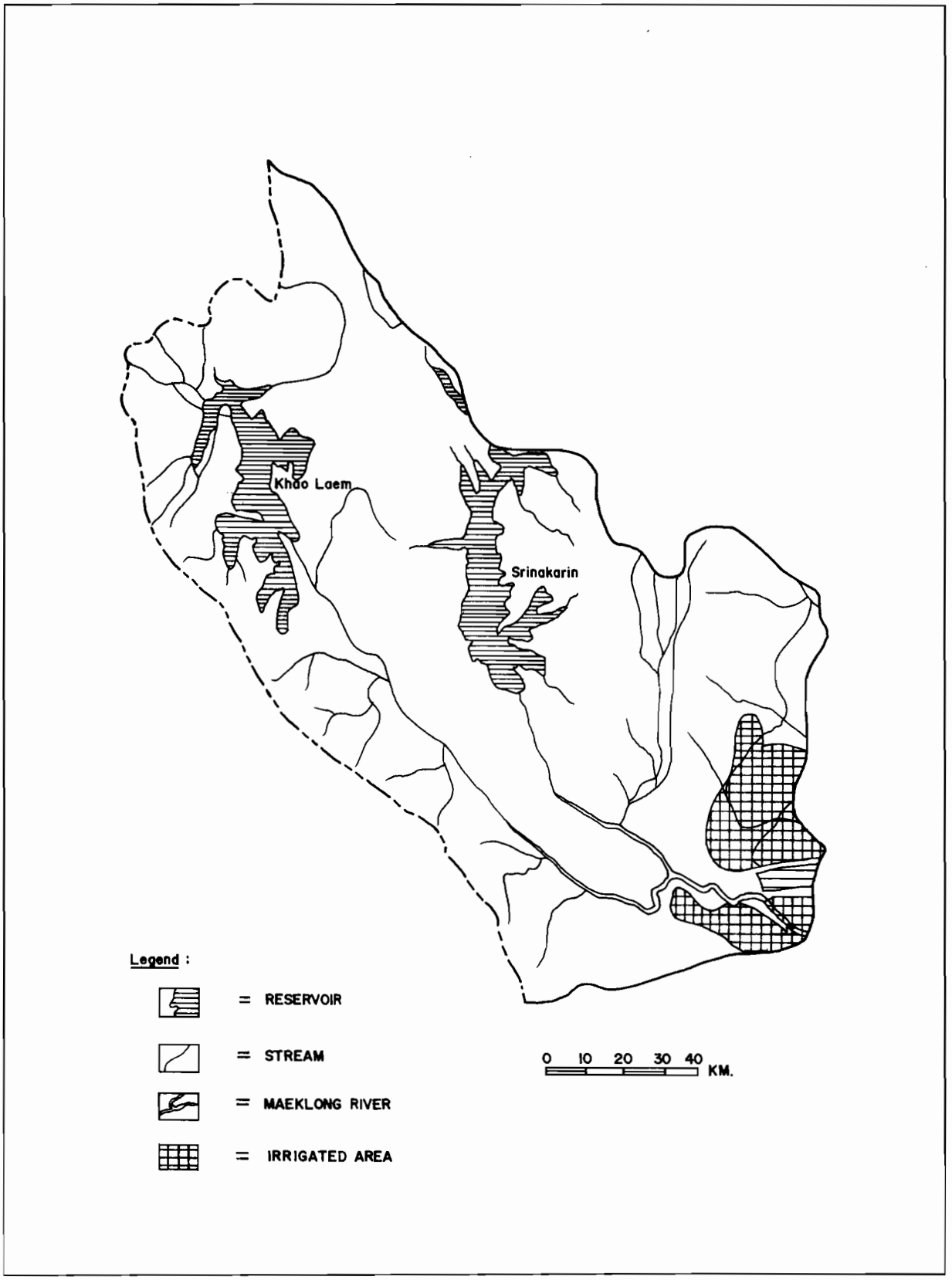
- a low population density,
- an uneven topography,
- the occurrence of large National Parks and military reserved areas,
- the recent ban on forest concessions,
- the limited availability of secondary roads to penetrate into the more remote secondary valleys.




**Map 2.** Geological map of Kanjanaburi province.




**Map 3.** Main soil units in Kanjanaburi province.




**Map 4.** Reservoirs, drainage and irrigation in Kanjanaburi province.

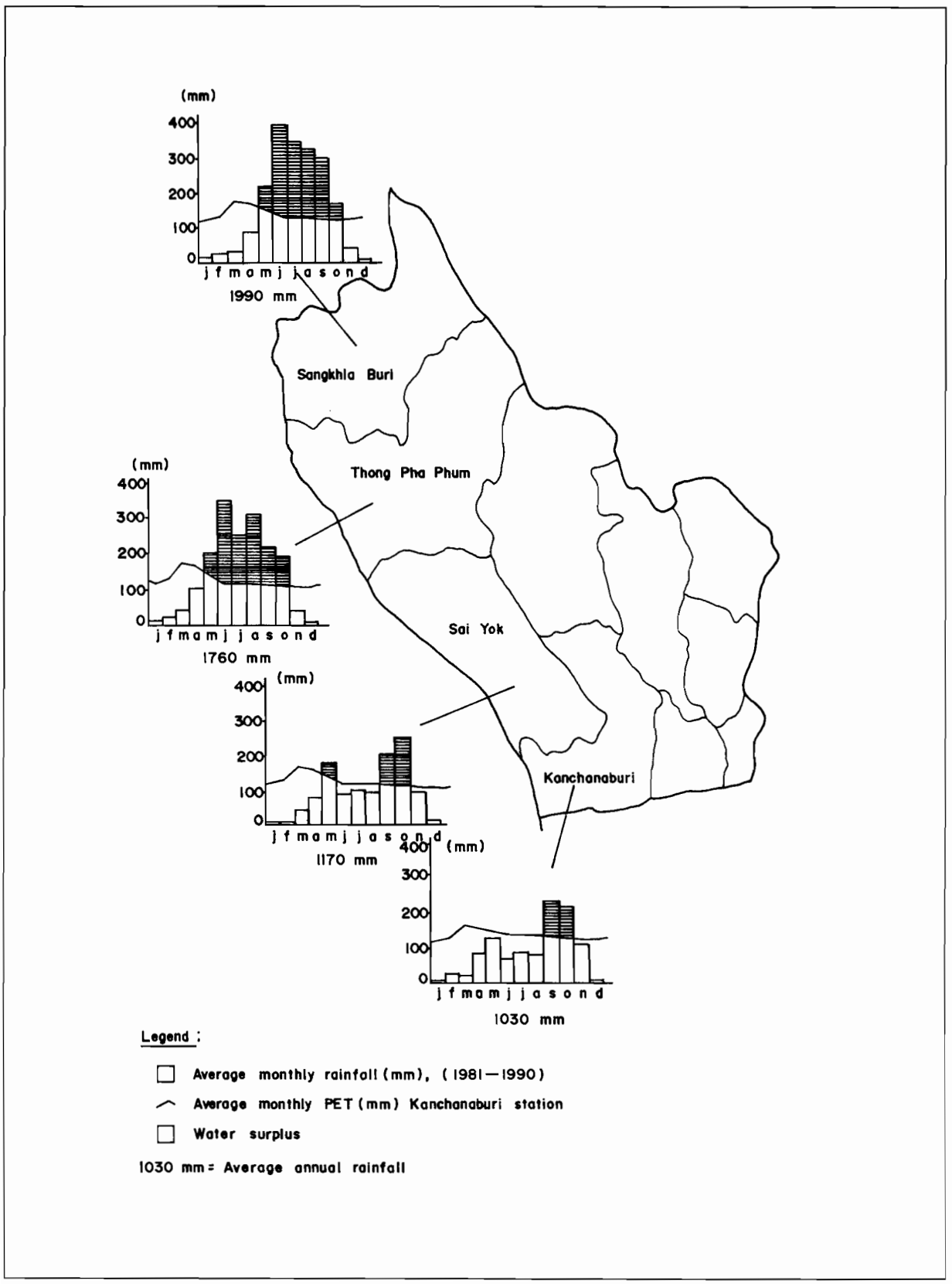



**Figure 4.** Average monthly rainfall at several climatological stations in Kanjanaburi province.

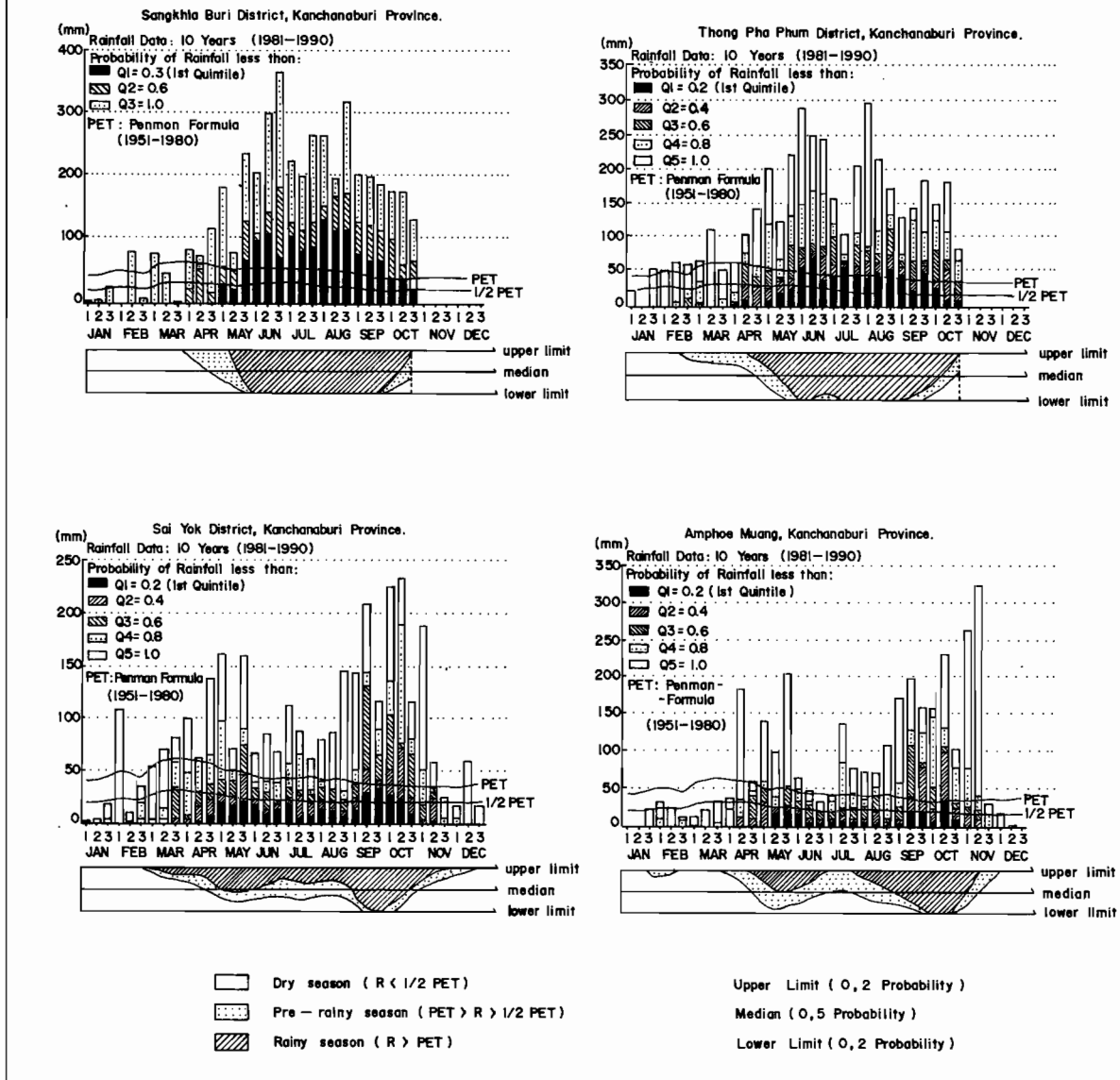
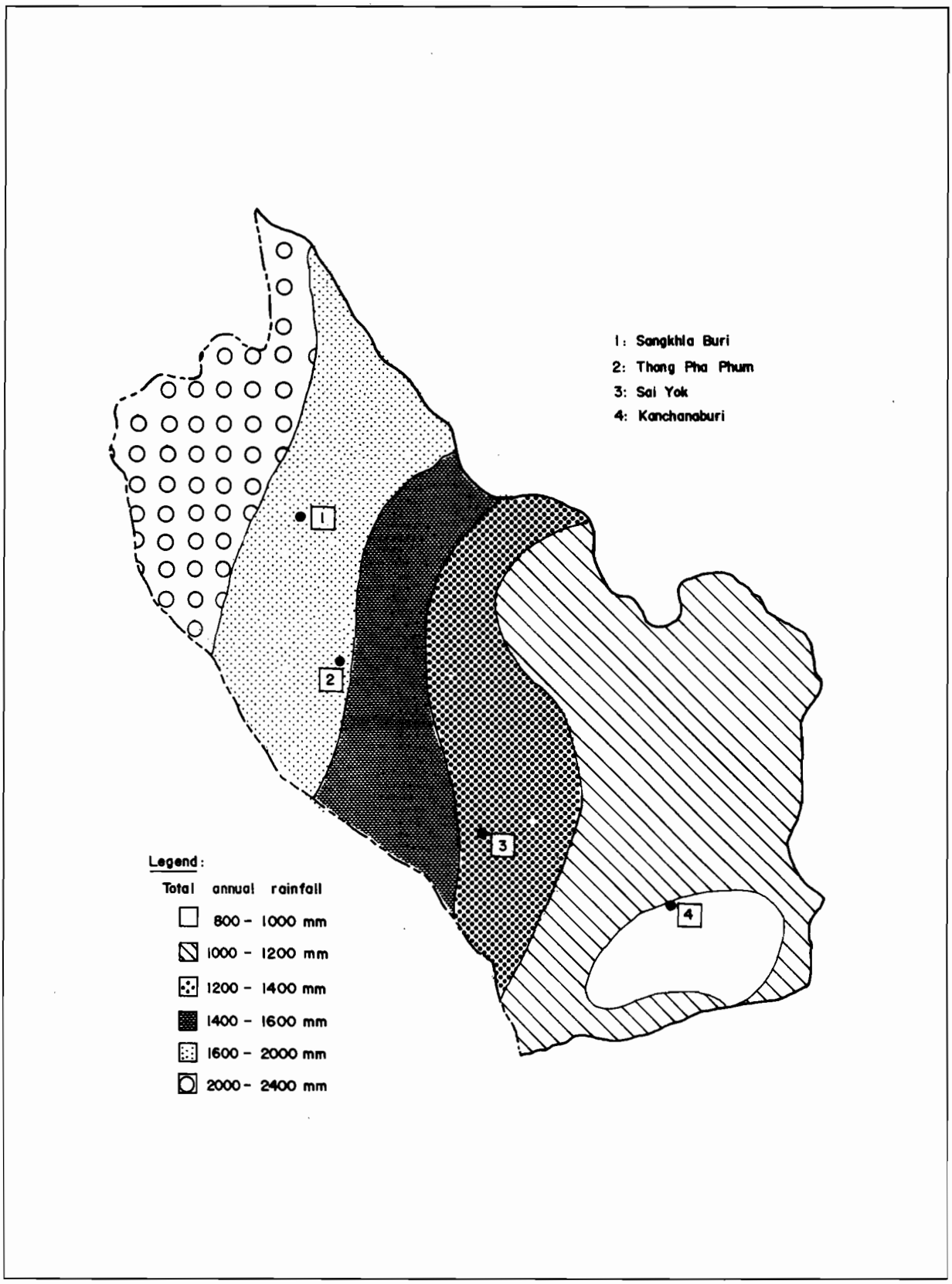
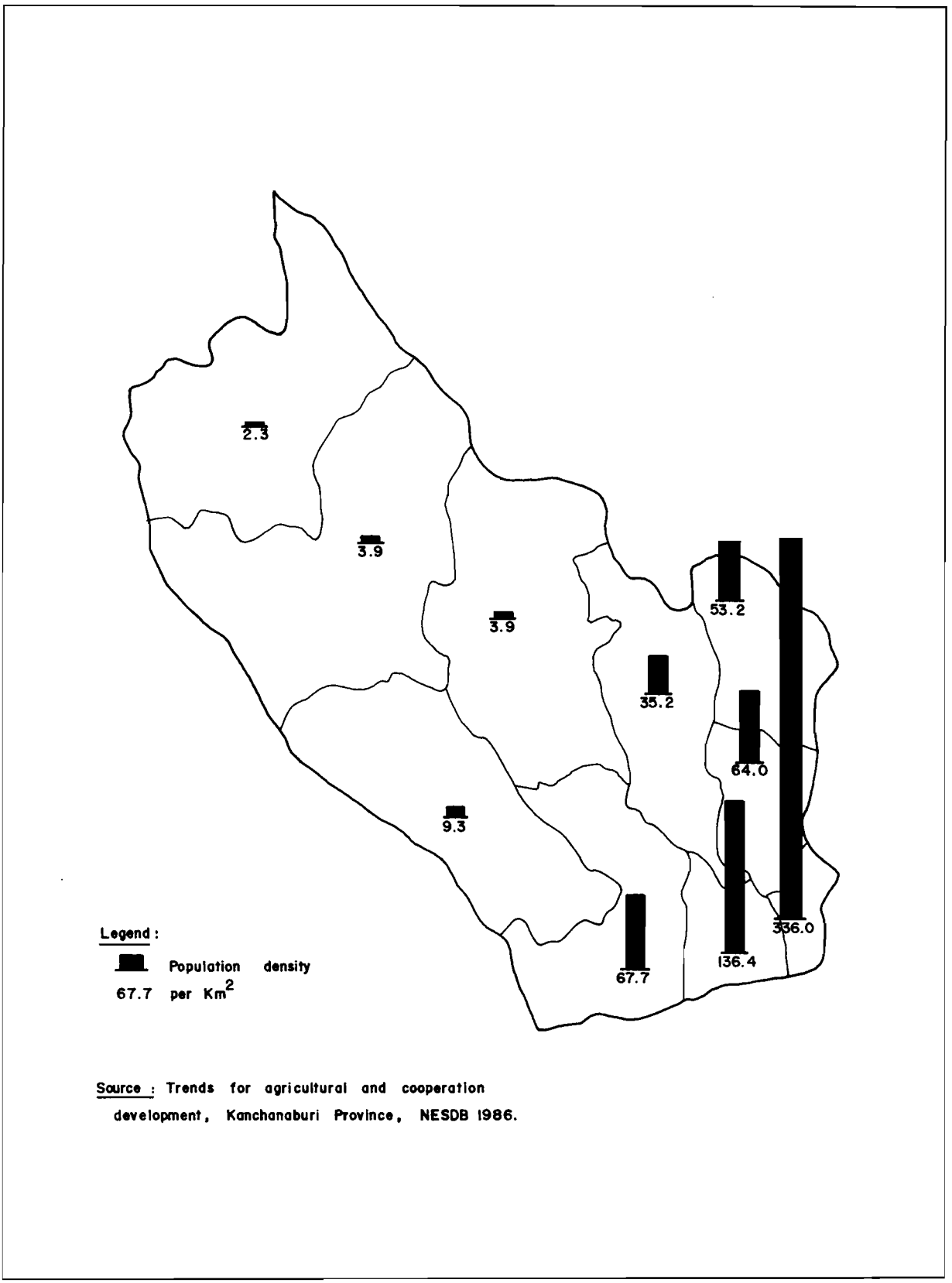


