Land Use Analysis in Thailand Through GIS

Supan Karnchanasutham*

Abstract

The Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives, is the principal agency responsible for agricultural statistics. Activities of remote sensing for land use in Thailand were initiated in 1975, in the field of Area Sampling Frame (ASF) to estimate the area, yield, production, related information for "major rice" (rainy season rice) along with ground truth data for remote sensing research *i.e.* training samples for image processing. In 1984, OAE initiated the forecasting of the planted area and crop production and related information about economic crops, using satellite data both at optical and microwave levels.

Applications of GIS were initiated in 1990, with a view to mapping the area suitable for the planting of economic crops in Thailand on a scale of 1:250,000 using Remote Sensing and Geographic Information Systems (GIS). The area was derived from the overlay of data of 312 soil series and thirty nine years of average rainfall as well as irrigated boundaries for 4 suitability classes, namely, highly suitable, moderately suitable, marginally suitable and unsuitable, in the main 25 watershed areas of Thailand. This map will enable to delineate forest conservation areas from forest legal boundary map, built-up areas and others from land use map. All these will overlay administrative boundaries such as provincial boundaries, district and sub-district boundaries, along with main road networks. The results will provide suitability maps for the area planted with crops of economic importance in Thailand along with the determination of high suitability, moderate suitability, marginal suitability, and unsuitability classes, existing forest area, deforestation area, water and built-up areas. The area of each class should conform to the administrative boundaries of the 76 provinces in Thailand (total area of 51.20 million hectares).

Land use analysis

Thailand is considered to be an agricultural country. The country's economy relies heavily on agricultural products. Therefore, timely and accurate statistics on annual agricultural production are needed. Besides conventional agricultural surveys from which planted area and production are estimated, remote sensing and crop forecasting are also carried out every month before the release of survey results. The Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives, is the principal agency responsible for undertaking agricultural statistics activities. Several approaches are employed and attempted as follows.

1 Area sampling frame (ASF)

The concept of ASF is to divide the total area to be surveyed into N small blocks without any overlap or omission. ASF construction in Thailand which has been used to estimate paddy requires 3 strata that were originally constructed. Stratum 10 was sampled as representative of paddy land, stratum 20 as representative of upland area and stratum 23 as representative of deforested land. The topographic maps, on scales of 1:50,000 were used to subdivide the strata into Primary Sampling Units (PSUs) and Secondary Sampling Units (SSUs). Aerial photographs were used for selected SSUs to further subdivide SSUs into Sampling Units (SUs). Often

* Office of Agricultural Economics, Chatuchak, Bangkok 109000, Thailand

three or four 1:15,000 scale photos were needed to cover the SSU. A total of 1:5,000 scale photos were needed to complete the ASF sample. Once the SSU was subdivided into SUs, the sampling units that are selected for each stratum in the frame called Segment, a photograph on a scale of 1:5,000 was used for field work. The boundaries were marked on the photos and these became a part of the interviewing materials as well as part of the ASF frame. Interviewers collect data from fields and farms inside segments. The size of a segment is about 200 rais (80 acres).

In this technique, however, segment boundaries on aerial photos are difficult to observe or are even inexistent in the field if the land changed, because aerial photos taken from the Royal Thai Survey are out of date and require a large number of experienced staff. Thus, at present, this approach is not used.

2 List frame sampling (LFS)

In the crop surveys, mostly stratified two-stage sampling is employed. For each crop, all the villages which reported having the crop under survey were stratified into 3-4 strata according to the reported crop acreages. The sample villages were randomly drawn from each stratum. About 10-20 crop growers in each sample village were selected randomly for interviews. The estimation of the total and mean of characteristics under study was obtained from this sample.

3 Crop forecasting

Thailand is an agricultural exporting country for which the exporting policy has to be formulated, if possible, well in advance before the actual harvest of each crop. Therefore, crop forecasting is an alternative to obtain this information at the early stage.

Two different techniques are applied for crop forecasting.

