CHAPTER II

LAND USE CLASSIFICATION

Remote Sensing Definition

Remote sensing can be defined as the method and techniques used to observe about an earth surface or phenomenon without being in contact with it (Howard, 1991, Barrett and Curtis, 1992, Buiten *et al.*, 1993, and Lillesand and Kiefer, 1994).

Remote Sensing Theory

Remotely sensed data include information recorded using balloon, aircraft and satellite, among these, satellite data is important information for earth observation. This observation are photographic technology and telecommunication which useful for data collection and record at signal receiver operational center more closely satellite real-time.

Generally, there are two basics components of remote sensing (Figure 2.1).

1 data acquisition

2 data analysis

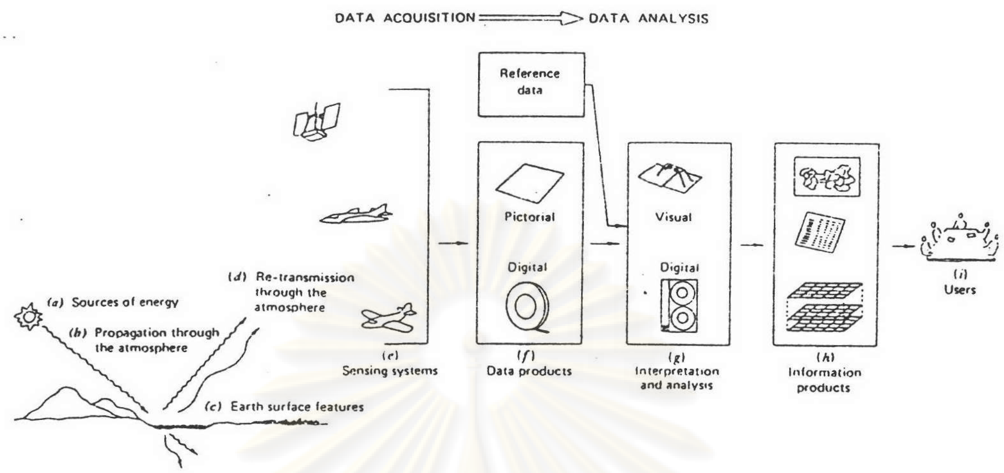


Figure 2.1 Electromagnetic remote sensing of earth resources (Lillesand and Kiefer, 1994).

Data Acquisition

Data acquisition consist of energy source, sensing system, energy interactions in the atmosphere, energy interaction with the earth surfaces, and spectral signature.

1. Energy source

The most important medium for environmental remote sensing is electromagnetic radiation. Information transfer from an object to detector is accomplished by electromagnetic radiation. Forms of electromagnetic energy consist of cosmic rays, gamma rays, x-rays, ultraviolet (UV), visible light, near infrared, mid infrared, thermal infrared, microwave and radiowave. Remote sensing classifies electromagnetic energy on the bases of wavelength location within the electromagnetic spectrum (Figure 2.2). Most sensing system operate in one or several of the visible, infrared or microwave portion of the spectrum. The most important source of electromagnetic radiation in these ranges is the sun.

The information to an object conveyed to us by light is of two main kinds. First, it relate to the object's morphology from the way and it is illustrated and shadowed by its relationship to the source of the light. This give information on size, shape and texture. The second kind of information is due to the way light is reflected and absorbed by the object. This shows up as the object's brightness and color. We use sensors to record variations in the way earth surface features reflect and emit electromagnetic energy.

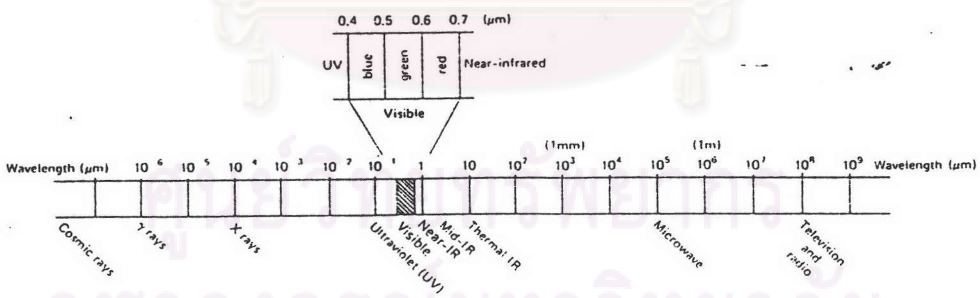


Figure 2.2 The electromagnetic spectrum (Lillesand and Kiefer, 1994).

2. Sensing system

Sensing systems are instruments capable of measuring electromagnetic radiation. They can BA categorized as passive and active sensors.

1. Passive sensors do not have their own source of radiation. They sense radiation from a natural origin, usually reflected sunlight or the energy emitted by an earth surface. Example are the multispectrum scanner.
2. Active sensor have a built-in source of radiation which is the detection of a signal that is artificially produced. Example are the radar.

Because using sun radiation makes sensor system coming less power consumption, passive sensors are the majority of remote sensing.