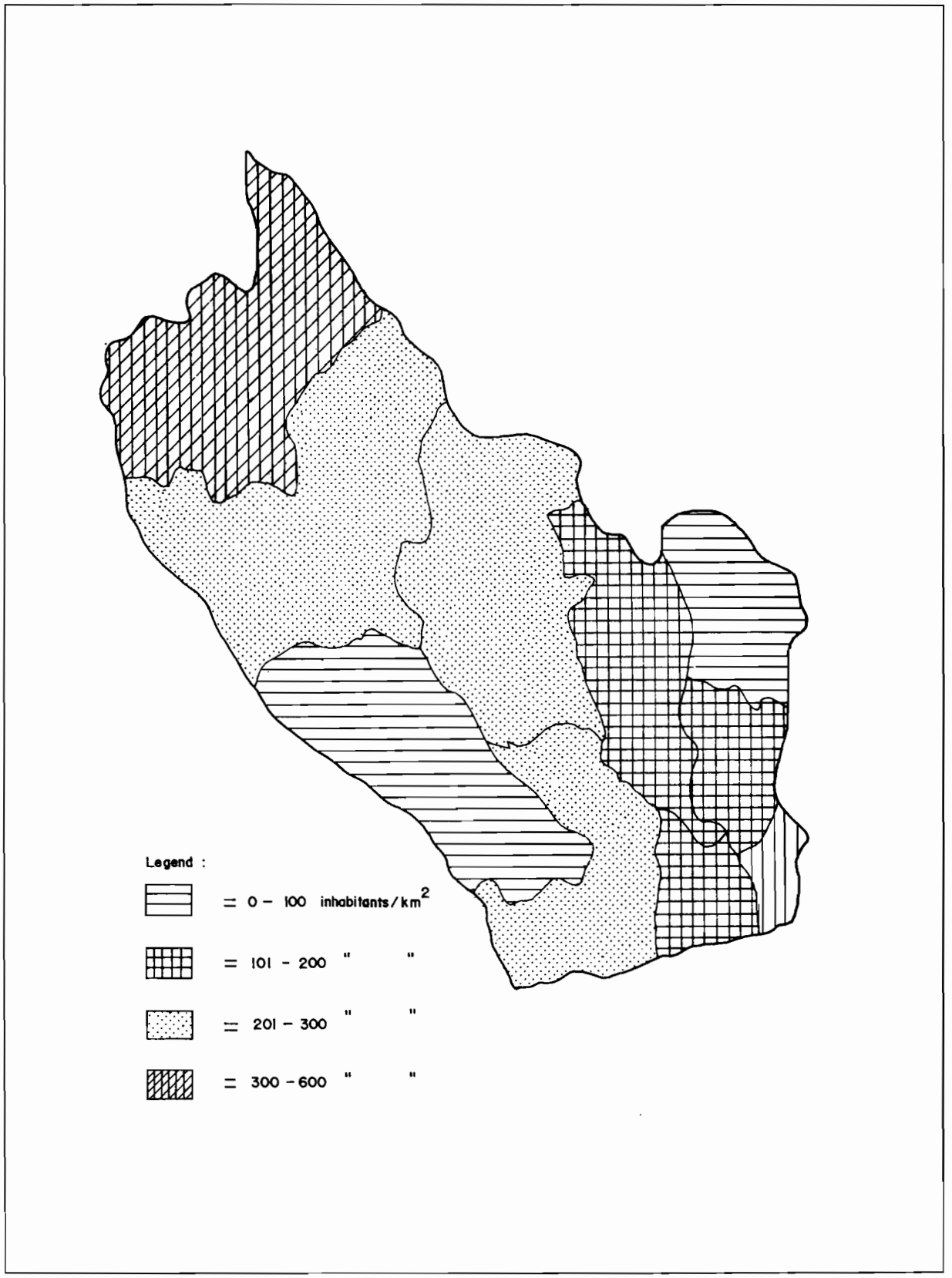

**Figure 5.** Frequential climatic analyses of Kanjanaburi, Saiyok, Thongphaphum and Sangklaburi districts climatological stations



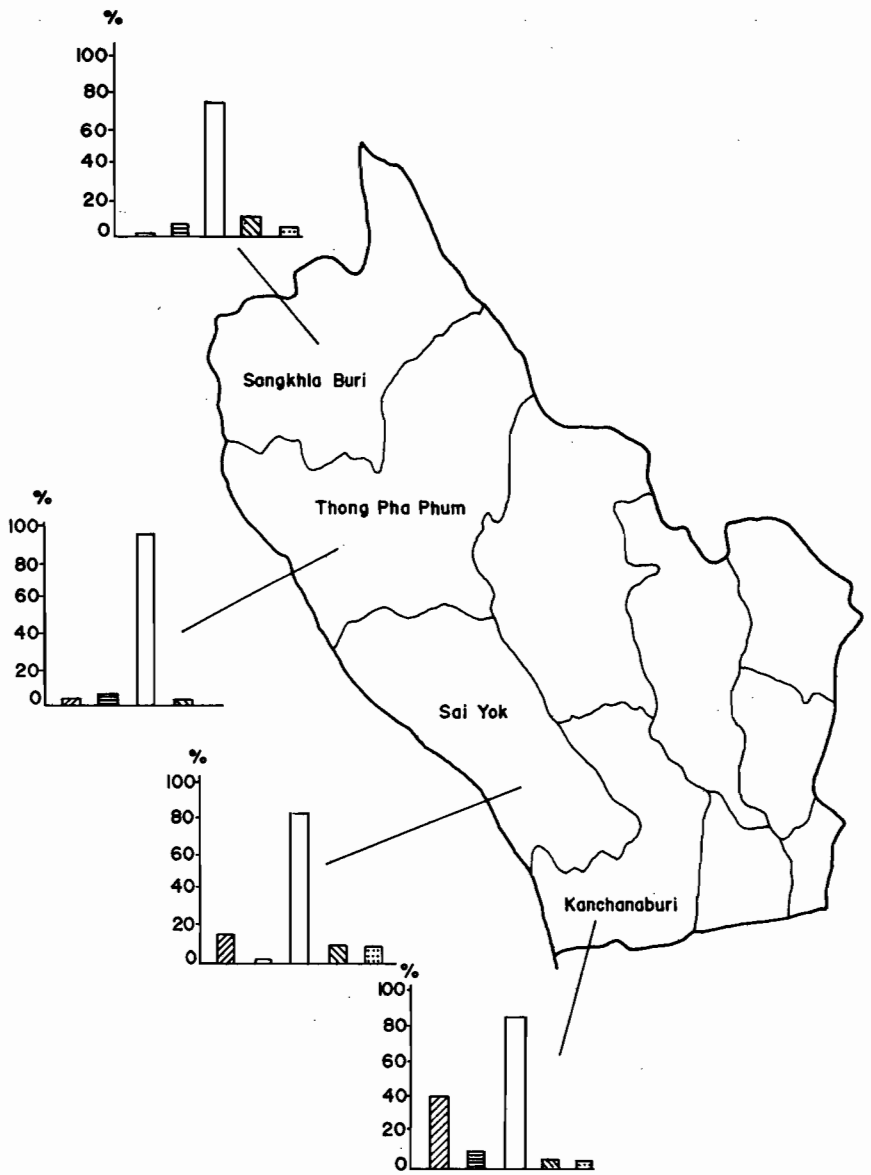

**Map 5.** Annual rainfall isohyets in Kanjanaburi province.




**Map 6.** Population density per district in Kanjanaburi province.

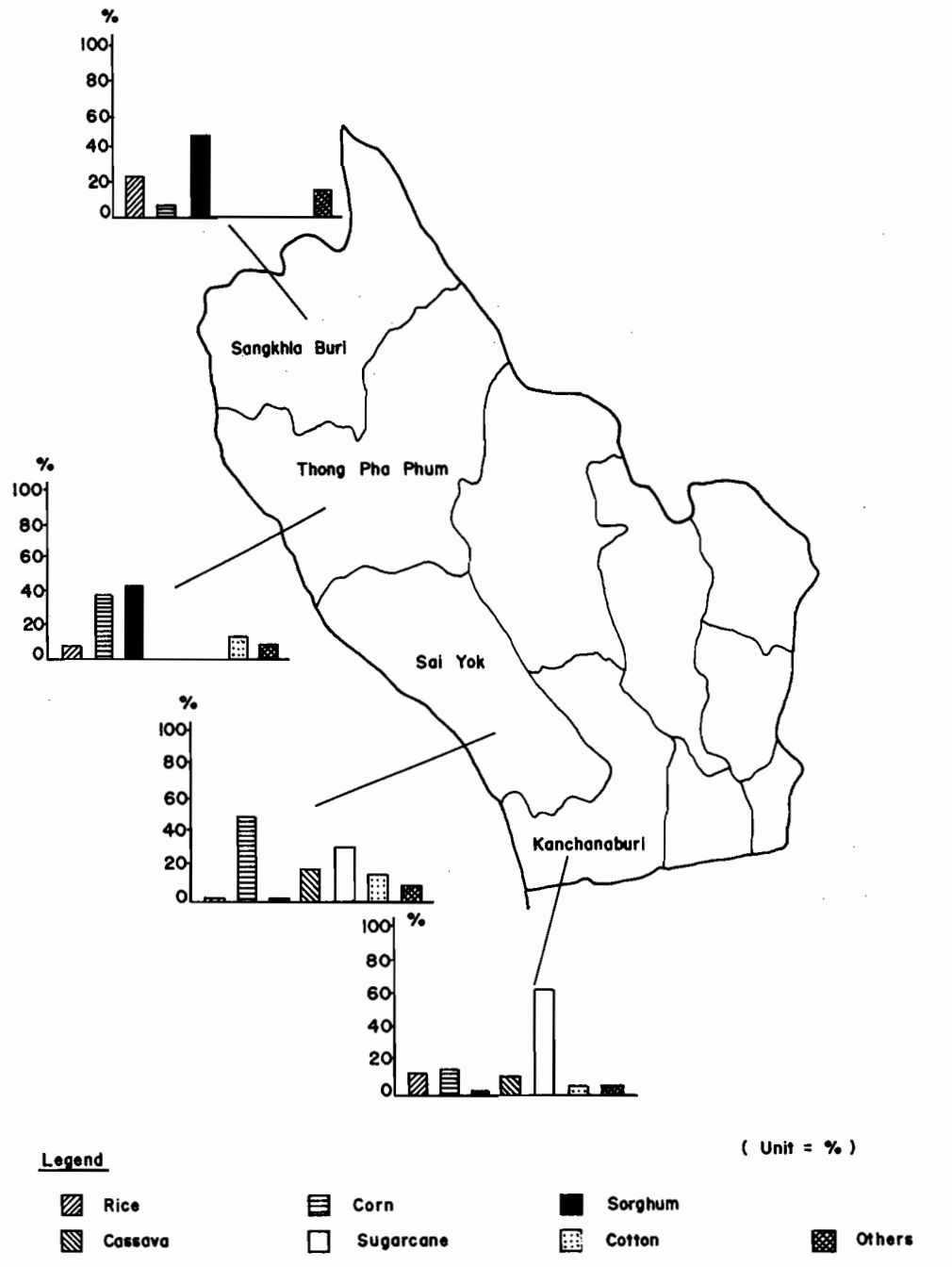



**Map 7.** Population density per farm land in Kanjanaburi province.



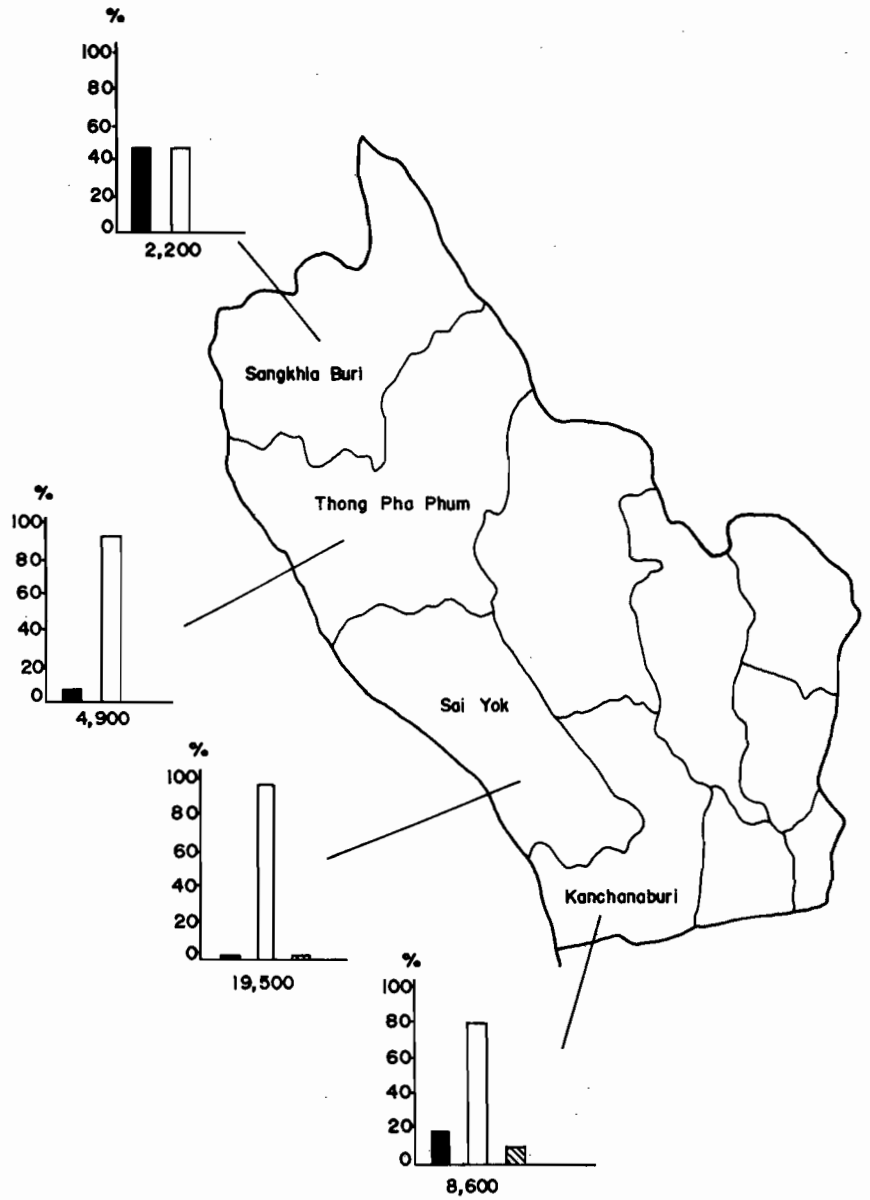

Source: Trends for agricultural and cooperation development, Kanchanaburi Province, NESDB 1986.

**Figure 6.** Agricultural land use patterns per district of Kanjanaburi province.




Source : Trends for agricultural and cooperation development, Kanchanaburi Province, NESDB 1986.

**Figure 7.** Crop distribution patterns per district of Kanjanaburi province.




Source : Trends for agricultural and cooperation development, Kanchanaburi Province, NESDB 1986.

**Figure 8.** Composition of average household income per district of Kanjanaburi province.

Several of the sketch maps show that the "frontier" characteristic of the regional agricultural systems is more and more pronounced when one travels from the lower (where agricultural production was introduced starting from the river banks some 50 years ago) to the upper part of the valley.

Yet, in some village territories the available favourable agricultural land seems to be already saturated because of both physical and agro-technical (uneven topography) and/or socio-economic conditions (large areas of reserved forest and national parks).

Based on such a review of secondary data and a rapid run of a complete transect along the valley from the provincial capital to the northwestern part of the province, several main zones can be identified from an agricultural land use point of view.