1) Econometric model

In general, in this approach two models are used: the acreage model and yield model. Presently, 12 crops are included in the monthly forecast for each province. For the mid-year outlook, 65 commodities are included in the national aggregate model. As for the acreage model, the planted area of concerned crops is specified as a function of the previous year price, lagged price of competing crop, and own lagged area. For rice, the amount and distribution of rainfall during the growing period are also considered as an important variable in the planted area forecast model. For the yield model in an early forecast, the average of historic yield of 3-5 years, excluding abnormal years due to drought, flood, diseases and pests is used. In later months, rainfall and inputs such as fertilizer application are used in the forecasting yield model. This production forecast is obtained by multiplying the data obtained in the acreage model by those obtained in the yield model.

2) Yield component model

For certain crops such as rice, corn, and soybeans, a yield component model is used in the forecasting of yield. In this approach, fields and plots of the concerned crop are randomly selected and the measurement of certain characteristics which appear to be related to the final yield of the crop is recorded during the growing period until harvest. These measurements are used as independent variables while the yield obtained from the crop cutting plot is used as dependent variable in the model. The regression models are developed and the coefficients are estimated separately for each stage of crop growth. This model is referred to as a yield component model because the yield forecast is obtained from two separate yield component models. For example, corn yield forecast is derived from the multiplication of number of ears harvested calculated in the forecasting model by the grain weight per ear calculated in the forecasting model. It is also referred to as the objective yield survey since it involves a survey in which objective measurement of yield-related characteristics of the crop in the sample plots is taken. This technique is very expensive and time-consuming and requires a large number of experienced staff. Thus, at present, this approach is adopted on a limited scale.

4 Remote sensing technique

Thailand has an experience of more than ten years in utilizing remote sensing technique for the classification and estimation of crop acreage. However, for most of the crops under scale ever conducted, the estimation of dry season paddy was carried out by OAE. In general, the results of this technique compared with other estimations were satisfactory. Nevertheless, several problems remain to be solved. The first and major problem is the cloud cover during the growing season when the information is needed. To obtain the estimation of the whole area, random sampling technique may be utilized. This technique, however, can give only a crop statistic or figure and not a geographic type of information. The other problem is the lack of equipment which is very expensive. Consequently, analysis of remotely sensed data cannot be accomplished soon enough for use in the early warning system. Furthermore, the image and computer-compatible tape (CCT) are very expensive to study temporal changes or to monitor crop production since many different images recorded on different dates have to be used.

5 Land use

Land use or land utilization in Thailand is classified into regions and provinces by the integration of every approach cited above and divided into 10 classes : forest land, housing area, paddy land, field crops, fruit trees, vegetables, grassland, idle land, other land and unclassified land. The total for each region or province is derived from the data collected by the Royal Thai Survey Department, while forest land is derived from LANDSAT satellite data acquired by the Royal Forest Department.

In 1995, land utilization of Thailand was as follows.

1) Forest land: 13,148,505 hectares (26%)
2) Farm land: 21,196,571 hectares (41%)
   - Paddy land: 10,926,840 hectare (51%)
   - Field crops: 5,121,790 hectares (24%)
   - Fruit trees and tree crops: 3,571,039 hectares (17%)
   - Vegetables and flowers: 153,269 hectares (1%)
   - Grassland: 121,750 hectares (1%)
   - Idle land: 515,434 hectares (2%)
   - Other land: 223,459 hectares (1%)
   - Housing area: 562,989 hectares (3%)
3) Unclassified land: 16,966,424 hectares (33%)

Geographic information systems (GIS)

Rice is the most important economic crop in terms of both domestic consumption and export. Thailand is ranking first among the world rice exporters with an income of hundred million baht. However, rice yield is still as low as 2,444 kg / hectare. Especially when compared with the rice yield in various countries, Thailand belongs to the group with the lowest yield. Yield is even lower than in Laos, Myanmar, Indonesia and China. Rice production has caused a rapid decrease of the forest area. During the 1961-1993 period, the annual decreasing rate of the forest area was 0.44 million hectares. In 1988, the forest concessions were canceled for the whole country. However, during the 1989-1993 period, the forest was cleared over an area of 0.99 million hectares corresponding to an average annual decreasing rate of 0.24 million hectares. In 1993 the existing forest covered therefore only 13.36 million hectares or 26% of the whole country area.