3. Energy interactions in the atmosphere

Electromagnetic energy interacts with the atmosphere in its passage from the sun to the earth surface and from there to the remote sensor. This process is important to remote sensing for two reasons. First, information carried by electromagnetic energy reflected/emitted by the earth surface is modified in traversing the atmosphere. This interaction generates geometric and radiometric distortion. The distortion can BA corrected by computer processing. Second, the interaction of electromagnetic energy with the atmosphere can BA used to obtain valuable information about the atmosphere itself.

4. Energy interactions with earth surface features

When electromagnetic energy is incident on earth surface feature, three fundamental energy interactions with the feature are possible (Lillesand and Kiefer, 1994). These are reflected, absorbed and transmitted. The proportions of energy reflected, absorbed and transmitted will vary for different earth features, depending on their material type and condition. Object reflects, absorbs and transmits the energy differently at different wave length. Earth surface reflection is the most important property in remote sensing system. Characteristic of earth surface reflection calls spectral reflectance. The reflection of the energy is detected by the sensor to produce an image of the area sensed. These images enable the interpreter to obtain useful information about the object of interest.

5. Spectral signature

Spectral signature is spectral reflectance pattern of features that can measure by remote sensors. The basic types of earth features spectral reflectance curve show in Figure 2.3 . Spectral signature of earth surface features are useful for image interpretation. The different of resources spectral signature provide the separation of feature in satellite image. These characteristics can classify by computer technique.

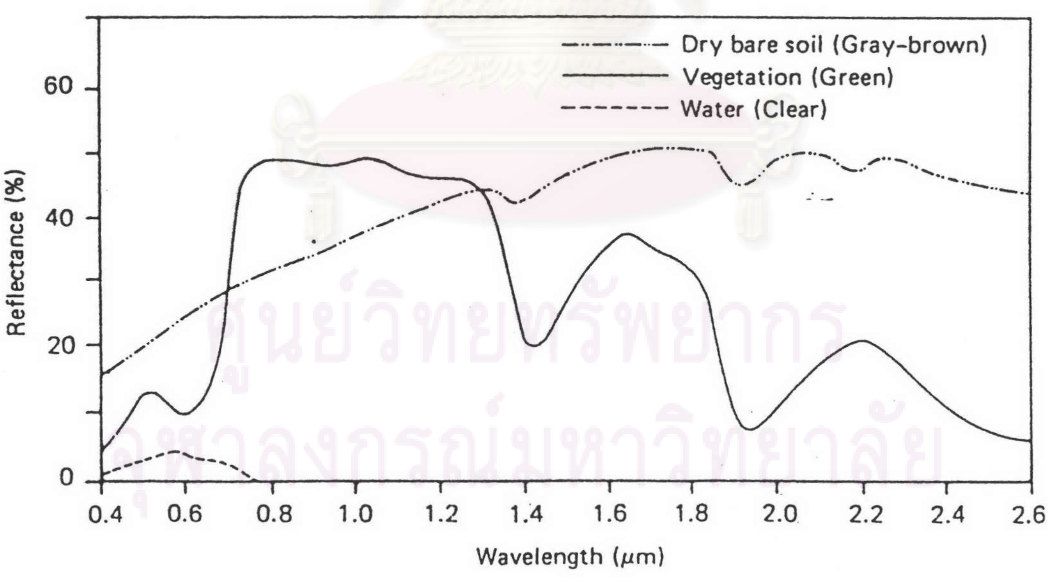


Figure 2.3 Typical spectral reflectance for earth feature (vegetation, soil and water) (Lillesand and Kiefer, 1994).

Data Analysis

Digital image from satellite data become widely available for land remote sensing applications. Because the low of cost, availability of efficient computer hardware and software and the sources of digital image data are many and varied. The digital image data can BA processed and analyzed using the digital image processing technique. Digital image processing involves the manipulation and interpretation of digital image with the aid of computer (Molenaar *et al.*, 1993).

Digital image processing compose of image rectification and restoration, image enhancement, image classification and classification accuracy assessment.

1. Image rectification and restoration

Image rectification and restoration aim to correct distorted image data to create a more faithful representation of the original scene (Lillesand and Kiefer, 1994). This process involves geometric correction, radiometric correction and noise removal in the raw image data. Geometric correction is the rectification of geometric distortion from earth surface curve. Radiometric correction and noise removal are the rectification of radiation noise and distortion from energy interactions in the atmosphere (Dowroeng, 1990). These distortion and noise can be corrected by computer processing for better image quality.

2. Image enhancement

The objective of image enhancement is modify the image to make them more suited to the visual interpretation. There are no simple rules for producing the best image for each application. Image enhancement techniques can BA categorized as contrast manipulation, spatial feature manipulation, or multi-image manipulation (Harrison and Jupp, 1990).

3. Image classification

The objective of image classification is to replace visual analysis of the image data with automatic techniques for quantitatively identification of features in a scene (Lillesand and Kiefer, 1994). The choice of these approaches depend on the nature of the data being analyzed and the intended application. There are three basic classification approaches to classify an image, namely, unsupervised classification, supervised classification and semi-supervised classification.