### *3.1.2. From a cropping pattern point of view, five main zones can be identified along the valley*

Based on a classification of the dominating modes of artificialization of the ecosystem for agricultural production, five main zones can be identified along the valley. Figure 5 shows that they are very much influenced by the changing climatic conditions (rainfall patterns and duration of the rainy/dry seasons). From lower south-east to upper north-west, they can be listed as follows:

(i) The transitional zone between the central alluvial plain, the Maeklong alluvial fan and the Mae Nam Kwae valley: irrigated rice (most of the time two crops/year) and sugarcane based production systems are dominating as the area is still close to a series of large scale sugar mills located downstream along the Maeklong river,

(ii) The lower part of the valley: sugarcane based APS (some of them showing relatively large scale and fenced plots under the control of absentee land owners) are predominant; maize and cassava are the secondary field crops and paddies are scarcely seen,

(iii) The medium part of the valley: while cassava and sugarcane are still common (and managed according to village middlemen strategies), the rainfed maize-cotton relay cropping system is dominating in the local farmer APS through a pattern of small-scale plots. Vegetable gardening (egg plant, chillies, etc.), orchards (sweet tamarind, mango, sugar apple, jackfruit, papaya, etc.) and bamboo plantations ("phai tong" variety) are other key sub-systems. In fact, these annual and perennial cropping systems are very linked at both the family-based production system and plot level. Very often, annual field crops are intercropped for several years in young orchards. It seems that in many places, the fruit trees sub-system tends to

replace gradually annual crops on the best farm land (plots located around the farmer's house, along the roads, owned with land titles, etc.). Map 8 display the land use pattern of such an area in 1989, south of Thongphaphum district.

The only significant livestock rearing system occurring in the valley is located in this zone. It consists in a string of large pastures managed by a military agency ("Ko Ro Po Klang"). But in some areas (some 300 ha), pastures have been recently replaced by sugarcane plantations.

(iv) The upper part of the valley: the maize-cotton cropping pattern is still practised but coexists with a more and more important fruit trees sub-system (mango, sweet tamarind, litchi, jackfruit, bamboo) as the duration of the rainy season is longer. Rubber and teak plantations can be observed from Thongphaphum area northwards.

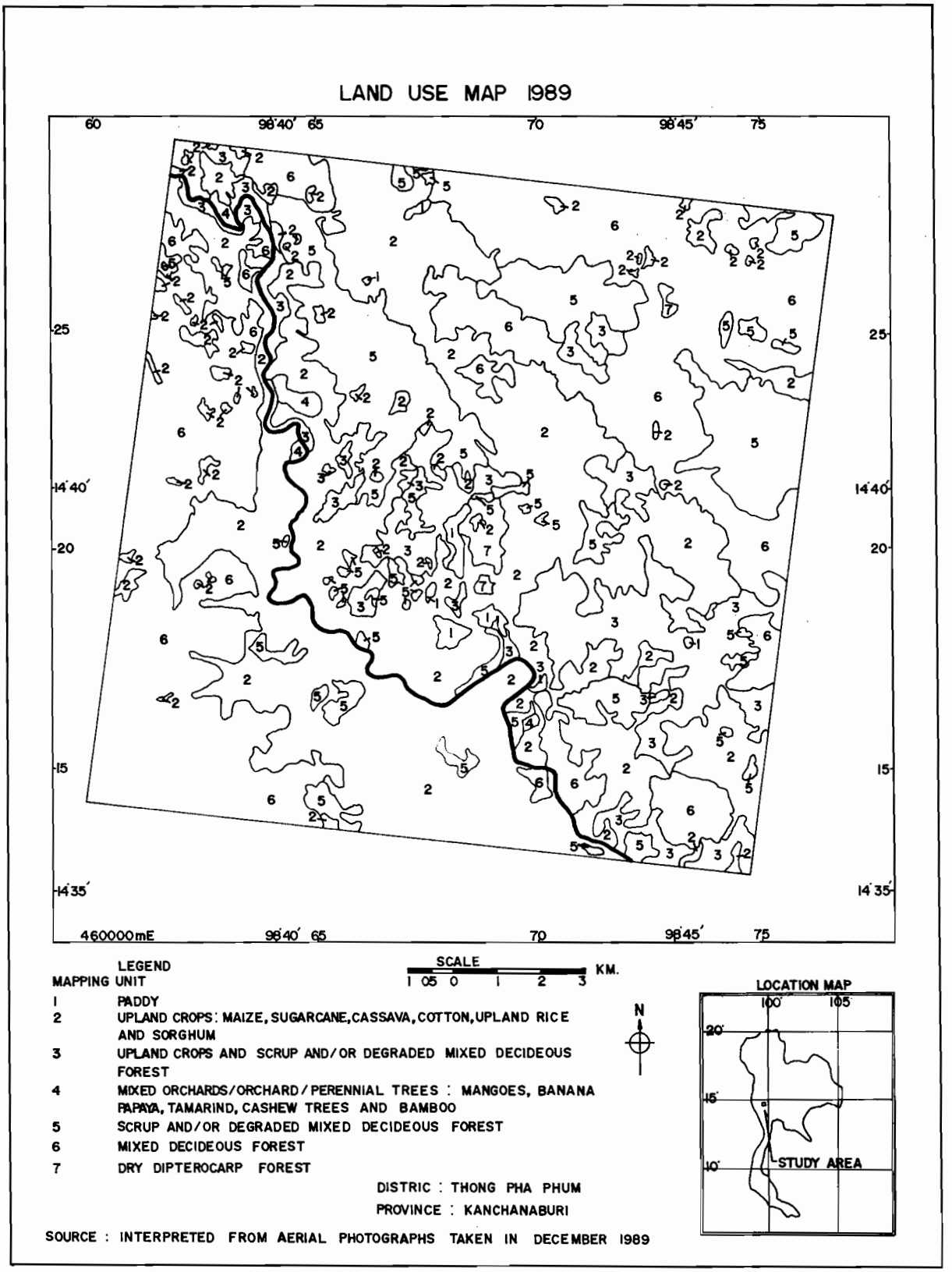
(v) The extreme north-west of the valley: only a few percentages of the area is cropped in this more remote area, but the farm land/inhabitant ratio is the highest for the whole valley. Paddies and some upland rice plots (for self-consumption mainly) are still playing a role because of the lower degree of integration of this area in the market economy due to its relative natural and historic isolation. The mixed deciduous and dense forest environment is still dominating and perennial crops occupy only very limited cultivated areas.

Because of the occurrence of the most diverse range of on-farm situations at that location, detailed studies on spatial zonation and agrarian history were subsequently carried out in the medium part of the valley.

### *3.1.3. Key questions and hypotheses generated by the preliminary analysis*

In the medium part of the valley the general hypothesis that can be formulated is about the domination of the agricultural development process by an advancing cultivated frontier provoked by continuous arrival of new settlers. The frontier operates through a first step of gradual degradation of the mixed deciduous or dry dipterocarp forest coverage followed by their conversion into new farm land used to expand the area of annual cash field crops, as market economy rapidly penetrates the valley along new roads.

At several places, perennial crops seem to have been introduced recently on some of the best plots of land. There, annual upland crops become intercrops in young plantations. A second




**Map 8.** Land use map south of Thongphaphum district, Kanjanaburi province in 1989.

hypothesis could interpret such a pattern of staggering the implantation of (often mixed) orchards and other plantations as a visual appraisal of the process of accumulation of capital and means of production on the small family-based APS. Step by step, short cycle crops are gradually replaced by perennial plantations. The beginning of this process can be recognized as early as on the 1979 aerial photographs of Thongphaphum area. Such a change in land use patterns on local farms could also accompany the transition from young and active labour to an older workforce along the family-based APS life. But of course, when tens of hectares of homogeneous monocrop orchards are seen (Map 8), this could correspond to a generally quite recent investment by an absentee landlord.

If further detailed studies confirm such hypotheses and general context, much importance should be given to the key issue of the security of land tenure on the different existing kind of farming systems.

Such hypotheses lead to the following key questions:

(i) When, how (like elsewhere: did logging open way to settlers?) and why (flow of migrants from very populated lowlands?) did this process of forest cover degradation get started? Was it a gradual progression over large areas or was it limited to certain types of land (first human occupation on river banks and flat, deep land of the bottom part of the valley)? Is the current farm land frontier closed?

(ii) If the available and most accessible farm land has already been cleared and the fruit tree sub-system tends to replace the maize-cotton cropping pattern, what will be the future consequences of such a process on the evolution and sustainability of the maize-cotton relay cropping system in the future? And then on the sustainability of local APS and the degree of differentiation among them at village and regional levels?

(iii) How are areas covered by different kinds of forest (degraded or not) used by local people (grazing? food gathering)?

(iv) What is the role played by recent large scale investments by businessmen and absentee landlords on land and labour distribution in the area?

### 3.2. Correspondence between the historical periods and dates of acquisition of the remote sensing imagery

Agricultural transformations in Tha Sao sub-district, north of Saiyok district occurred several years earlier than similar changes in the southern part of Thongphaphum district which is

located upstream in the valley. This is because of a general process of penetration of migrants, agricultural production and market economy in the forest dominated ecosystem along communication infrastructures that were gradually built and upgraded upward in the valley starting during the late sixties.

Nevertheless, the historical profile prepared for Tha Sao area presented in Figure 9 shows that key agro-technical transformations and changes in socio-economic conditions occurred at the end of the sixties and again during the late seventies and early eighties. Fortunately, the availability of aerial photographs at each of these dates also allowed the mapping of the state of land use patterns south of Thongphaphum area at each of these key transitory stages.

The preparation of land use maps for the 1967-70 period, in 1979 and again in 1989 led to mapping of changes that occurred between 1970 and 1979 (Map 9), 1979 and 1989 (Map 10). The rapid transformations of agrarian landscapes displayed in these maps are dominated by the following three successive components of an extensive process of:

(i) degradation of the mixed deciduous forest coverage,

(ii) conversion of degraded forest types into farm land for annual field crops production which increased more than 3 times during the past 20 years (Table 1),

(iii) re-introduction of trees through orchards and other perennial plantations at favourable locations, a very recent process that could not be completely mapped and quantified.

In comparison, the importance and distribution of rice paddies in the area is far more stable. At some locations, the rainfed lowland ricefields were converted into upland cash crop plots as the local agriculture became more commercialized.

The global quantitative results of this process of artificialization of the ecosystem for this small study area of 225 km$^2$ are summarized in Table 1. Figures 10 and 11 also visualize such key changes in two different ways.

**Figure 9.** Agrarian historical profile of Tha Sao sub-district, Saiyok district, Kanjanaburi province.

| AGROECOSYSTEM TRANSFORMATIONS | DATES | ECONOMIC AND SOCIAL CHANGES |
|---|---|---|
| Gradual deforestation of the flat/undulating lower part of the valley; bamboo and patches of mixed deciduous forest elsewhere and on slopes<br><br>Manual clearing and slash and burn cultivation of mixed cropping systems based on upland rice, egg plant, pumpkin, chillies | **1945** | As soon as end of 2nd world war logging companies are active in the valley (first phase of industrialization by import substitution)<br>Gradual migration of settlers from lower parts of the basin; buy land at cheap price from local people who settled before<br>First generation of "Taokae" brings in limited amount of capital from the outside<br>Only one market at Tha Sao waterfall |
| First introduction of cotton variety for textile mills: Stoneville 213 in 1964 followed by the hairy REBA B 50 in 1966<br><br>Introduction of large tractors and motorized ploughing by local "taokae": the market-oriented rainfed relay cropping system based on maize-cotton spreads and replaces food crops associations for family consumption or local village market | **1966** | **1970** Local "taokae" expand their clientele among new migrants and develop trading activities of farm products, inputs, consumer goods for capital accumulation<br>Creation of a market at Phu Ong ka village<br>Opening of a dirt road through the area in 1968<br>Opening of an all weather through the area in 1970 |
| First wave of farm inputs from industry distributed by "taokae": chemical fertilizers, insecticides and knapsack sprayer (for the control of sucking insects in cotton fields)<br>Beef cattle breeds for market production are introduced | **1971** | **1975** Farm credit available from "taokae", local branch of the agricultural bank opens in 1972<br>Wage earning labour introduced on the local farming systems |
| Smooth leaf cotton varieties Tak Fah 1, Srisamrong 2 and 3 replace the hairy REBA BTK 12<br><br>First serious infestation of cotton fields by American bollworm in 1980/81: insecticides sprays are intensified Leaf roll disease spreads in cotton fields | **1976** | **1980** 9 inhab./km² in the area<br>Creation of a "Land Reform Cooperative" which offers credit for purchase of farm land<br>Government supported campaign for promoting cotton production<br>Saiyok National Park created Electrification of villages |

| | |
|---|---|
| **1981** | **1985** 10 inhab./km² in the area |
| Engine-powered mistblower sprayer is introduced by big cotton growers and middlemen | Land reform in northern part of the area: new clearings are becoming officially illegal |
| Second wave of farm inputs from industry introduced: post emergence herbicides, foliar fertilizers, growth regulators, etc | Population is reported to be increasing at an annual rate of 5% as more migrants arrive |
| Second and most serious outbreak of American boll worm in cotton (up to 100% of the crop is lost): some farmers decide to switch to other crops **1986** | **1990** 12 inhab./km² in the area |
| | More Mon people are migrating to escape insecurity in Burma, they rent land from "taokae" and provide them cheap wage labour |
| Tree crops for market are more and more planted: maize-cotton system tends to become an intercropped one in young perennial plantations of tamarind, mango, sugarapple, papaya or bamboos | Cotton marketing channels between local "taokae" and giners are established and give birth to a new generation of "taokae"(some are local large cotton growers) getting capital from industry-trade links |
| Introduction of sericulture, its adoption is very limited by two main constraints: lack of irrigation system and scarcity of skilled labour | An "Integrated Cotton Production Project" is launched by Government agencies and private sector:its impact is limited |
| Okra type cotton varieties are introduced to help improving pest control | Emergence of tourism-related employment in the area which pushes farm wages upward |
| | Official closure of forest concessions nation-wide in Nov.88 |
| | A private company starts to buy silk cocoons and a training centre is established nearby |
| Many farmers sell farm land or plant trees in medium part of valley and move to cultivate cheaper, larger plots upstream | Land speculation leads to an annual 20% increase in land prices; most of new owners are absentee landlords |

**Table 1.** Quantitative evaluation of land use changes for the past 20 years south of Thongphaphum district in Mae Nam Kwae Noi valley of Kanjanaburi province.

| LAND USE TYPE | Units | 1967-69 | 1979 | 1989 |
|---|---|---|---|---|
| Dense mixed deciduous or dry dipterocarp forest | Hectare | 17.836 | 9.143 | 7.082 |
| | index | 100 | 51 | 40 |
| | % total | 79.3 | 40.6 | 31.5 |
| Degraded mixed deciduous or dry dipterocarp forests | Hectare | 1.692 | 8.665 | 6.310 |
| | index | 100 | 512 | 373 |
| | % total | 7.7 | 38.5 | 28.0 |
| Annual cash field crops and rainfed lowland paddies | Hectare | 2.943 | 4.675 | 9.014 |
| | index | 100 | 159 | 306 |
| | % total | 13.1 | 20.8 | 40.1 |
| Mature orchards and other perennial crops[/1] | Hectare | - | 15 | 95 |
| | index | - | 100 | 633 |
| | % total | - | 0.1 | 0.4 |

[/1]: young perennial plantations could not be extracted, because most of them were still intercropped with annual field crops. According to Thongphaphum Agricultural Office, orchards and other tree crops were occupying 570 ha of agricultural land in the district in 1991. That is to say an area more than six times the one mapped from the Landsat TM image.

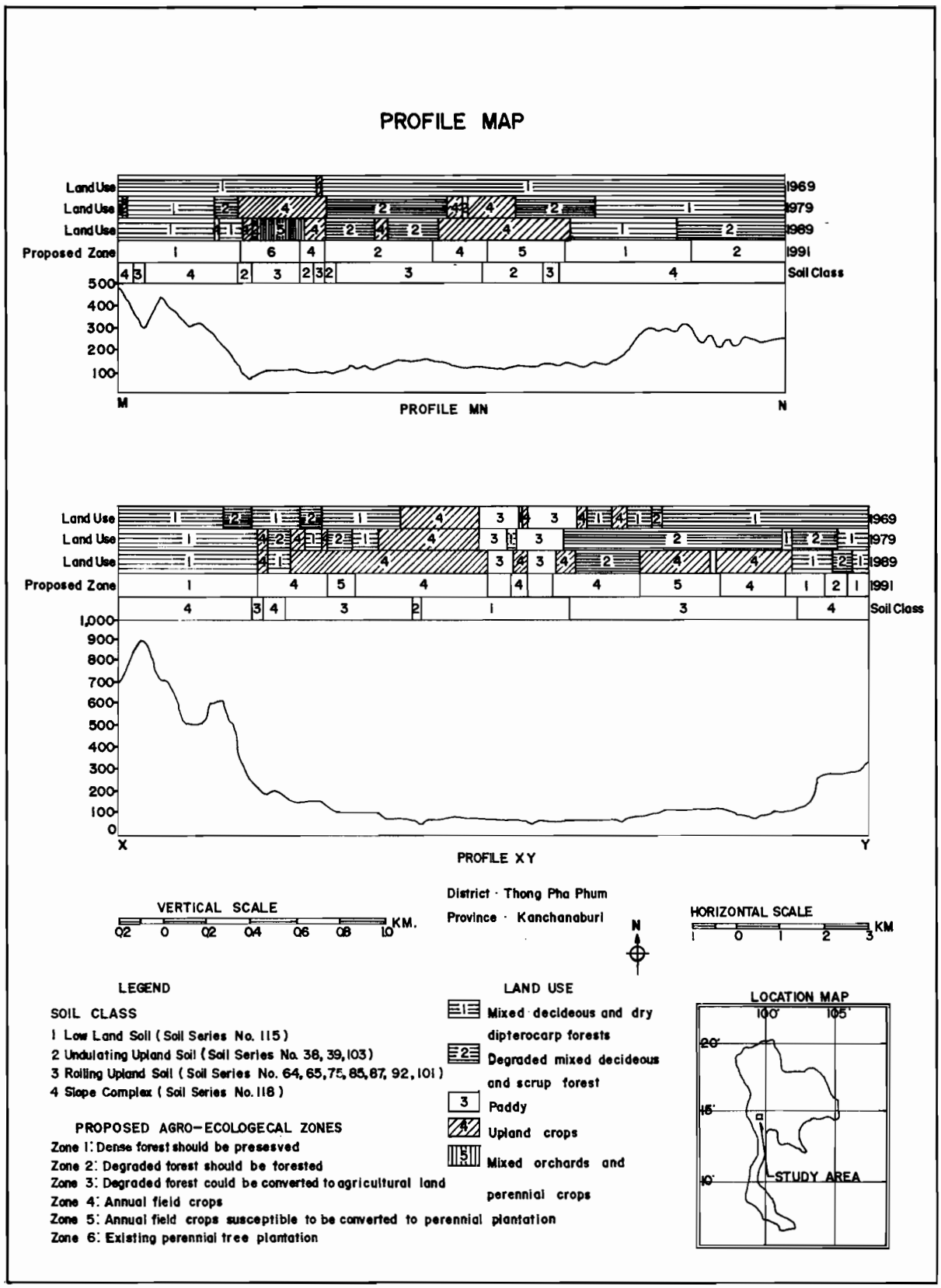



**Figure 10.** Changes in land use during each successive kind of agrarian system along two profiles across the valley, south of Thongphaphum district, Kanjanaburi province.