Presently, it is necessary to improve the yield because the rice area can not be further expanded into the forest. The Department of Agriculture has been conducting relevant studies to improve rice yield such as selection of rice varieties, fertility enhancement, pest control, etc. However, the yield has still not substantially

increased due to the unsuitability of the area for rice cultivation, and to physical or economic factors. The use of Geographic Information Systems (GIS), the integration between spatial and attribute data, is therefore necessary for the allocation of suitable areas for rice cultivation, which will eventually lead to agro-economic zoning in the future. The objectives are to produce maps of rice suitability area with respect to the physical potential of the area and these maps will lead to agro-economic zoning in the future.

1 Methodology

1) Data conversion

Data from the existing maps are converted into digital format by compiling such maps from relevant agencies. If some thematic maps are not available or obsolete, up-to-date maps will be produced by the Office of Agricultural Economics (OAE). The converted relevant maps include:

(1) Watershed base map obtained from the National Committee on Hydrology, National Research Council of Thailand (NRCT). Watershed area refers to the area into which rainfall is drained. Watershed classification and terminology are undertaken based on the respective main streams except in coastal areas and the area near the Cambodia border where main streams are absent. Watershed classification and terminology of such watersheds are therefore based on geographical locations such as east coast, western coast, southeast, and southwest.

Watershed area allocation is made by defining the derivation from a topographic map of 1:50,000. Thailand has a total of 25 main watersheds, each of which includes 4 levels of streams: a) main stream b) substream c) perennial gully and d) seasonal gully.

(2) Provincial soil series maps, on a scale of 1:100,000 or 1:50,000 obtained from the Land Development Department (LDD), which include 312 soil series for the whole country.

(3) Irrigation map obtained from the Royal Irrigation Department (RID) which includes both irrigation and non-irrigation zones.

(4) Average rainfall maps of 39 years from 1951 to 1989 obtained from the Department of Meteorology in which the average rainfall is classified into 10 levels as follows:

- Rainfall of 1,000-1,100 mm.
- Rainfall of 1,100-1,200 mm.
- Rainfall of 1,200-1,400 mm.
- Rainfall of 1,400-1,600 mm.
- Rainfall of 1,600-2,000 mm.
- Rainfall of 2,000-2,400 mm.
- Rainfall of 2,400-2,800 mm.
- Rainfall of 2,800-3,200 mm.
- Rainfall of 3,200-4,400 mm.
- Rainfall of 4,400-5,000 mm.

(5) Forest legal boundary maps, on a scale of 1:250,000 obtained from the Royal Forestry Department, which include both inland forest and mangrove boundaries. Inland forest is categorized into 2 zones:

- Economic forest boundary
- Conservation forest boundary

Mangrove land use is categorized into the following zones:

- Conservation zone
- Economic zone with 2 categories namely:
- Economic zone A
- Economic zone B

(6) Road network maps, on scales of 1:1,000,000 and 1:250,000 obtained from the Department of Highway and the Royal Thai Survey Department, include:

a) Roads:
- Highways with number
- Provincial roads with number
- Roads under the Office of Accelerated Rural Development
- Dirt roads, etc.

b) Railway

c) Roads along irrigation canal

(7) Administrative boundary maps, on a scale of 1:250,000 obtained from the National Statistical Office, include:
-Province boundary
-District boundary
-Sub-district boundary
-Location of province, district and sub-district offices

The information obtained in 1997 involved 76 provinces, 812 districts, 7,409 sub-districts and 68,700 villages.

(8) Present land use map, on a scale of 1:250,000 obtained from 1994 satellite image interpretation by OAE, includes 30 categories.

2) Data analysis

Data analysis was carried out by using INTERGRAPH GIS and ORACLE software under WINDOW NT 4.0 operating system with the following steps:

(1) Project construction and database establishment to integrate spatial information obtained from digital map and attribute information (so-called topology).