1. The unsupervised procedure, image data are automatically classified by aggregating them into the natural spectral grouping or clusters present in the scene (Harrison and Jupp, 1990).

2. The supervised classification approach, representative sample site of known cover type are selected to compile a numerical interpretation key that describes the spectral attributes for each feature type of interest. Each pixel in the data set is then compared statistically to each category in the interpretation key.

3. The semi-supervised classification is the combination between unsupervised and supervised classification. First, representative some sample site are selected like supervised classification. Then image data automatically classified by grouping them into representative sample site.

4. Classification accuracy assessment

The most common way to assess the accuracy of classification image is by comparing the classified image area that has Been correctly classified with reference data or ground truth data (Janssen and van de Wel, 1994). This accuracy is usually derived from a tally of the correctness of the classification generated by sampling the classified data and expressed in the form of an error matrix or confusion matrix or contingency table (Story and Congalton, 1986).

Remote Sensing for Land Use Application

Impacts of coastal tourism indicators were uncontrolled urbanization (Smith, 1994, Sudara, 1989, and Wong, 1991), marine water pollution and solid wastes (Sudara, 1989), coastal erosion (Suphapodock and Dobias, 1988), and environmental degradation (Smith, 1992 and Miller, 1993). The purpose of this study was the detection of land use change from tourism urbanization for evaluate the further impacts that effect from land use change. Therefore, this study require land use information. The required information were the data in the recent year and the past which can provide by satellite data.

Satellite remote sensing is widely used for land use mapping. Because land use map is one of the most important map that provide the planner with the present status of land use and pattern of its change. Ford, Algazi and Meyer (1983) demonstrated the determination of land use for hydrologic planing purposes from the Landsat digital data. This is the application of the procedure to urban watersheds that provide the results comparable in accuracy and lower in cost than the procedure.

Land use change is now very fast in the world and this is one of the major factors affecting global environment conditions such as social, economic and ecological (Murai, 1991 and Dale, 1993). So, up to date land use map is required for monitoring the urban and rural environment. From remotely sensed data, a measure of the change can BA obtained by comparing the brightness values for each pixel location in a scene with the corresponding values acquired for the same area but on the different date

Remotely sensed data from Landsat is suitable for land monitoring. As the study of Toll (1980) can provide land use maps of urban changes in the UK. The appropriate information was Landsat image which give over 90% accuracy.

Dale *et al.* (1993) studied about cause and effects of land use change in central Rondonia, Brazil. It was the integration of Landsat data and simulation model procedure. This provided results that remotely sensed data are useful to test the change in land use predicted by spatially explicit models.

In addition, Thematic Mapper image is useful for land use change detection for example :

Haack (1983) used TM for monitor the utility for urban and near-urban land use delimitation of Los Angeles Basin in 1980. Spectral data for six of the thematic mapper channels were transform to a UTM projection and aggregated to 30-m resolution, 120 m for the thermal band. There are 21 training sites representing 8 land use types. The result showed the data from the channel at 30-m resolution is more useful for classification than the channel having 120-m resolution. Selection of bands was using transformed divergence calculation for analysis of intraclass variability. So, the data obtained from the improved resolution and additional spectral bands of the Thematic Mapper appear to BA useful in urban and near-urban land use delimitation using digital processing techniques.

Howarth and Boasson (1983) demonstrated enhancements Landsat TM digital of Hamilton, Ontario for change detection in urban environment. Comparison of the classification from two dates showed limited success. The study used different color enhancements, an overlay of band 5, ratios of band 5 and a vegetation index, were generated using 1974 and 1978 image. The ratios can only emphasize major changes. The band 5 overlay shows change most clearly. The vegetation index enhancement was almost as good and show emphasize the urban boundary and the major road network.

Many researches combined Landsat Thematic Mapper and other satellites data for land use change detection, Because they can provide high resolution and easy to classify. Expands of researches are as follows.

Phuc (1991) used Landsat 3, 4 and SPOT image to generate land use map. The results showed that making land use maps by satellite images is quick cheap with the accuracy of 80% and reduced 50-70% of field work.

Barrett and Curtis (1992) suggested that urban areas can BA classified by using the high resolution data from Landsat Thematic Mapper and SPOT multispectral or panchromatic system. These can provide high accuracy if ground truth were better.

Fung and Chan (1994) studied about spatial composition of spectral classes : a structural approach for image analysis of heterogeneous land use in Hong Kong. The spectral classes generated from Landsat Thematic Mapper and SPOT HRV data. The spatial composition of these spectral classes within a certain spatial range or window can BA useful information for image analysis. Ranges of spatial composition of spectral classes were used for post-classification labeling to identify different land use types. The results showed that a 7 by 7 window size was suitable for this classification.