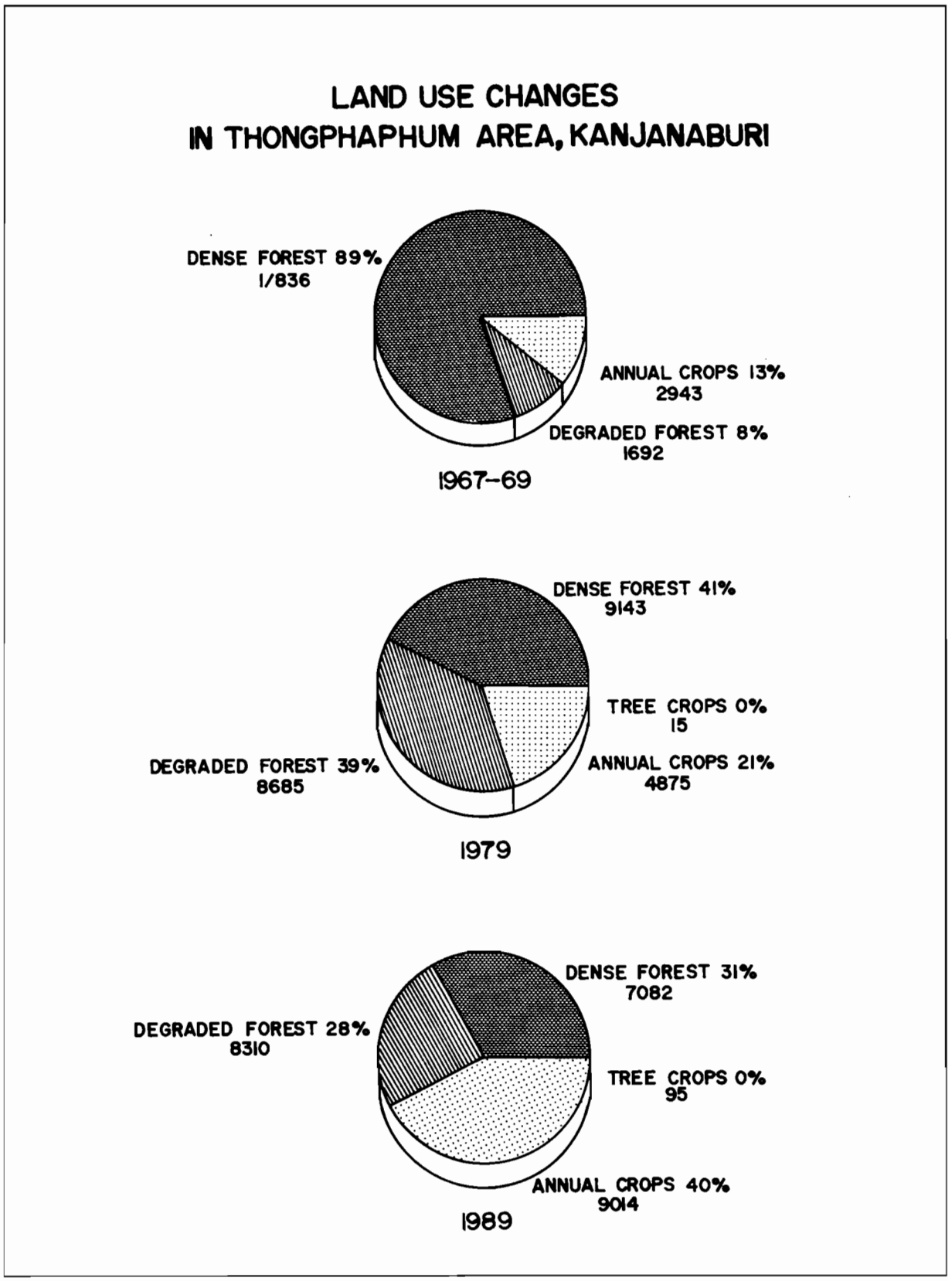



**Figure 11.** Pie diagrams displaying the evolution of the main types of land use for each successive kind of agrarian system south of Thongphaphum district, Kanjanaburi province.

## 3.3. A gradual degradation and recession of the mixed deciduous forest environment

### *3.3.1. Facts displayed by spatial zonation*

The following 6 types of land use classes could be extracted from both aerial photos and Landsat TM imagery. They were used to map landuse changes (Map 9):

**FARM LAND TYPES:**

**1. Rainfed lowland paddies**: these paddy fields after harvest were very clearly identified on both aerial photos and Landsat TM image,

**2. Upland cash crops**: main field crops that were merged in this class are maize, cotton, sugarcane, cassava, sorghum, castor bean and upland rice; including an increasing area of annual crops intercropped in young tree plantations,

**3. Perennial crops**: bamboo plantations and fruit tree crops such as mango, tamarind, sugarapple, jackfruit, cashew nut, etc. As only mature tree crops could be extracted, the extent of this category should be considered as underestimated.

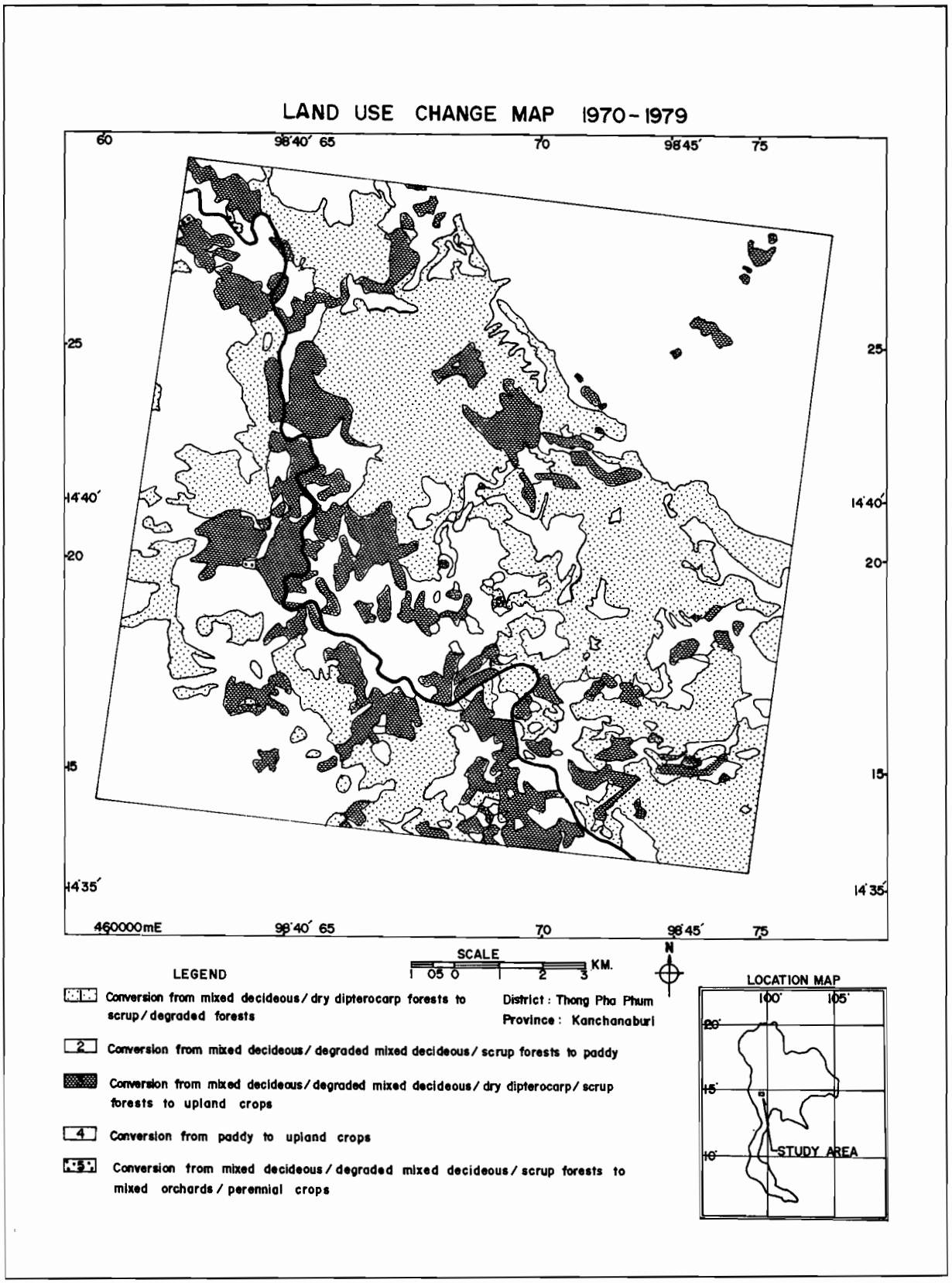
**FOREST TYPES:**

**4. Scrub & degraded forest**: this class was not always easy to differentiate from upland crops after harvest, or idle land that used to be cultivated recently. A large part of that area was under degraded mixed deciduous forest,

**5. Mixed deciduous forest**: usually associated with bamboo as a low layer, this kind of "healthy or dense forest" did not show clear boundaries in a number of situations. Such final delineated boundaries could vary according to the interpreter, nature of data and scale of the images,

**6. Dry dipterocarp forest**: this particular type of forest cover occurred only on certain well-drained soil types with high gravel or laterite fractions.

In 1967-70, mixed deciduous and dry dipterocarp forests occupied more than three-fourth (79 %) of the whole small study area south of Thongphaphum district and was distributed from the banks of rivers to the tops of mountains. Most of it looked dense and healthy with significant number of large trees. Only a few places had already been intruded (some 7-8 %) for both logging and shifting cultivation. Those areas were later gradually degraded.




**Map 9.** Map of land use changes between 1970 - 1979 south of Thongphaphum district, Kanjanaburi province.

Even though the whole forest area did not decrease so much during the 1970's, in 1979 the mixed deciduous forest was not as dense as before. It had to be classified into two types: dense and degraded or even scrub forests. Degraded forest comprising a majority of smaller trees indicating that the forest was disturbed. The evidence could be confirmed by the observation of logging activities that were displayed on aerial photos at that time. The dense forest accounted for less than 41% of the mapped area whereas the degraded forest made almost 39 % of it.

Between 1979 and 1989, the dense forest area decreased again by more than 22% (down from 91.1 to 70.8 km²). 28% of the area was under degraded forest in 1989, especially along the drainage system, roads and tracks, as well as where the slope is not very steep (about less than 16 %). Such correlations can be displayed by overlaying the drainage, road or slope sketch maps (see transparencies provided in Appendix) onto the land use maps.

Two types of mixed deciduous forest could be identified on the 1989 Landsat TM image. The northeastern side of the river is occupied by a drier and less dense type of forest, dominated by smaller and more scattered trees with a lot of bamboos occurring throughout the area (Photo 2). Whereas the mixed deciduous forest of the southwestern side of the river looks more healthy and presents larger trees. Depressions and pits between ridges of steep limestone hills offer favourable conditions (deep soil, high moisture) for vegetation growth.

In general, the surface coverage of both types of forest decreased significantly by almost one third, from some 195 and 178 km² in 1967 and 1979 respectively to only 134 km² in 1989 respectively. When tree density is considered, the ratio of dense forest to degraded forest decreased from 10:1 in 1967 to 1:1 in both years 1979 and 1989.

### *3.3.2. Interpretation provided by historical analysis*

Tables 2, 3 and 4 propose a chronological series of successive agrarian systems (AS) for Tha Sao area. In Table 2, the post second world war former AS is presented. The very low population density, the availability of only manual tools and the domination of subsistence farming limited the expansion of agricultural production at the expense of forest environment until the late sixties.

At that time, the penetration of market economy in the area and the process of mechanization of several key practices such as land clearing and ploughing characterize what we call the phase of expansion of the current dominating AS that is described in Table 3. During the last

**Photo 1.** A block model of the central part of Mae Nam Kwae Noi valley

**Photo 2.** Aerial view of the cultivated frontier during the dry season in Saiyok district, Kanjanaburi province

**Table 2.** Characterization of the post second world war agrarian system in Tha Sao sub-district, Saiyok district, Kanjanaburi province.

| A.S. VARIABLE COMPONENTS | 1945 FORMER AGRARIAN SYSTEM 1970 |
|---|---|
| ECOLOGICAL EVENTS | Gradual degradation and deforestation of the mixed deciduous forest on flat or undulating land in lower part of the valley by settlers coming after logging companies |
| MEANS OF PRODUCTION | Manual tools for clearing of mixed deciduous forest then slash and burn cultivation of small plots with gradual removal of tree stumps |
| TECHNIQUES APPLIED | Mixed-cropping of an extensive range of food and cash crops (village market only). No crop-livestock association |
| PRODUCTIONS | Upland rice, maize, egg plant, pumpkin, chillies, cassava, castor bean, cotton (start in 1964), sugarcane; fruit trees in village gardens. Gathering of forest products : bamboo shoots, mushrooms, etc. |
| DEMOGRAPHIC PRESSURE | Sparsely populated by Thai, Lao, Karen, Mon ethnics. Population density is less than 4 inhabitants/km$^2$ |
| MARKETING CONDITIONS | Apart from timber, limited but increasing exchanges of cash crop products outside sub-district boundaries. One single village market, then two at the end of 60's and village traders ("taokae") shops are being established |
| FARM SUPPLIES (INPUTS, EQUIPMENT) | Home-made manual tools dominate, but imported goods become more frequent after roads are opened at the end of 60's (see also above) |
| RURAL CREDIT PATTERNS | Village traders arrive with limited amount of capital from past activities in the central plain and lend to new settlers to grow annual cash crops |
| LAND TENURE PATTERNS | First settlers, including "taokae", control (no land title) up to 50 ha and sell farm land + 5 ha at low price to new settlers coming from lowlands |
| LABOUR MARKET | Off-farm employment in logging companies only. Mainly family labour and limited mutual help are used on the farms. "Taokae" start building their clientele among new settlers |
| STATE INTERVENTION | Very limited. Several roads are built at the end of the 60's. Village and sub-district headmen are also often "taokae" traders. |
| FARMER INCOME, PRODUCTIVITY | Domination of subsistence farming gradually recedes in front of expansion of cash crops and market economy in the late 60's. No differential in labour productivity as only manual tools are used. |
| FARM DIFFERENTIATION | Mainly between "taokae", first settlers and the ones who arrived later. APS size ranges from 5 to 50 ha |

**Table 3.** Characterization of the phase of expansion of the current agrarian system in Tha Sao sub-district, Saiyok district, Kanjanaburi province.

| A.S. VARIABLE COMPONENTS | 1970 CURRENT AGRARIAN SYSTEM: phase of expansion 1980 |
|---|---|
| ECOLOGICAL EVENTS | Acceleration of the process of degradation of mixed deciduous forest cover and conversion into field crop plots. Build up of leaf roll disease, sucking insect pests, then bollworms in cotton fields |
| MEANS OF PRODUCTION | Motorized clearing/ploughing of plots is now widely available (4-wheel tractors). Chemical inputs (fertilizers, insecticides) start to be systematically applied in cotton and vegetables productions |
| TECHNIQUES APPLIED | Extensive adoption of maize-cotton relay cropping system in rainfed conditions, often repeated on the same plot without rotation with other crops (sometimes with local vegetables) |
| PRODUCTIONS | Domination of maize (April-August) and cotton (July-January) cash crops. Several traditional food crops start to be phased out (such as upland rice). Beef cattle rearing is introduced in the area by a government agency |
| DEMOGRAPHIC PRESSURE | More migrants (mainly Thai families from lowlands) arrive. Population density reaches 8 inhab./km² |
| MARKETING CONDITIONS | All weather road opens across the area facilitating exchanges of goods with outside. "Taokae" play more and more important role in marketing all annual field crops: they are key actors in setting up farm product marketing channels |
| FARM SUPPLIES (INPUTS, EQUIPMENT) | Chemical fertilizers, insecticides, manual sprayers are easily available from village traders' shops that also provide tractors and corn ginning equipment for rent |
| RURAL CREDIT PATTERNS | A local branch of the Bank for Agriculture and Cooperatives (BAAC) opens in the district, but money lending by "taokae" is still dominating (no collateral requested) |
| LAND TENURE PATTERNS | Creation of a land reform cooperative offering credit to purchase limited acreage of farm land. Delivery of "Po.Bo.To. 5,6" land titles to Thai farmers |
| LABOUR MARKET | Wage earning labour is introduced on larger farms at maize and cotton harvesting periods |
| STATE INTERVENTION | Infrastructures = roads, dams under of construction<br>Institutions = BAAC, military agency promoting cattle rearing, land reform project, agricultural extension office (T and V), promotion of cotton production, etc. |
| FARMER INCOME, PRODUCTIVITY | Subsistence farming recedes as upland rice disappears. Cash income grows with generalizing of maize-cotton, but input cost rises over the period. Little differential in labour productivity as dependence on "taokae" gives any farmer access to an incomplete range of motorized equipment |
| FARM DIFFERENTIATION | Increased differentiation among Thai and ethnic minority groups (access to land, credit, etc.). "Taokae" accumulate capital through diverse trading activities and money lending |

**Photo 3.** Maize harvest and emergence of the cotton relay crop on the cultivated frontier in Saiyok district, Kanjanaburi province

**Photo 4.** Maize and cotton intercropped among young sweet tamarind trees in Saiyok district, Kanjanaburi province

20 years, the dense mixed deciduous forest was extensively degraded and replaced by a range of annual field crops dominated by the maize-cotton relay cropping system.