(2) Data analysis was undertaken by overlaying multi-layer spatial information. The data are as follows:

a) Soil series were categorized, in accordance with suitability conditions, into 4 levels namely:
- High suitability for rice cultivation
- Moderate suitability for rice cultivation
- Marginal suitability for rice cultivation
- Unsuitability for rice cultivation

b) Rainfall maps were categorized into 4 levels namely:
- Rainfall of 1,100-1,400 mm. with high suitability for rice cultivation.
- Rainfall of 1,000-1,100 mm. and 1,400-1,600 mm. with moderate suitability for rice cultivation.
- Rainfall of 1,600-2,000 mm. with marginal suitability for rice cultivation.
- Rainfall of 2,000-5,000 mm. with unsuitability for rice cultivation.

c) The rainfall map was overlaid onto the irrigation zone and soil series maps to obtain the map of suitability area for rice cultivation as follows:

d) Map of suitability area for rice cultivation was then overlaid onto the present land use map and forest legal boundary map to remove undesirable areas including conservation forest, water body, and others.

e) Calculation of the suitability area for rice cultivation in each province and district covers the whole country.

2 Results

The results consist of 2 types of information : map and level of suitability area for rice cultivation in each watershed classified into 8 levels, as follows:
- High suitability area
- Moderate suitability area
- Marginal suitability area
- Unsuitability area

- Existing forest area
- Degraded forest area
- Water body
- Residential area, city, and other built up areas.

The details are as follows:

The northeastern region, with 19 provinces and a total area of approximately 16.96 million hectares, comprises 0.64 million hectares with a high suitability for rice cultivation while 7.2 and 1.92 million hectares with medium and low suitability, respectively. The total suitability area for rice cultivation is therefore 9.76 million hectares. The provinces with a high suitability area for rice cultivation are Roi Et and Nakhon Ratchasima.

The central plain, with 19 provinces and a total area of approximately 6.88 million hectares, comprises 1.12 million hectares with a high suitability for rice cultivation while 1.44 and 0.64 million hectares with moderate and marginal suitability, respectively. The total suitability area for rice cultivation is therefore 3.2 million hectares. Chacherngsao is a province with a high suitability area for rice cultivation.

The northern region, with 17 provinces and a total area of 16.96 million hectares, comprises 1.6 million hectares with a high suitability for rice cultivation while 2.08 and 1.12 million hectares with moderate and marginal suitability, respectively. The total suitability area for rice cultivation is therefore 4.8 million hectares. The provinces with a high suitability area for rice cultivation are Nakhon Sawan, Phichit, Phetchaboon, and Phitsanulok, respectively.

The southern region, with 14 provinces and a total coverage of 7.04 million hectares, comprises 0.16 million hectares with a high suitability for rice cultivation while 0.32 and 0.48 million hectares with medium and low suitability, respectively. The total suitability area for rice cultivation is therefore 0.96 million hectares. The provinces with a high suitability area for rice cultivation are Nakhon Si Thammarat and Phattalung.

In summary, in the whole country, among the 76 provinces with approximately 51.20 million hectares, 4.48 million hectares show a high suitability for rice cultivation, 11.68 million hectares show a moderate suitability, and 3.68 million hectares show a marginal suitability. The total suitability area for rice cultivation in the whole country is therefore 19.84 million hectares. The ten provinces with a high suitability area for rice cultivation are 1) Nakhon Sawan, 2) Phichit, 3) Phetchaboon, 4) Roi Et, 5) Lop Buri, 6) Phitsanulok, 7) Suphan Buri, 8) Nakhon Ratchasima, 9) Ratchaburi, 10) Chacherngsao.

References

1) Pongsrihadulchai, A. (1996): Agricultural Statistics in Thailand. Office of Agricultural Economics, Ministry of Agriculture and Co-operative, Bangkok, Thailand.

2) Pongsrihadulchai, A., Karnchanasutham, S. and Rodprom, C. (1996): Rice Monitoring Using ERS-1 SAR Data in Kanchanaburi Province Thailand. ERS-1 Project (ALA/91/28), Bangkok, Thailand.

3) Center for Agricultural Information (1998): Agricultural Statistics of Thailand Crop Year 1996/1997. Office of Agricultural Economics, Bangkok, Thailand.

4) Karnchanasutham, S. (1998): Using Remote Sensing and Geographic Information System for Agricultural Zoning. Dissertation, Asian Institute of Technology, Bangkok, Thailand.