Haack and Slonecker (1994) integrated of Landsat Thematic Mapper (TM) and Shuttle Image Radar-B (SIR-B) digital data for locating village in Sudan. The study wanted to detect ongoing change in pattern of land use and the location of the village from the irrigation projects, the migration and agricultural. The TM and SIR-B data were merged together into a common file format and then were classified into 3 categories, namely, urban vegetation and other land use, by parallelepiped classification procedure. The study showed the combination of TM3, TM4 and TM6 well suited for vegetation and TM1, SIR-B and TM6 for urban areas which has overall classification accuracy of 94.1%.

Land Use Classification Methodology

Materials and Equipment

The following equipment and materials were used in the study.

1. Satellite data of the study area

Satellite data in the computer compatible tapes (CCTs) form recorded remotely sensed data. Data covered the study area (TM : path 129 row 53) were acquired on 24/10/1988, 28/3/1993 and 23/9/1994. CCTs received by Thailand Remote Sensing Receiving Station, National Research Council of Thailand.

2. Tape Drive

3. Personal Computer

4. Software

Image processing used version 3.2 of microBRIAN program. This software was developed by the Water Resources Division of CSIRO and the MPA Ltd. in Australia.

Data analysis used IDRISI program which developed by Clark University, USA.

5. Topographic map with a scale 1:50,000 which prepared and published by the Defense Mapping Agency Topographic Center, Washington, DC. incorporation with the Royal Thai Survey Department. The study area are covered by map sheets number 4928I and 4928II, L7017 and 2-RTSD edition which were published in 1983.

Land Use Classification Methodology

Digital image processing was performed as following steps:

1. Image Rectification and Restoration

The process can BA considered as preprocessing state before conducting image classification. The base maps used in rectification process were 1 : 50,000 topographic maps of the study area. The coordinate system for registration is the Universal Transverse Mercator Projection (UTM).

This study performed image rectification procedure as follows (Figure 2.4)

1. Ground Control Points (GCPs) were selected both from the map and the image. GCPs distributed over the whole image to BA rectified and the total number of GCPs were 10 points (Table 2.1). These comprises natural structure that are difficult to change through time . The points can BA observed both from the map and the image.

Table 2.1 UTM coordinate of ground control points

Ground Control Points	UTM Coordinate	
	Easting	Northing
Sam Rong Cape	617600	1060350
Chon Khram Cape	601000	1048950
Mai Kaen Cape	614600	1057200
Thong Yang Cape	617800	1047500
Ka Thong Cape	620000	1057800
Thong Po Cape	618750	1059700
So Cape	606300	1040000
Na Hin Daeng Cape	600850	1057000
Hin Khom Cape	602450	1040800
Na Phra Lan Cape	607900	1059500

2. Transformed the both set of GCPs (image and map) to the form of program used. The image GCPs (TM) transformed to satellite model and the map GCPs (UTM) transform to Local Transverse Mercator Projection (LTM).

3. Find the best fitting transformation model to register coordinates between image reference and map reference which calculated by the program. For this study, the best fitting transformation model is a cubic model.

4. Cubic model were used to register the image and map reference by the program module called Remapper. The result of this process were the rectified remotely sensed image of each year having the same points as map reference.

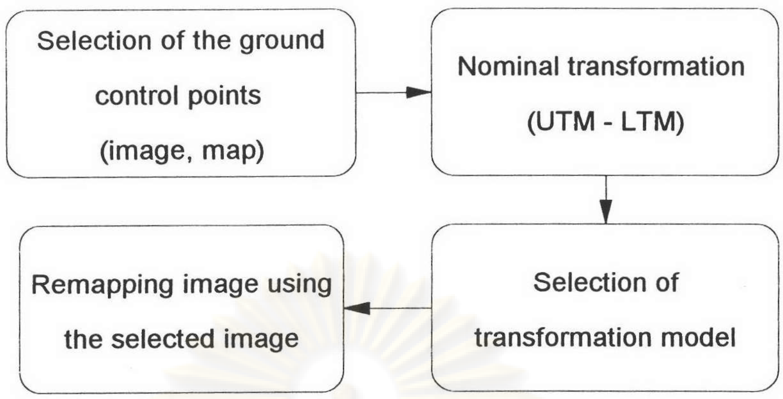


Figure 2.4 Rectification (geometric correction) procedure

2. Image Enhancement

Image enhancement in this study used the linear contrast stretching. The method expands the narrow range of brightness values typically presented in an output image over a wide range of gray values (Fisher, 1994, Lillesand and Kiefer, 1994). The result from this process was used for visual classification at a later step.

To produce the best image contrast, a suitable range for the image must BA found. In this study, each image used its own range experimentally defined from its appearance.

3. Image Classification

This study classified land use into 5 classes (as shown in Table 2.2) according to specific problem of the objective of the study.

Table 2.2 Land use classes definition

Symbol	Class	Definition
UB	Urban/Tourism area	area of seaside constructing and tourism service
FR	Forest area	natural forest but may BA mixed with coconut field
BA	Beach area	area covered by natural Beach
AG	Agricultural area	area of coconut field, paddy field and others agricultural
UN	Unclassified	unclassified area that include water bodies, cloud, open area and etc.