## 3.4. An impressive expansion of annual field crops along the cultivated frontier

### *3.4.1. Facts displayed by the spatial zonation*

The expansion of upland cash crops into scrubby and degraded mixed deciduous forest can clearly be seen in Maps 9 and 10 as well as in Figures 10 and 11 and Photo 3. They show that, most of the time, upland cash crops are replacing degraded mixed deciduous forest, following prior logging and land clearing activities. At some places, paddies were converted into upland cash crop fields.

For approximately ten years, between 1967-70 and 1979, upland crops expanded on both sides of the Mae Nam Kwae Noi river and its tributaries. With the exception of very few places, it happened where the slope is gentle (less than 2 %) and the elevation not over 100 m above mean sea level (amsl). Throughout that period, the area under upland cash crops increased by almost 60% from 29.4 to 46.75 km² in 1967-70 and 1979 respectively.

During the 1979-1989 period, the cultivated area under upland cash crops increased dramatically again by more than 90% to 90 km². This was possible by encroaching on undulating (2-8 %) and rolling (8-16 %) sloping land at elevations ranging from 100 to 200 m amsl. At some locations in the north-western part of the area, maize crops could be observed on steeper land having slopes superior to 16 %, that make land preparation difficult and increase soil erosion hazards. On the other hand, in the south-western part of the area, the expansion of upland crops seems to have stopped when they reached around 200 m elevation. Above that level, slopes are ranging between 16 and 60 %, some hills reaching 800 m amsl.

On the north-eastern part of the mapped area, the expansion of upland crops reached already the 200 m elevation at most places, but future expansion seems to be still possible on slopes ranging from 8 to 16 %, particularly along the drainage system and access roads or tracks.

### *3.4.2. Interpretation provided by historical analysis*

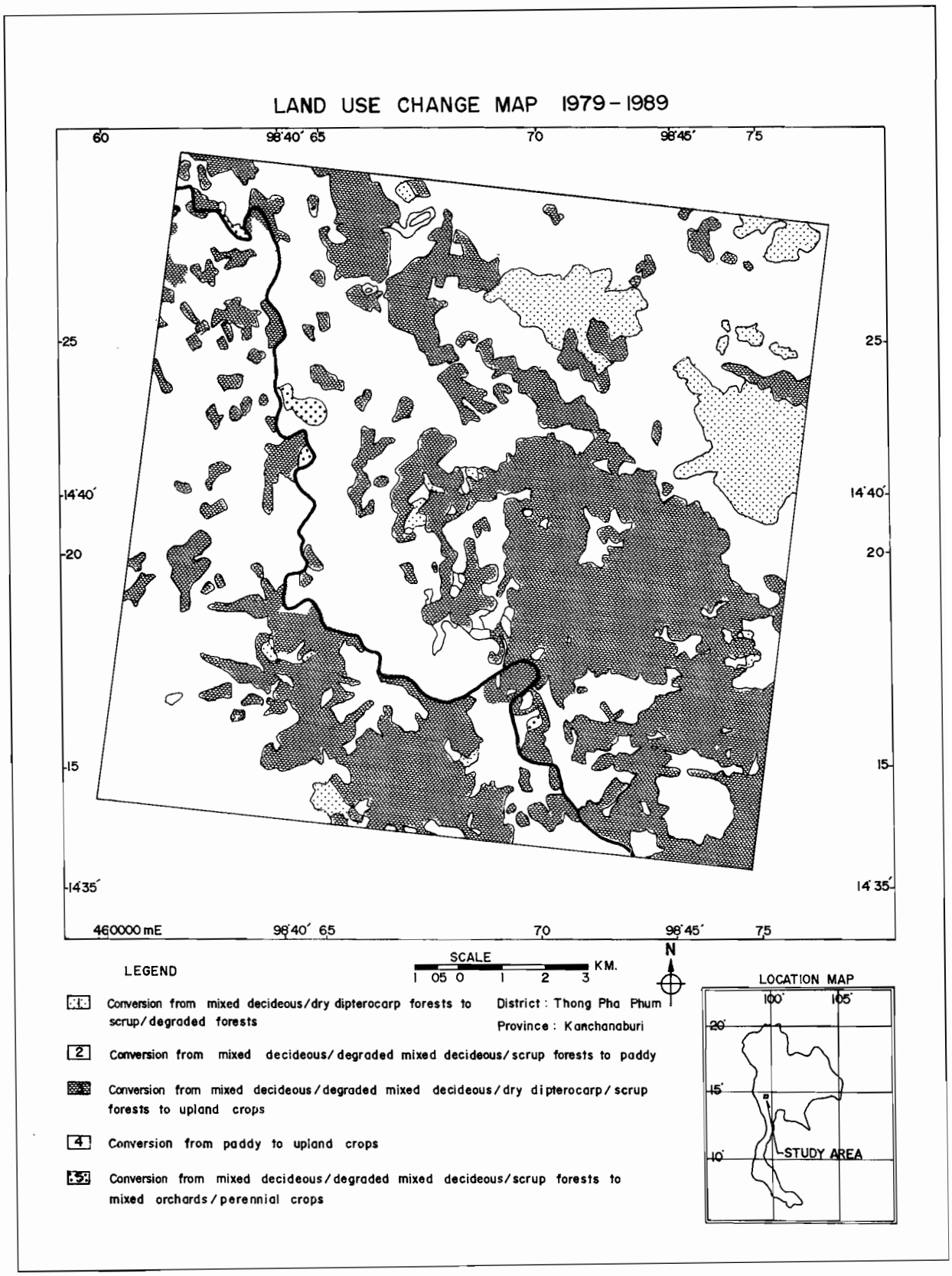
During the 1970-1980 period, the rapid penetration of the cash economy in the countryside brought markets for field crops and procured chemical inputs from industry for fertility maintenance and pest control. The efficient organization of agricultural product marketing channels and input procurement systems are due to the key role played by village traders as can be seen in Table 3. The occurrence of large scale clearings operated by these "taokae" for annual cash crop production using wage-earning labour shows that their influence encompasses the range of activities from direct production to product delivery at agro-processing plants. For small farmers and early squatters, the official distribution of land classified as degraded forest (up to 3.2 ha per household) to families that occupied such plots for already more than 15 years also favoured the expansion of annual cash crop production.

## 3.5. A recent, still limited trend towards a return of trees in farming systems through more orchards and other perennial plantations

### *3.5.1. Facts displayed by spatial zonation*

While the area under mature orchards is still very limited, it increased six times to reach nearly 1 km² in 1989. It is understood that a far more important area under recently planted fruit tree and young bamboo plantations could not be mapped separately. This is due to the fact that intercropping of young mixed fruit trees with several upland crops, such as maize-cotton or cassava (Photo 4), is a very popular practice in recently planted perennial plantations (most of them being under 5 year old and having a limited ground coverage).

The increasing popularity of such perennial plantations was checked during field surveys. The most popular fruit species are sweet tamarind, mango, pomelo, jackfruit, cashewnut, banana and papaya or sugarapple when topsoil is shallow. Bamboo plantations can also frequently be seen. Along roads on the western side of the river rubber is also a newly introduced economic crop. The implantation of cash perennial productions is conducted through the introduction of high quality varieties from other provinces: sweet tamarind from Petchabun, bamboo from Prachinburi, mango from various places of the central region. Small plots of mulberry trees can also be seen at several locations, usually along roads and close to human settlements. Teak and eucalyptus reafforestation plots managed by the Forestry Department can also be found, especially in the north-eastern corner of the area where a large teak plantation could be observed.




**Map 10.** Map of land use changes between 1979 - 1989 south of Thongphaphum district, Kanjanaburi province.

**Photo 5.** Large scale cassava plantation in Saiyok district, Kanjanaburi province

**Photo 6.** Aerial view of a mango orchard along the main road in upper Mae Nam Kwae Noi valley, Kanjanaburi province

More and more often, the occurrence of large size monocrop plantations (Map 10 and Photos 5 and 6) indicates that land ownership has been transferred from local farmers to landlords, most of them living in Bangkok or neighbouring provincial capitals. Most of these recent orchards and plantations are located along the Mae Nam Kwae Noi river or scattered along the road between the Huai Ung Thi and Huai Diso rivers (see overlay with drainage system sketch map).

### *3.5.2. Interpretation provided by historical analysis*

What we call here the second phase of the current AS is characterized by an ecological crisis in cotton fields (repeated severe outbreaks of the American bollworm *Helicoverpa armigera* that became resistant to the widely used pyrethroid insecticides [CARON, 1992]) which is described in Table 4. Increasing use of a very sophisticated range of chemical inputs at a time when market prices for field crops were declining eroded their profitability. At the same time, the recent availability of new (including export) markets for fruits and vegetables created the necessary conditions for the introduction of more fruit trees on several categories of APS having accumulated enough means of production (titled land and cash savings).

**Table 4.** Characterization of the second phase of current agrarian system in Tha Sao sub-district, Saiyok district, Kanjanaburi province.

| A.S. VARIABLE COMPONENTS | 1980 CURRENT AGRARIAN SYSTEM: 2nd phase >1995? |
|---|---|
| ECOLOGICAL EVENTS | Expansion of annual crops in degraded forest on undulating land continues. Severe outbreaks of Helicoverpa armigera in cotton (pest becomes resistant to insecticides). Appearance of perennial plantations near roads, river, villages |
| MEANS OF PRODUCTION | Motorized sprayers introduced to increase labour productivity in pest control. Herbicides are used to decrease labour requirements at weeding. A more and more sophisticated range of agro-chemicals are available at village shops (including foliar fertilizers, growth regulators, etc) |
| TECHNIQUES APPLIED | More inputs are used on annual crops, especially cotton, raising their cost of production. More and more often, annual cash crops become intercrops in young orchards or plantations |
| PRODUCTIONS | Despite successive changes in varieties, pest control problems in cotton erodes profitability of the crop, makes it more risky: the area under cotton tends to decrease. An array of perennial crops is introduced on the farms (mango, sweet tamarind, jackfruit, sugarapple, mulberry, bamboo, etc) |

| A.S. VARIABLE COMPONENTS | 1980 CURRENT AGRARIAN SYSTEM: 2nd phase >1995? |
|---|---|
| DEMOGRAPHIC PRESSURE | Due to insecurity in neighbouring Burma, more Mon ethnics arrive. Population density reaches 12 inhab./km² and 85 inhab./km² of farm land |
| MARKETING CONDITIONS | Strengthening of commodity marketing channels between "taokae" and agro-processing factories (that provide capital to a new generation of "taokae", some of them being large cotton growers). Marketing channels are more diverse in fruit (directly to consumers, exports, etc.) and vegetable productions, making producers less dependent on "taokae" |
| FARM SUPPLIES (INPUTS, EQUIPMENT) | Rapid increase in range of chemical inputs offered to growers at village shops (without adapted technical advice). Nurseries provide seedlings of selected fruit tree/bamboos |
| RURAL CREDIT PATTERNS | Only 200 farmers use BAAC service that remain dominated in influence by the "taokae" seasonal credit system. Land speculation at the end of the 80's leads some farmers to sell their plots and buy larger ones upstream in the valley |
| LAND TENURE PATTERNS | Land reform carried in villages of the northern part of the area (delivery of "So.Po.Ko.401" land titles, maximum size family holding=8 ha, loans to be repaid in 10 years) Land speculation drives prices to summits (US$ 25-37,000/ha) |
| LABOUR MARKET | Cheap wage earning labour belonging to Mon ethnic group is available on larger farms. But tourism-related off-farm employment starts competing for labour at some places and push wages up to Baht 60/day |
| STATE INTERVENTION | Cotton projects to improve quality of output and pest management lead to better awareness of problems on the farms, but have very limited impacts on farmer practices. Opening of a sericulture training centre in the area has a limited impact |
| FARMER INCOME, PRODUCTIVITY | A new generation of "taokae", very closely linked to agro-chemical companies and processing factories emerges. Switching to perennial crops is depending on rights on the land and cash-balance situation on the APS. No introduction of farm equipment to increase differential in labour productivity (cheap farm labour still available) |
| FARM DIFFERENTIATION | Because of different situations regarding access to land and capital, Minority ethnics, Thai, "taokae" production systems adopt different strategies and practices. The range of holding size is from 0.16 to 150 ha |

Other less successful types of APS have no other choice than to continue converting the mixed deciduous forest into annual field crops plots (Map 10). Recently, the marketing channels controlled by "taokae" and farmers personal relations of dependence on these village traders have been reinforced (see Table 4).

The 1989-90 boom in land speculation marked by a rapid increase in land prices (jumping from Baht 2,000 to up to 100,000 per rai during the past ten years) had also a significant impact on the distribution of the best agricultural land (limited slope, easy access to the plots) and favoured investments in fruit tree plantations by absentee landlords. But it also increased the competition for land and water resources between farming and non-agricultural tourist-oriented activities (golf courses, resorts).

### *3.5.3. Hypotheses for solution to the current crisis*

Only a solution to the current growing agro-ecological crisis in annual crop fields can help a majority of local Thai small-scale producers to be able to diversify their production base through the introduction of more perennial plantations, a labour intensive vegetable-based sub-system and sometimes a new type of crop-livestock association. Such a trend could foreshadow the emergence of a new, more diversified and complex AS.

Bringing trees or beef cattle in local production systems could improve significantly their sustainability. Therefore, the key agricultural development problem in that area is how to create conditions that will allow a majority of farmers to afford planting tree or rearing beef cattle? Lessons learned from the analysis of the local agrarian history indicate that this could be achieved through the improvement of the competitiveness of the maize-cotton relay cropping system, by decreasing their cost of production and improving the quality and amount of product per land unit.

There are no "bad" crops, only the way they are grown has sometimes to be changed. For example, it is obvious that the past sharp increase in cotton production costs during the last ten years is partly due to a lack of relevant (locally validated) technical recommendations in pest control and mineral fertilization and partly because of the social and economic conditions of the farm environment. These are dominated by the powerful role of village traders that do not see their interest in the extension and adoption by farmers of such input saving technical recommendations.

Another key aspect of the social conditions to be created in order to favour the appearance of more sustainable APS is the legal status of Mon migrants and other minority ethnic

groups. Without legal access to land and security of tenure, they will not be interested in investing in perennial crops. They already represent the majority of cotton growers, but their personal and economic dependence on "taokae" added to their lack of fluency in Thai prevent them from following relevant technical advice.

## 4. CONCLUSIONS: ARTICULATION WITH SUBSEQUENT RESEARCH WORK AT FARM AND PLOT LEVELS

### 4.1. Remote sensing: an operational tool for agricultural development?

This case study shows that provided one who knows exactly what he is looking for and why, remote sensing can be a powerful tool to help provide pertinent hypotheses and guidance to agricultural development specialists who would like to base their recommendations on an understanding of past transformations of agrarian landscapes.

To do so, the systematic articulation of spatial zonation with agrarian history analysis proved to be an interesting approach for the delimitation of pertinent classes for action. Later such outputs from the preliminary diagnostic phase could be used again for the evaluation of the impact of the proposed interventions. This case study also demonstrated the necessity of a combination of visual and digital analysis of remotely sensed data to produce pertinent outputs.

### 4.2. Planning of subsequent research work at farm and field levels

Landscape dynamics analysis provides just an introduction to the knowledge of a region prior to intervention on its existing realities. It puts the current situation into historical perspective at project preparation stage. Later, at project or programme evaluation stage, it can again be used as a tool for impact assessment.

Even without farm surveys, by elucidating the main positive or negative trends, landscape and agrarian historical analyses provide pertinent information to diagnose agricultural problems in broad terms and set up general hypotheses for their solutions. Nevertheless, complementary to them, an in-depth on-farm analysis of the functioning of farmer diverse categories of APS is necessary to verify them and assess the range of possible adapted solutions to their respective key problems.

A limited sample of diverse household-based APS was systematically analyzed to understand the differentiated functioning of their production systems, their goals, strategies and key management criteria as well as related current problems. Because the outputs of the zonation and analysis of the agrarian history elucidate the extent and origins of the diversity of on-farm situations, they were used to select such a limited sample of diverse APS. It was assumed that they belong to each of the successive kind of AS identified such as:

(i) APS using only manual tools and in which food crops are playing a more important role than cash crops (remnant of the former AS),

(ii) APS growing mainly several annual cash field crops with limited amount and types of inputs (representative of the first phase of current AS),

(iii) APS having introduced perennial plantations and/or crop-livestock interaction besides annual cash crop production grown with an extensive range of inputs (which belong to the second phase of current AS),

(iv) APS in which mature tree crops and/or livestock production are dominating the annual cash crop production (that announce the emerging future AS).

The APS survey will lead to the proposition of an operational farmer typology based on their APS functioning and history. The farm survey will also help to answer the following key questions:

(i) Can the positive current trend toward the re-introduction of trees as a major component in farming systems be interpreted as an endogenous farmer answer to the sustainability challenge? What kind of farming systems can afford to do so?

(ii) For other types of APS, how to accelerate their accumulation of means of production to help them join the previous category? Is it through the improvement of the current annual field crop systems or through a different diversification of their activities?

This complementary farm survey will allow the on-farm researcher to prioritize agro-ecological zones, APS types and key on-farm limiting factors to be improved by further agronomic research and development activities at the field level. At completion of such a diagnostic study, it will become possible to:

(i) Adapt technical advice to local bio-physical (agro-ecological zones) as well as socio-economic (farmer types) circumstances and test innovations to improve agricultural productivity and/or stability of the production with a reasonable chance of success,

(ii) Target extension activities and their differentiated messages toward one or several specific groups of APS having similar functioning and goals, and therefore also similar needs in terms of agricultural development,

(iii) Feed back on-station and on-farm research with key research topics corresponding to the needs of a majority of resource-poor farmers,

(iv) Provide planners and decision makers with useful information for the definition of a relevant state agricultural policy, to forecast its impact and provide pertinent indicators for the measurement of agricultural transformations.

The results of this farm survey carried out in Tha Sao sub-district will be presented in a separate publication.

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# GLOSSARY

**Agrarian System (AS)**: an historically constituted and durable mode of exploitation of the environment, a technical system adapted to the bioclimatic conditions of a given area and which complies with its social conditions and needs at that moment (MAZOYER, 1985).

The concept of agrarian system can be defined as a combination of the following essential and interrelated variables:

- the *cultivated environment* : the original environment and the historical transformations which it has undergone,
- the *instruments of production* : tools, machines, crop varieties, breeds of livestock and the (physical as well as intellectual) labour which uses them to produce, maintain, exploit the cultivated environment. A coherent tooling system to grow the selected crops and raise animals which are themselves compatible with the kind of environment. A technical system to cultivate this environment but which is also necessary and sufficient to maintain its conditions of production (soil fertility, land development techniques and infrastructures such as canals, etc),
- the *resulting mode of exploitation of the environment* : the product of the agricultural work, using an adapted combination of inert and living means of production to maintain and exploit the cultivated environment in distinct but complementary sub-systems. But such internal coherence of the mode of exploitation itself refers to the technical, economic and social conditions of production at a larger scale,
- the *division of labour* among agriculture, crafts and industry which provides for the replacement of tools and equipment and, as a result, for the agricultural surplus beyond the needs of the agricultural producers which supports the other social groups. A specific division of labour corresponds to the state of the forces of production; it is not the same for manual, draft animal or motorized cultivation,
- the *relations of exchanges* between these associated economic sectors, the *ownership and power relationships* which regulate the *distribution* of the fruits of labour (production and consumption goods) and the relations of exchanges between systems (competition),

- finally, the collection of *ideas and institutions* which are necessary for society to continue : production, relations of production and exchanges, distribution of the products (MAZOYER, 1985).

**Agricultural development**: the gradual changes occurring in the agricultural production processes that are assumed to be socially beneficial (MAZOYER, 1985).

**Agricultural Production System (APS)**: the whole structured set of plants, animals and other activities selected by a farmer for his production unit to achieve his goals. The APS is a global system that is finalized by farmer's socio-economic objectives and related management strategy.

**Cropping System (CS)**: The set of techniques performed on plots which are handled in an identical way. Each cropping system is defined by:

- the kind of crops and their succession order,
- the itineraries of techniques applied to these several crops, including the choice of varieties for the selected crops (SEBILLOTTE, 1990).

**Land use/land cover**: land use is defined here as human activity associated with a specific piece of land; land cover is the type of feature present on the surface of the earth.

**Cultivated frontier**: the demarcation between the degraded forest or agricultural land and the non disturbed forest environment.

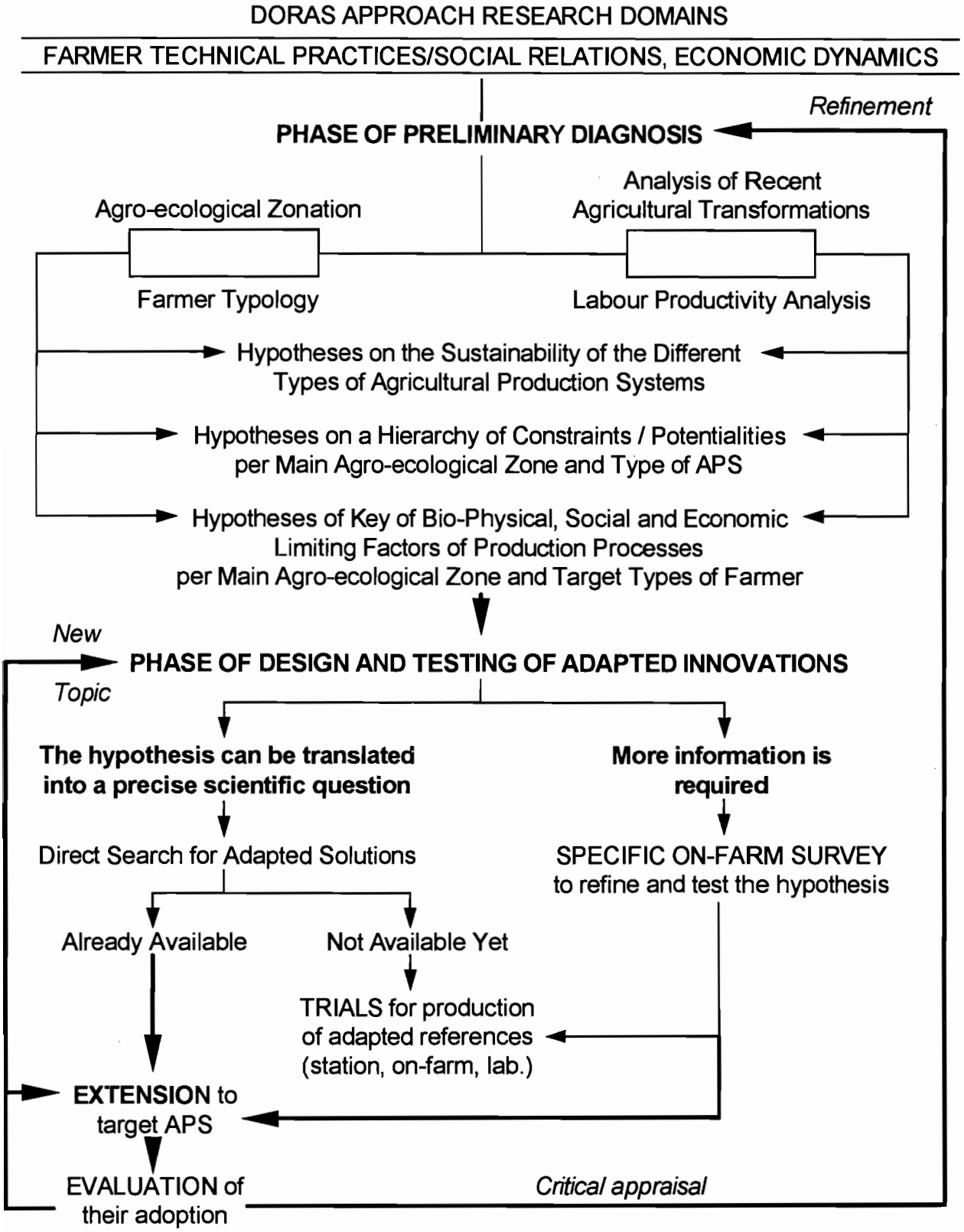
**Transect**: A well-selected itinerary across the study area to be run for field data gathering. It is chosen so as to cut a maximum number of heterogeneities identified in a minimum length and so field work time. Two complementary kinds of transect can be distinguished:

- primary transects cutting heterogeneities born from bio-physical parameters (man response to different environments), and
- secondary transects (sometimes perpendicular to the previous type) looking at the diversity of social and economic origin within a rather homogeneous agro-ecological zone (various farming system adaptations to a given bio-physical environment).

# APPENDICES

# APPENDIX 1

**ARTICULATION BETWEEN THE FOUR ITERATIVE PHASES OF DORAS APPROACH AND THE INTEGRATION OF ITS RESEARCH AND EXTENSION ACTIVITIES**



# APPENDIX 2

## HELPER FOR ORGANIZING KEY INFORMATION ON LANDSCAPE OBSERVATION

**TOPOGRAPHY:**
- altitude
- natural landform
- exposition
- slope assessment

**GEOLOGY/SOILS:**
- nature of bedrock and relations with derived soils,
- soil characteristics: depth, texture, structure, acidity,
- hydrological features
- micro climate
- special phenomena: hydromorphy, erosion,...

**NATURAL VEGETATION:**
- density and continuity of vegetation cover
- distribution of species: layers, size, age
- identification of plant groups, communities
- spot man-made effects

**HUMAN SETTLEMENTS:**
- location, size, density,
- pattern of distribution
- key infrastructures

**LAND USE:**

* *Not cultivated:*
- gathering
- grazing
- vegetal cover deterioration

* *Cultivated area:*
- shape, size of plots, nature of boundaries
- type of crops and their distribution
- observed farmer practices

**MAIN LANDSCAPE/AGRO-ECOLOGICAL UNITS:**

Dominating mode of artificialization of the ecosystem

**DIVERSITY OF SOCIO-ECONOMIC ORIGIN INSIDE MAIN AGRO-ECOLOGICAL UNITS:**

Variability of farmer practices (inputs and farm equipment)

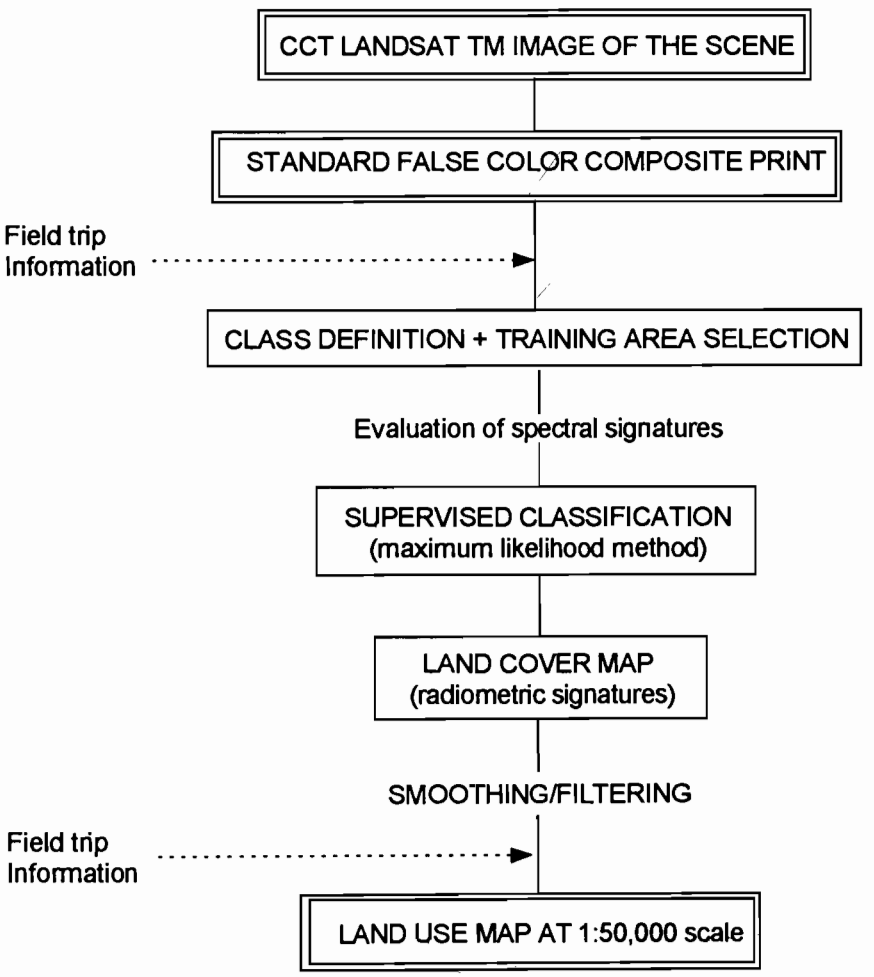
# APPENDIX 3

## DIGITAL IMAGE PROCESSING

**Digital image processing is an automatic classification of digital data through computer software.**

The Landsat TM scene of 21 December 1989 was used in this study. This data in the form of computer compatible tape (CCT) were processed and analyzed on the MULTISCOPE image analysis system at the Remote Sensing Laboratory of the Asian Institute of Technology. The following is a diagram showing the work flow through the analysis.

**FLOW DIAGRAM FOR SUPERVISED CLASSIFICATION**



## Image Analysis and Classification Techniques

Various techniques for classification were attempted including image enhancement, principal component analysis (PCA) and maximum likelihood classification. The classification steps are as follows:

1. Preliminary classification: the pre-classification of the area was performed on image to generate preliminary thematic maps for use in the field surveys. One image was produced in the false colour composite of bands 4, 3, and 2 while the other in the PCA analysis image. These coloured images were enhanced such that land cover types could be easily separated based on their digital values.

2. Supervised classification. The maximum likelihood classification technique was employed in this analysis. Number of land cover types/classes were decided according to the ground information of the area as obtained in the field observation. The training areas were selected and evaluated for the classification. Land cover types could be classified at first to be 15 classes and later combined into substantially 6 classes that are 1) Evergreen, mixed deciduous and dry dipterocarp forests 2) Degraded forest 3) Upland crops 4) Sugarcane 5) Cassava and 6) Paddy and Grass land (see map 15).

3. Post-classification processing. In order to smooth the classification results, small patches of some classified pixels were removed to produce a smooth colour pattern. The method used here is called " filtering ". It was done by replacement of the scattered small area with its surrounding pixels.

# APPENDIX 4

## RECAPITULATION OF RECENT AGRICULTURAL TRANSFORMATIONS FOR EACH KEY COMPONENT OF THE AGRARIAN SYSTEM

### CASE STUDY OF TAMBON THA SAO, AMPHOE SAIYOK, CHANGWAT KANJANABURI

Record the nature, date, causes, origin, extent and consequences of each of the changes mentioned by informants in the ecological conditions, technical system, social and economic components of the agrarian system.

### 1. RECORD OF MAJOR ECOLOGICAL EVENTS

Principle: description of the process of *simplification* of the natural ecosystem through its *artificialization* by man to satisfy his needs; steps towards the creation of the current, more fragile, agro-ecosystem: relations between climate/water, topography/soil, plants and animals, weeds, pests, etc.

1945-70: Dense forest ecosystem populated with large wild mammals is still dominating, but forest cover decreased for the last 40 years as new settlers follow logging companies and open more land for cultivation. Logging companies were active along the Mae Nam Kwae Noi valley as soon as the end of the second world war.

1970: Populations of large wild animals begin to decrease significantly and become to be scarce around 1985 after decades of hunting and deforestation.

1980-81: First report of a rather severe infestation of cotton fields by the american bollworm (*Helicoverpa armigera*), approximately one half of the production is lost and more insecticides are used during the following years.

1986: Very important infestation of american bollworm in cotton fields (total loss of the harvest at some locations, 175 kg/ha at one informant's field against 1,400 kg/ha on an average year) attributed to favourable climatic conditions and misuses of pyrethroid leading to a significant level of pest resistance to this family of insecticides. This event accelerates the switch to other cash crops (vegetables, fruit trees) by many local farmers.

1985-90: Impact of leaf roll disease tends to decrease in local cotton fields.

1988 (Nov): Government decision to close all forest concessions nationwide: final limit of the cultivated ecosystem?

1990: Lower part of valley is deforested, bamboo forest and patches of mixed deciduous forest dominate on sloping land.

Almost 100% of the agricultural land is rainfed and no irrigation schemes are planned.

## 2. EVOLUTION OF AGRICULTURAL PRODUCTION SYSTEMS

Principle: Record changes is use of varieties/breeds, tools, equipment and machinery, inputs, agriculture-related infrastructures.

### 2.1. Means of production

1945-73: Only a *manual tooling system* is available. Gathering of food and cash products in the forest is still playing a significant role.

1969: First introduction by local "taokae" (village traders) of *four-wheel tractors* (70 cv) for land clearing and ploughing (rental fee= 70 Baht/rai). They are also equipped with a corn sheller for post-harvest processing and favour a rapid expansion of the maize-cotton growing area the following years.

This rainfed relay cropping system based on *only two annual cash crops* replaces the previous mixed cropping practices of food and cash crops. Its expansion follows the increase of farmer needs for cash incomes as the market economy penetrates deeper in the area.

1970-75: Insecticides against cotton sucking insects (aphids, which transmit the leaf roll disease, jassids) are first introduced and followed later by similar chemical pesticides against bollworms.

Introduction of the knapsack sprayer for insect control in cotton (maximum productivity: 10 rai/worker/day) which replaces the manual powder applicator (maximum productivity: 6 rai /worker /day).

Chemical fertilizers are introduced in maize and cotton fields through the "taokae" village shops. Rapid growth in chemical input consumption feeds the reinforcement of the technical (introduction /testing of innovations) and economic (credit, input procurement and marketing of farm products) dependence of client farmers ("luk rai") on "taokae" middlemen in a global context of strengthening of the local market economy.

1980-82: Introduction by local "taokae" of the mistblower sprayer *for motorized spraying* in cotton fields (maximum productivity: 25 rai/worker/day). It is widely adopted by farmers having at least 50 rai of cultivated land. Enterprise work is available for spraying against cotton pests leading to an increase in the use of insecticides (more than ten insecticide applications per crop cycle is common).

1980-85: Introduction by "taokae" of post-emergence *herbicide* (paraquat) and *foliar fertilizers* in cotton. Even growth regulators are available! By 1990 their use is almost generalized leading to an increase in the cotton cost of production.

## 2.2. Agricultural techniques used by farmers

1945-70: Newly opened forest land must be cleared and cultivated by using the *slash and burn manual technical system* for three years before the first *motorized ploughing* can be carried out.

Crop associations based on upland rice (*for home consumption*) and a variety of *cash crops* (castor bean, pumpkin and gourd, chillies, eggplant, maize, cotton, etc) are widely grown on newly opened land along the forested cultivated frontier.

1964: Introduction by the Department of Agricultural Extension (DOAE) of Stoneville 213 cotton variety to improve productivity and lint quality.

1966: Introduction by DOAE of the *hairy* and widely adopted Reba B 50 cotton variety introduced by IRCT-France.

1970-80: As soon as *motorized ploughing* is available, the *maize-cotton rainfed succession of cash crops* replaces the former crop association. Rice for family consumption is now bought on the market as the cash economy is spreading quickly. Cotton fields receive chemical fertilizer and insecticide.

1973: Reba BTK 12 variety (also introduced by IRCT-France) is released by DOAE and adopted by most of the local cotton growers.