Image classification in this study was carried out by using the Nearest Neighbor Classification technique with semi-supervised classification procedure. Figure 2.4 summarized the classification process.

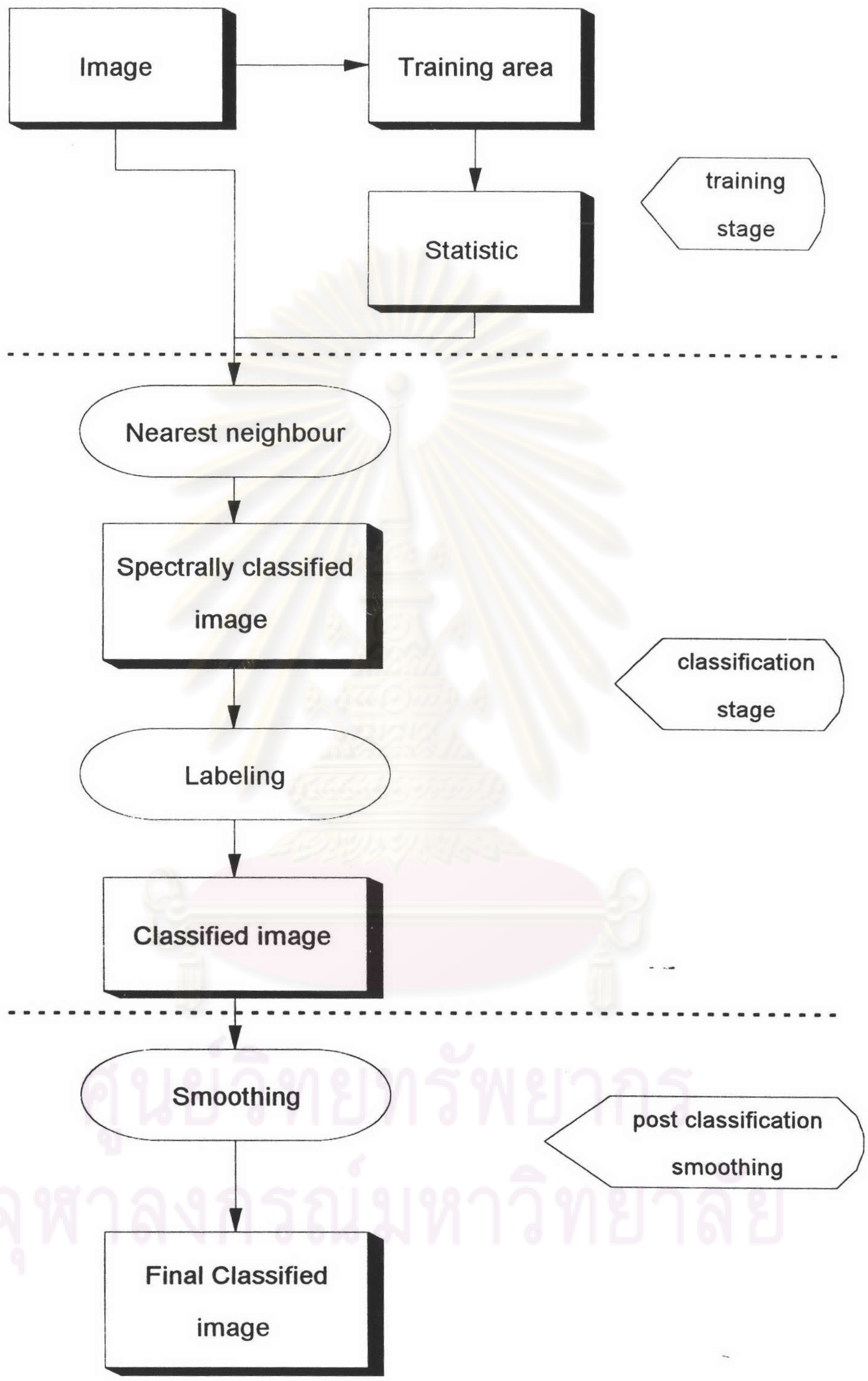


Figure 2.5 Image classification procedure

1. Training Stage

The image were delineated into a number of training areas to represent land use classes which having homogeneous spectral values relate to the knowledge of the ground cover of the study area. A statistical characterization of the reflectance for each information class was developed.

2. Classification Stage

The data in the image is categorized into the land use classes identified in the previous stage by considering the most closely of their spectral values. After this, land use classes were assigned to each final label classes.

3. Post Classification Smoothing

This procedure is desirable to smooth the classified image to show only the dominant classification. The process used a 3×3 matrix as the filter to replace the center cell of matrix by mode of cell values of the entire matrix.

4. Classification Accuracy Assessment

Ground truthing for this thesis were done in March, 1995 and January, 1996. A Global Positioning System (GPS) was used to help identifying coordinates of ground control positions. Land cover type and environment of each ground control position was recorded for analysis result. This study determined 123 ground control positions over the study area. All the ground control points can be categorized as the followings ; AG 27 points, FR 9 points, BA 13 points, and UB 74 points. Because urban area category (UB) is the aim of this study, so ground truthing were concentrated in this class.