1970-80: Dissemination of new breed of beef cattle among the local farmers by the " ko ro po klang" military agency.

1978: Introduction by DOAE of the widely adopted Tak Fa 1 cotton variety (Stoneville 213 * Reba BTK 12) because of its high yielding potential.

1980: The Srisamrong 2 cotton variety (a re-selection of G115-7 introduced by IRCT-France) which is reputed to be more *tolerant to leaf roll disease* is disseminated by DOAE and ginners among the local cotton growers and replace Tak Fa 1 cultivar.

Extensive adoption of Suwan 1 maize variety for sale to animal feed mills.

1980: Beginning of application of limited amount of chemical fertilizer also in maize.

Insecticide sprays against aphids (leaf roll disease) and jassids are increasing (before those against the American bollworm).

1980-85: *More perennial cash crop* plantations (bamboo) and orchards (sweet tamarind, mango, sugarapple, jackfruit, papaya) are established. The maize-cotton relay cropping system is more and more frequently intercropped in young tree plantations for 5 to 8 years (depending on spacing and growth of tree crops).

1981-82: Introduction of Srisamrong 3 (= DI 5, a mutant of Deltapine Smooth Leaf) cotton variety in this area by DOAE because of its high yield potential. It is sparsely adopted.

1986: Introduction by DOAE of Nakhon Sawan 1 (= DI 9,) cotton variety. But rising costs of production are making cotton less attractive to Thai growers. Mon migrants continue to grow it as they do not have any alternative choice (no access to land, high level of personal dependence on village traders).

1987: Introduction at several locations (on-farm trials) by Kasetsart University of Ratchada 1 and 2 *hairy* cotton varieties for their tolerance to insect damages. No dissemination followed because their low ginning outturn and fibre technological characteristics are not making them attractive to local ginners.

1990: The Srisamrong 60 (AG18) is introduced in cotton fields by some local " taokae". It is reported by farmers to be less sensitive to shedding than Srisamrong 2. Where its fibre characteristics are acceptable to the buyer it tends to replace the Srisamrong 2 variety. Cotton cost of production continue to rise as most farmers now mix foliar fertilizers with insecticides at each pesticide application.

Introduction by Saengtawee ginning company (at the request of its spinning mill buyer) of a variety of G. Barbadense at a few locations in Tha Sao sub-district because of the high demand for its extra long fibre. Farmers do not adopt it because of the time consuming picking of its small bolls.

1992: Okra leaf cotton varieties are introduced. Farmers complain about the small size of their bolls.

### 2.3. Productions

1945-75: A *wide range of crops* mainly for family consumption and local market are produced on the farm: upland rice, maize, cotton, castor bean, pumpkin and gourd, eggplant, chillies, mango, papaya, tamarind, etc. Gathering of forest products (bamboo shoots, mushrooms, medicinal plants) and hunting still plays an important role.

1970-75: The *rainfed maize-cotton cash crop system becomes more and more important* on more specialized production systems. Two other important cash crops are sugarcane and cassava. Castor bean production is receding.

1970-80: Beef cattle rearing production is boosted by the establishment of a "Ko Ro Po Klang" local station. Artificial insemination and veterinary services are introduced.

1977-82: Castor bean production decreases because of low price and insect problems (it was traditionally associated with cotton but its production seems to have almost disappeared in 1987). At the beginning, it is replaced by cotton on most of the farms.

1980: Introduction of the "Phay Thong" variety of bamboo from Prachinburi Province. Sugarapple production starts to increase also at the same time (especially on shallow soils not suitable for other fruit trees).

1981: Beef cattle production is increasing as new breeds and loans are available from the local "Ko Ro Po Klang" station (some 10 head per rearing household adopting this production). It can be interpreted as the first attempt to introduce the crop-livestock association on local farms.

1982: End of upland rice production for family consumption at Ban Phu Toey, Saiyok district (an indicator of the final disappearance of the former agrarian system!).

1982-83: Introduction of *sweet tamarind* varieties ("Si Thong", etc) from Petchabun Province. Beginning of the process of diversification of crop production by Thai farmers, as cotton production becomes technically more risky (pest problems) and economically less attractive (rise in costs of production erodes gross margins).

The start of the introduction of various perennial plantations (especially fruit tree species) can be interpreted as an indicator of the emergence of a new agrarian system (a new mode of artificialization of the agro-ecosystem).

1985-86: Introduction of market-oriented production of mango varieties for the domestic ("Kiao Saweuy") or export ("Nam Dok Mai") markets.

1988: Introduction of papaya "Khaek Dam" variety.

1988-89: Sericulture is introduced in the area by DOAE and a private company (" Mongkol Mai Thai Co.") and adopted by only two farmers at Ban Phu Toey (64 producers for the whole Saiyok District). Its potential could be limited by unfavourable climatological conditions (lack of irrigation, hot season) and decline in price paid to producers (competition with Vietnam). At a few locations, this new production leads to a limited decrease in the area devoted to maize-cotton crops.

## 3. EVOLUTION OF SOCIAL AND ECONOMIC COMPONENTS

### 3.1. Demographic pressure

1945-55: Only three households are established in the vicinity of Ban Phu Mud and Ban Phu Toey, Tha Sao sub-district. Among them are the two current village traders or "taokae" who arrived with a limited capital coming from their parents past trading activities. Early migrants during this period include Thai, Laotian, Karen and Mon families.

Until now, more *Thai families* are migrating in this area regularly, coming from many different provinces (mainly from the western and northern parts of the central plain) because of the lack of agricultural land there (as few as 1-2 rai per family member).

As soon as they settle in the area, most of them become linked to a local "taokae" who gives them access to the land, production inputs and markets. Most of the time people settle in small and scattered groups of 3-20 persons.

The estimated population density during that period is around 4 inhabitants/km².

1985-90: Arrivals of more Mon people who are escaping insecurity in Burma. They now represent some 20% of the total local population. Population density reaches 10 inhabitants/km² in 1985.

1978-91: Population is reported to have increased at a yearly rate of 5% during that period. Population density reaches 12 inhabitants/km², but 82 inhabitants/km² of farm land, in 1990.

1991: Different villages are dominated by different ethnic groups: Ban Phu Toey: Thai mainly, Ban Phu Mud: mainly Laotians, Ban Phu Ong Ka: Thai + Mon mainly.

### 3.2. Marketing conditions

1950's: Arrival of two "taokae" and first settlers in this area at Ban Phu Mud and Ban Phu Toey respectively. By using a limited amount of family capital, they immediately start to operate shops buying farm products and selling basic consumer goods.

1945-65: The Tha Sao sub-district market is the only one for selling agricultural products (cotton, maize, castor bean, chillies, pumpkin, gourd, etc) and procurement of basic consumer goods.

1965: A new market is established at Ban Phu Ong Ka.

1968: A dirt road is constructed throughout the area.

1970: Opening of the all weather road ("Thanon Asia") throughout the area.

1986-87: The Cotton Integrated Production Project introduces grading and pricing according to quality among its members (1,500 rai in 1986, but reaches only 400-500 rai in 1991).

1986-87: Emergence of cotton marketing links between "taokae" and ginners; the high demand for cotton lint gives birth to a new generation of local "taokae". They get their revolving funds directly from ginners and some of them are former cotton growers.

1988: A private company ("Mongkol Mai Thai Co.") starts buying silk cocoons.

### 3.3. Farm supplies

1945-70: Very low consumption of farm inputs, seeds produced by farmer, limited amounts of locally collected "guano" from limestone caves are used as fertilizer.

1970-75: Most of the farmer starts using more industrially manufactured inputs through local village middlemen. The range of inputs is more and more diversified.

1970: Technical assistance for beef cattle production is available from "Ko Ro Po Klang" station.

1985-86: An attempt is made by private companies at introducing contract farming in several villages. Perceived as unfair by farmers, it fails.

1986-87: The "Integrated Cotton Production Project" opens its office at Tha Sao market but has only a limited impact.

1988: A private company ("Mongkol Mai Thai Co.") starts buying silk cocoons.

### 3.4. Rural credit

1970-75: Loans from "taokae" to finance new inputs (motorized ploughing, chemical fertilizer, insecticides) for cash crop production are introduced (no interest charged, but increased price for each commercial inputs).

1972: A local branch of the Bank for Agriculture and Cooperatives (BAAC) is established at Tha Sao and starts to offer agricultural loans to farmers in 1973: 8 loans first and some 200 members in 1991. Most of them are also members of organized producer groups. Because it cannot compete with the more flexible (no collateral required) credit system operated by village traders, the BAAC branch has only a limited impact.

1977: A newly created "Land Reform Cooperative" also provides agricultural credit in Saiyok district.

1986-87: The "Integrated Cotton Production Project" is established at Tha Sao and provides credit for production inputs to its members.

1991: Global level of farmer indebtedness is at a relatively low level in comparison with other regions of the country.

### 3.5. Land tenure

1950-70: New migrants buy land from local people (10-150 Baht/rai, then 300 Baht/rai in 1967), some of them having up to several hundred rai without any land titles. The range of APS size is about 30 - 300 rai per household.

1970-80: "Po Bo Tho" 5 or 6 land titles are delivered to local farmers.

1977: Creation of a "Land reform Cooperative" at Saiyok district to enforce the 1975 national land reform amendment. A total of 100,000 rai will be affected including land belonging to 9 villages in Tha Sao sub-district.

1983: A land reform is carried out in the "military zone" north of this sub-district. Land is bought from local "taokae" and sold to small farmers (10 to 15 rai per household) at 3,500 Baht/rai to be paid over 10 years. "So Po Ko 401" land titles are delivered. Land can be legally cultivated for small-scale family farming, a ceiling of a maximum of 50 rai per farming household is officially established.

Land sales continue after the land reform, some small landowners sell their plots in Tha Sao sub-district (up to Baht 100,000 per rai) to buy larger plots of cheaper land upstream in the valley and migrate northward in Thongphaphum district (for some Baht 5,000 per rai).

1980-90: Arrival of more Mon illegal migrants escaping insecurity in Burma. some of them rent land from Thai farmers (200 Baht/rai/year).

1986-90: Price of land increases sharply (some 20% per year) to reach 100,000 to 150,000 Baht/rai in 1991. Most of the buyers are *absentee landlords*. Often, the former owner stays on the land and work to maintain it. Tourism related activities are introduced in the area (7-8 resorts in Saiyok district) competing with agriculture for land and pushing labour prices up (to Baht 60/ day).

### 3.6. Labour market

1970-75: Wage labour starts to be used in agricultural production.

1985-90: Increased migration of Mon people provide more wage earning labour for farm works (60 Baht/day, sometimes as low as 6,000 Baht/year). Gathering of forest products for sale (bamboo shoots providing up to 100 Baht per day) tends to push up daily wages for farm labour.

1987: Emergence of tourism-related employment in the construction and service sectors (only 50% of the total number are reported to be farm households at B. Phu Toey).

### 3.7. Social infrastructures

1960: Wat Tha Sao is the single Buddhist temple in the area.

1968: A dirt road is constructed through the area.

1970: Opening of Ban Phu Toey primary school.

1970: Completion of the all weather road Kanjanaburi - Thongphaphum which is passing through the area and increases the marketing opportunities.

1980: Construction of Ban Phu Mud temple.

1981: Construction of Ban Phu Toey temple.

1977-82: Electrification of the local villages.

1990: Opening of Ban Phu Mud primary school.

### 3.8. State intervention

1967: The counter insurgency military agency "Ko Ro Po Klang" establishes a station to provide community services and focus on supporting beef cattle production by providing artificial insemination, new breeds and veterinary care.

1978: An official campaign for the promotion of cotton production for import substitution is launched and followed by the introduction of new varieties and production techniques by DOAE.

Creation of Saiyok National Park.

1983: Land reform in the northern part of the sub-district (affecting 50% of the area); new clearing is not legally feasible any more.

1986-87: The "Integrated Cotton Production Project" Office is established at Tambon Tha Sao and begins to offer technical, commercial and financial assistance to local cotton growers. It is a cooperative project between the concerned public agencies (DOA, DOAE) and some private companies (Yong Suwat Co.). The project covers some 1,500 rai of cotton plantations the first year, but only 400-500 are left in 1991 as most of the growers find the project (that introduced grading of seed-cotton at harvest among its members) less attractive than the "taokae" seasonal credit and marketing channel.

1988: Establishment of a technical centre for the promotion of sericulture in Tambon Tha Sao.

1987-89: An Integrated Pest Control (IPC) Project is carried out in Saiyok District to improve methods of pest control management. 4-5 growers participate in each village, the project increases the awareness about the problem but the proposed techniques do not disseminate among the local farmers.

### 3.9. Farmer income, productivity and differentiation

1990: The average annual budget of a local farm household is made of a gross product evaluated at some Baht 50,000. Variable costs and other farm expenses amount for some Baht 20,000 and the farmer annual income left is about Baht 30,000.

1990-91: Approximately 5% farmers are landless among the Thai families. Most of the APS cultivate some 25-30 rai, an official maximum is 50 rai, but influential "taokae" can control several hundred rai. The range of holding size is from rai 1 to 900.

The Mon minority does not have legal rights on the land and are either wage earners or tenant farmers.

The land accumulation threshold under which a local APS cannot survive is estimated by informants at around 10-15 rai.

# APPENDIX 4 (continued)

## ANALYSIS OF RECENT TRANSFORMATION OF AGRICULTURAL PRODUCTION PROCESSES

DATE OF INTERVIEW

SURVEYOR'S NAME =

INFORMANT'S NAME =

ADDRESS =

| DATE | NATURE OF THE TRANSFORMATION | CAUSES OF THE TRANSFORMATION | ITS ORIGIN | ITS EXTENT | ITS CONSEQUENCES |
|---|---|---|---|---|---|
| | | | | | |

# APPENDIX 4 (continued)

## CHARACTERIZATION OF LOCAL AGRARIAN SYSTEM

LOCATION..... INFORMANT..... DATE.....

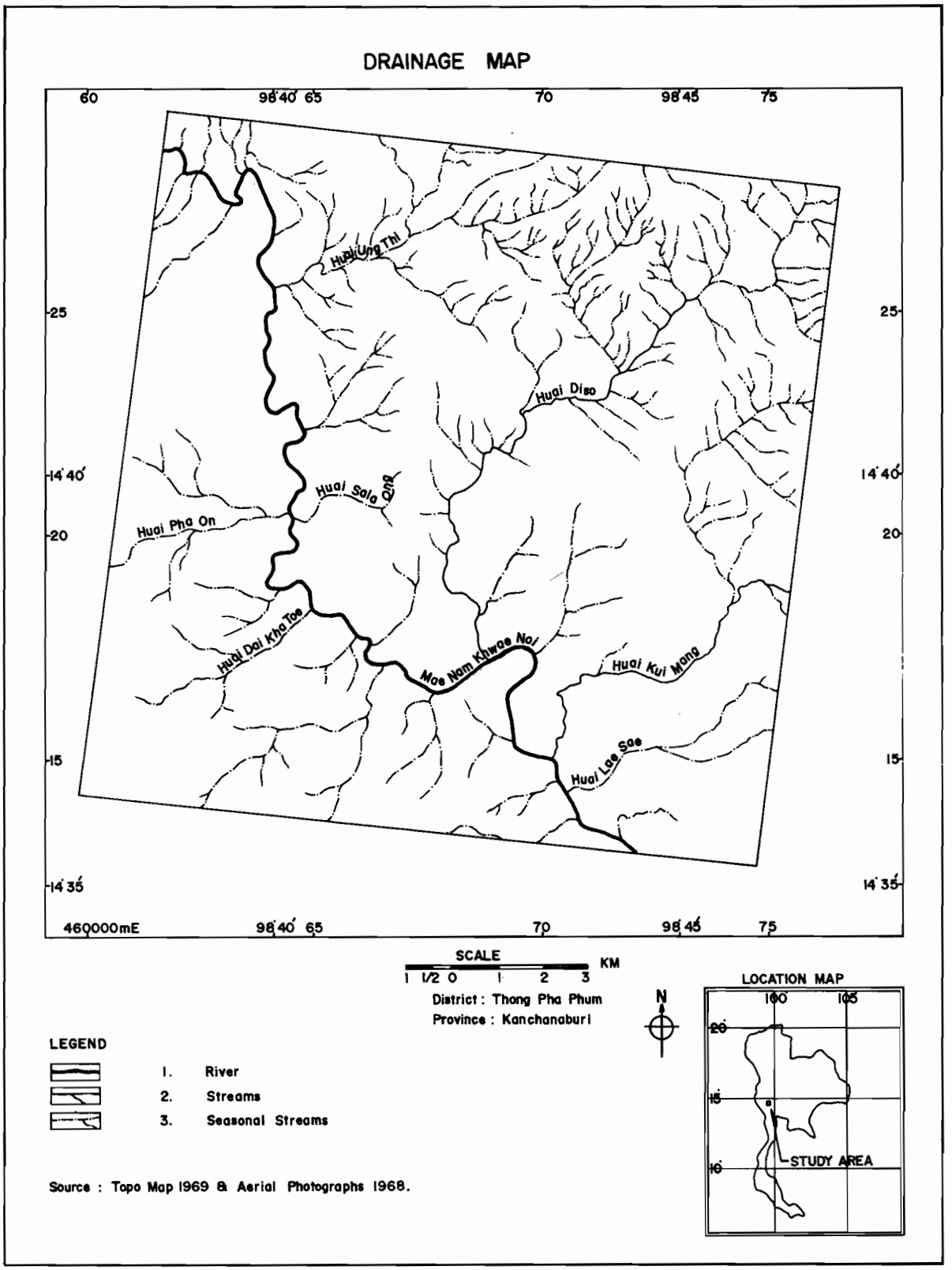
| | |
|---|---|
| A.S. VARIABLE COMPONENTS | |
| ECOLOGICAL EVENTS | |
| MEANS OF PRODUCTION | |
| TECHNIQUES APPLIED | |
| PRODUCTIONS | |
| DEMOGRAPHIC PRESSURE | |
| MARKETING CONDITIONS | |
| FARM SUPPLIES (INPUTS, EQUIPMENT) | |
| RURAL CREDIT PATTERNS | |
| LAND TENURE PATTERNS | |
| LABOUR MARKET | |
| STATE INTERVENTION | |
| FARMER INCOME, PRODUCTIVITY | |
| FARM DIFFERENTIATION | |

# APPENDIX 5

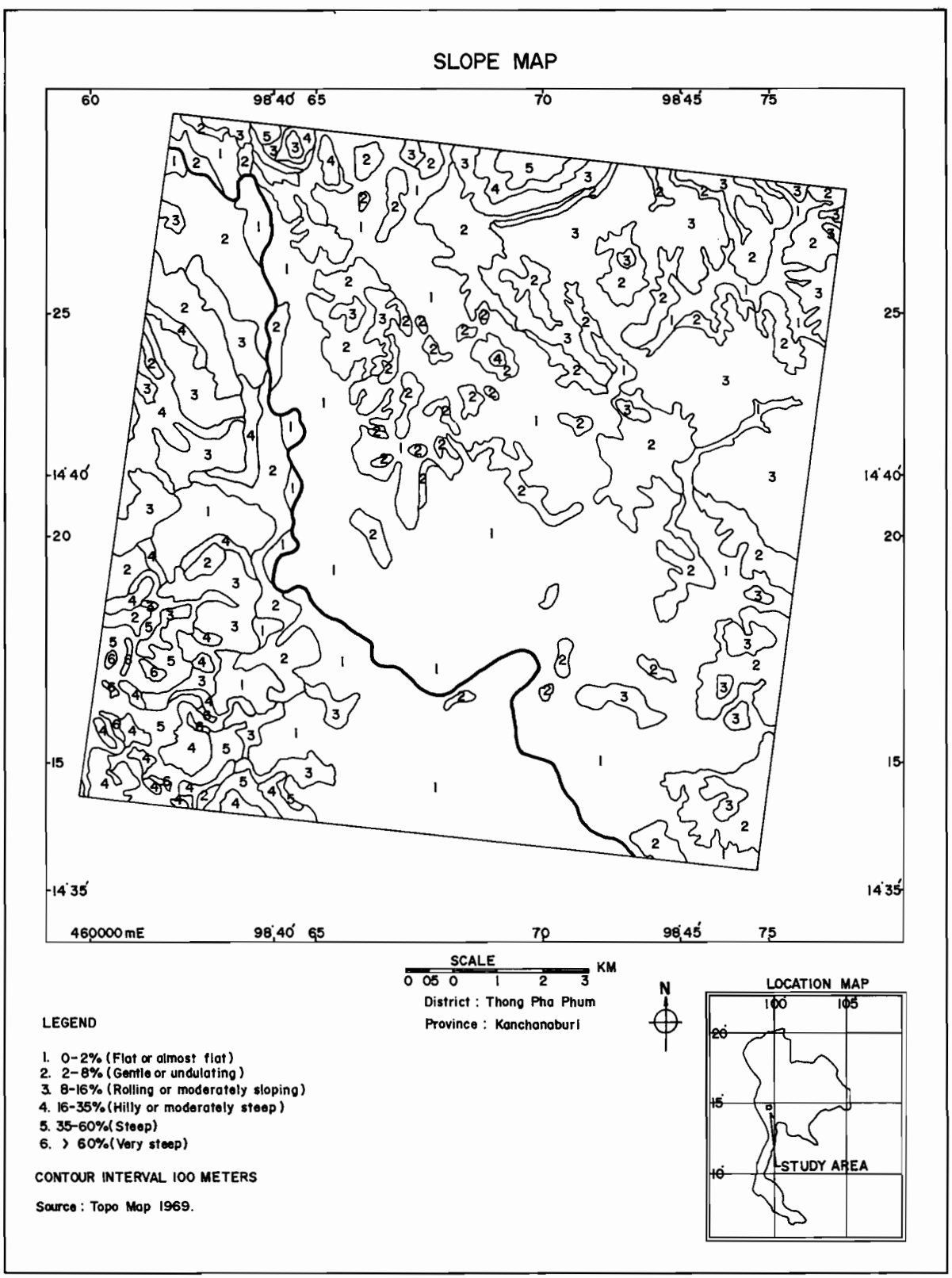
## CHRONOLOGY OF COTTON VARIETIES INTRODUCTIONS IN THA SAO SUB-DISTRICT, SAIYOK DISTRICT, KANJANABURI PROVINCE

| DATE | VARIETY NAME | ORIGIN | CHARACTER CAUSING ITS INTRODUCTION | FARMER ADOPTION |
|---|---|---|---|---|
| 1964 | STONEVILLE 213 | DOAE | productivity<br>lint quality | unknown |
| 1966 | REBA B 50 | DOAE | hairiness | extensive |
| 1973 | REBA BTK 12 | DOAE | hairiness, GOT | extensive |
| 1978 | TAK FAH 1 | DOAE | yield potential | extensive |
| 1980 | SRISAMRONG 2<br>= G 115 - 7 | DOAE | tolerance leaf roll | extensive |
| 1981-82 | SRISAMRONG 3<br>=DI5(mut.DPSL) | DOAE | yield potential | limited |
| 1986 | NAKHON SAWAN 1 | DOAE | | limited |
| 1987 | RATCHADA 1/2 | Kasetsart | tolerance to pest | no |
| 1990 | SRISAMRONG 60<br>= AG 18 | DOAE | less shedding/SR2 | extensive |
| 1990 | "SIGMA<br>(G.barbadense) | Ginner | lint quality | rejected |
| 1992 | Okra type var | DOA | improv. pest cont. | n.a. |

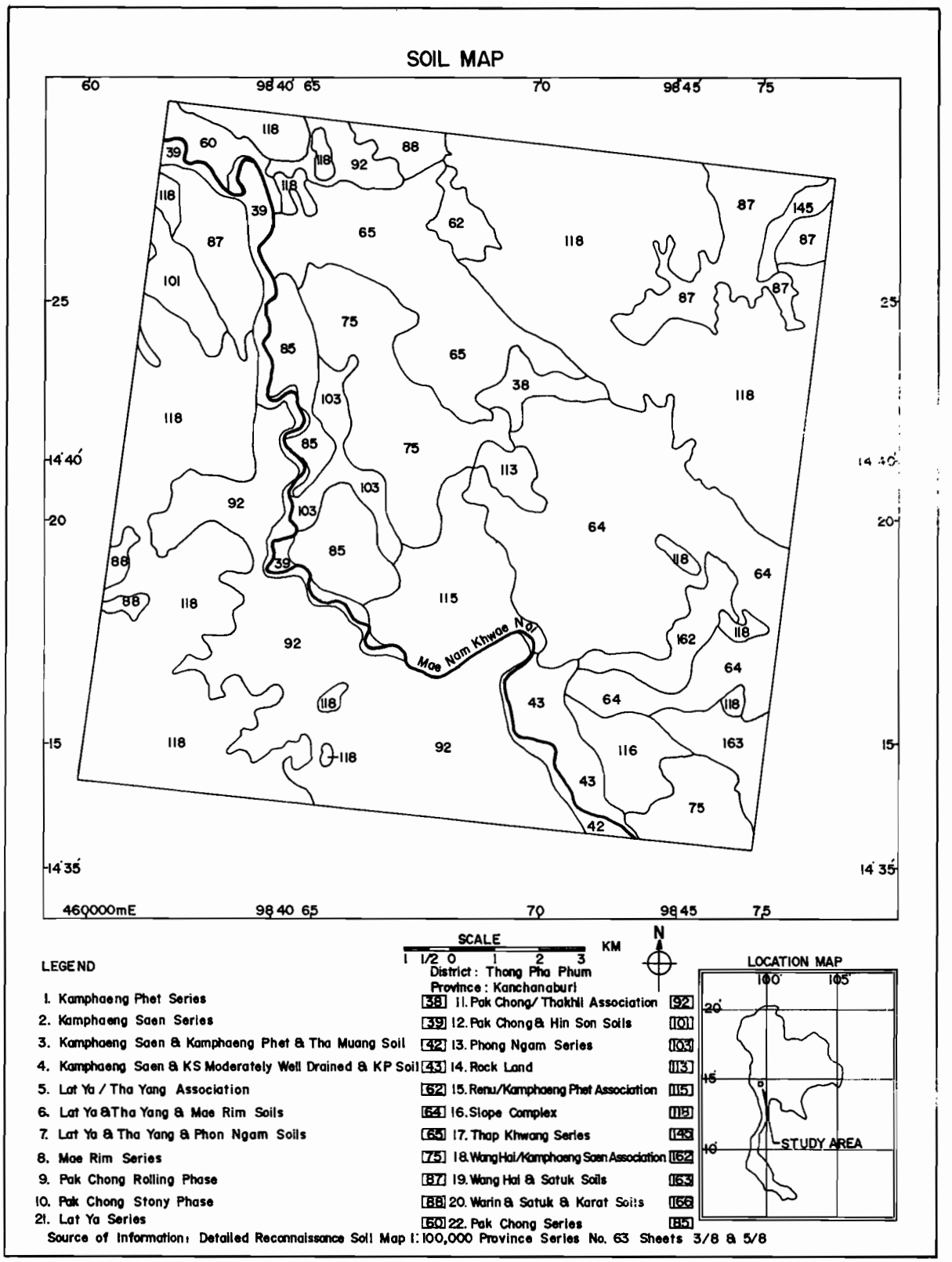
# APPENDIX 6



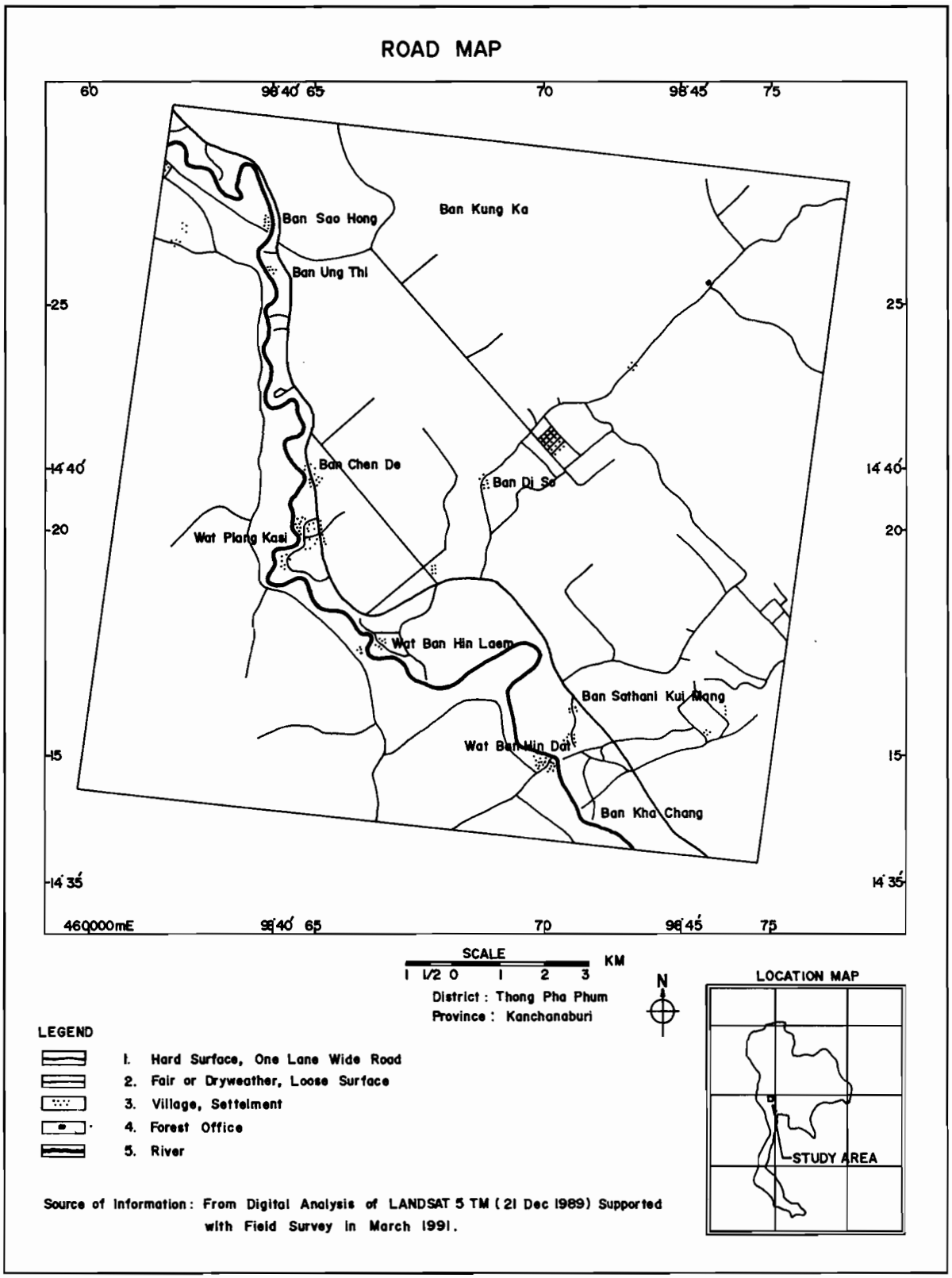

**Map 11.** Soil map of the southern part of Thongphaphum district, Kanjanaburi province




**Map 12.** Slope map of the southern part of Thongphaphum district, Kanjanaburi province




**Map 13.** Drainage system in the southern part of Thongphaphum district, Kanjanaburi province




**Map 14.** Road map of the southern part of Thongphaphum district, Kanjanaburi province

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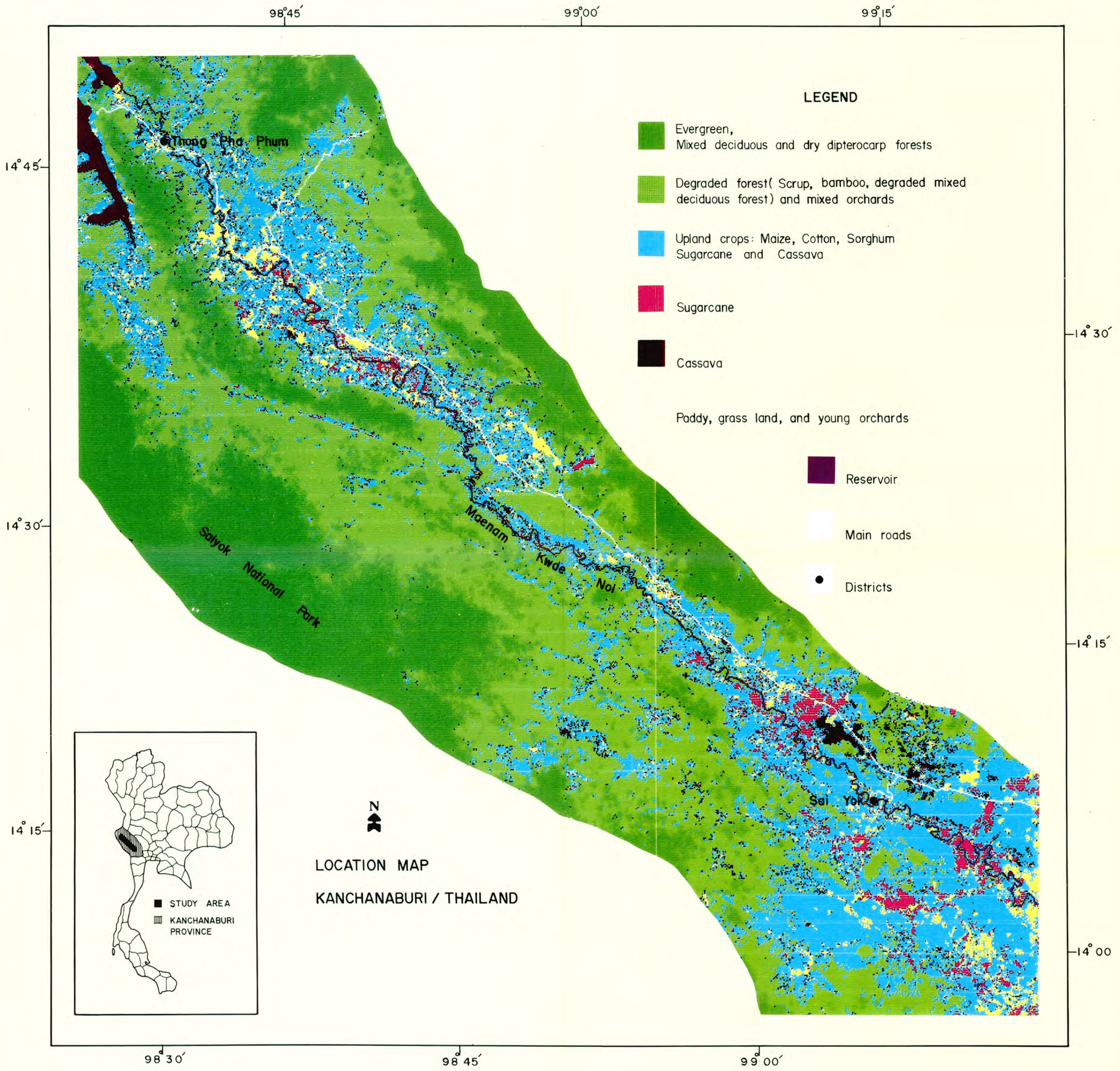
# WESTERN THAILAND

# LAND USE MAP OF MAE NAM KHWAE NOI VALLEY

## SCALE 1 : 250,000

SRISAANG KAOJARERN INRDM/AIT
GUY TREBUIL DORAS / CIRAD–CA




DIGITAL IMAGE CLASSIFICATION OF LANDSAT–TM
SCENE 130–050 TAKEN ON 21 DEC 1989

Data Processing at Remote Sensing Laboratory of
Interdisciplinary Natural Resources Development
and Management Program (INRDM).
Published with Cooperation of Ministry of Foreign Affairs of France

**Map 15.** Land use map of Mae Nam Kwai Noi valley, Western Thailand