Classified image accuracy consists of three accuracy types, first, overall accuracy which represent the accuracy of the entire product, second, producer's accuracy which the producer of the classified image is interested in how well a specific area on the earth can be mapped, and third, user's accuracy which a map user is interested in the reliability of the map in how well the map represents what is really on the ground (Story and Conflation, 1986, Congalton, 1991).

Classification accuracies are defined as:

Overall Accuracy = $\sum_{i=1}^{k} x_{ii} / N$

Producer Accuracy for class i = $x_{ii} / \sum_{j=1}^{k} x_{ji}$

User's Accuracy for class i = $x_{ii} / \sum_{j=1}^{k} x_{ij}$

where

X_{ij} = a value of the error matrix for an element in row i column j

k = the number of classes

N = the total number of sampling cells

i = class i^{th} as classified by ground truthing

j = class j^{th} as classified by classified image

Land Use Classification Result

Land use classification

Ko Samui land use classification in 1988, 1993 and 1994 results were presented in Plate 2.1, 2.2, and 2.3 and summarized in Table 2.3. Urban area increased during 1988 to 1994 from 14.22 to 38.93 and 41.65 square kilometers. Since the increasing of population in the island is around 1.62% per year (TISTR, 1988). The sharply increasing of the urban area is only explainable through the relation with tourism activity.

Table 2.3 Area of land use classes in square kilometer (km^2)

Class	1988 (km^2)	1993 (km^2)	1994 (km^2)
AG	164.43	149.86	138.75
FR	66.28	48.45	45.78
BA	6.12	2.6	2.05
UB	14.22	38.93	41.65
UN	1.95	13.16	24.77

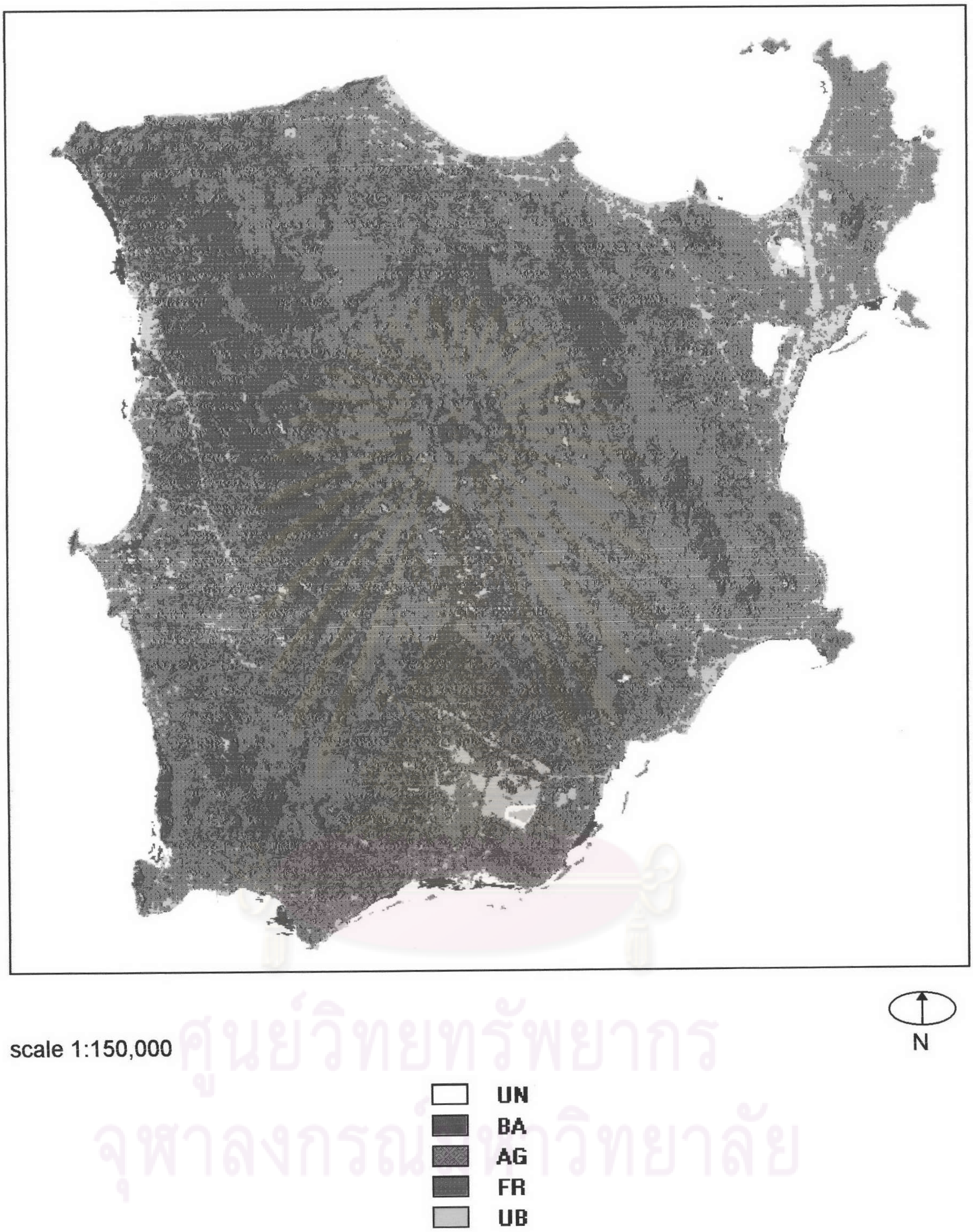
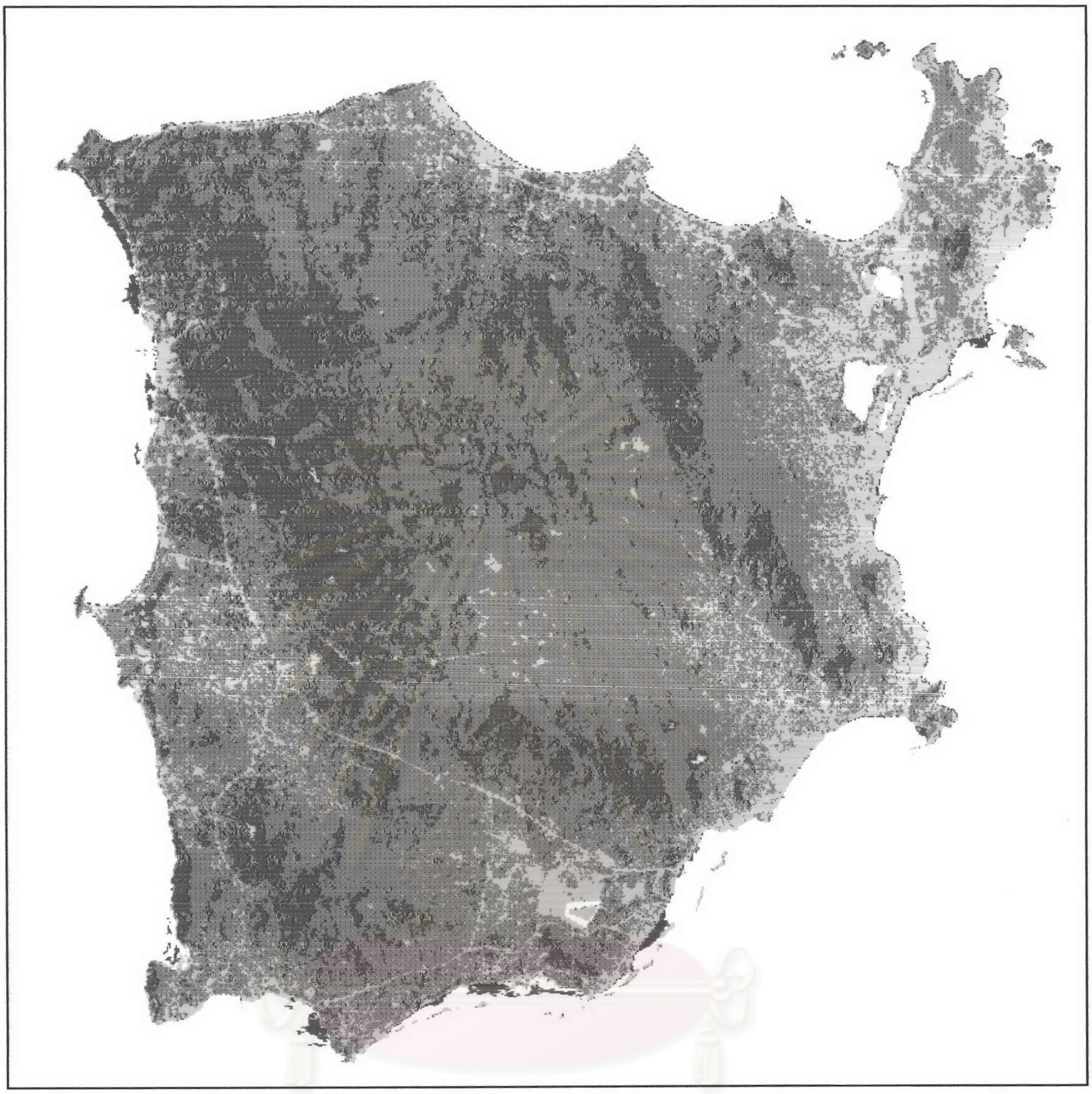


Plate 2.1 1988 classified image of Ko Samui

(source : Landsat TM path 129 row 53 aquired on 24/10/1988)



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N

UN
BA
AG
FR
UB

Plate 2.2 1993 classified image of Ko Samui

(source : Landsat TM path 129 row 53 aquired on 28/3/1993)

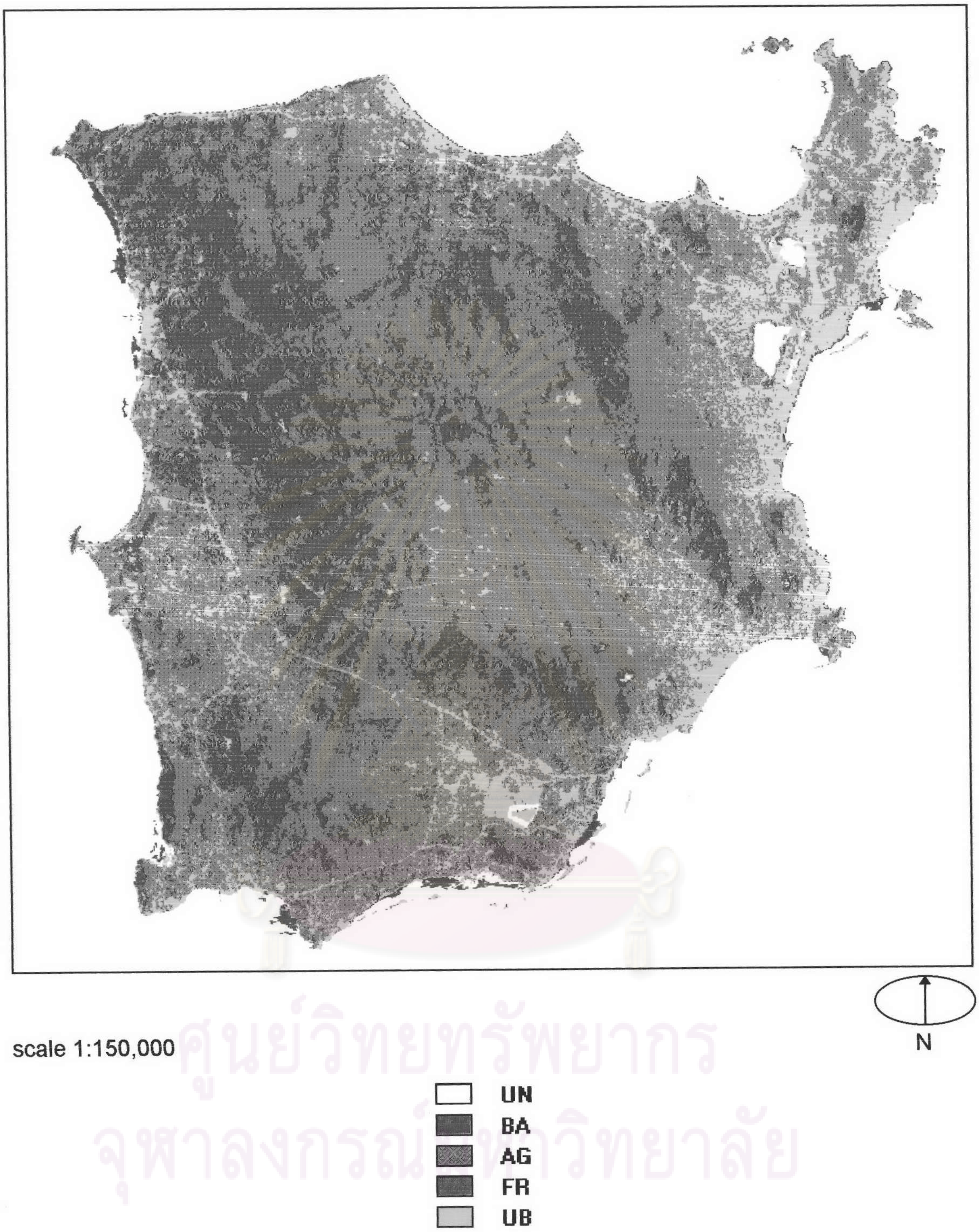

Plate 2.3 1994 classified image of Ko Samui

(source : Landsat TM path 129 row 53 aquired on 23/9/1994)

Classification Accuracy Assessment Result

Classification accuracy assessment are summarized from error matrix in Table 2.4 for 1993 and Table 2.6 for 1994. These information were acquired from ground truthing which used for accuracy assessment only 1993 and 1994. Accuracy of the 1988 classified image was not determined, although it could be estimated from aerial photography, but there were no photo available.

Table 2.4 Error matrix for land use classification in 1993

Classified Image	Ground Truth				
	AG	**FR**	**BA**	**UB**	**total (point)**
AG	**23**		2	15	**40**
FR	3	**8**	1	3	**15**
BA			**6**	1	**7**
UB	1	1	4	**55**	**61**
total	**27**	**9**	**13**	**74**	**123**

Overall accuracy = 92/123x100 = 74.8%

Table 2.5 Producer and user accuracy for land use classification in 1993

Accuracy	User		Producer	
	Ratio	%	Ratio	%
AG	13/40	**32.5**	13/27	**48.1**
FR	8/15	**53.33**	8/9	**88.88**
BA	6/7	**85.71**	6/13	**46.15**
UB	55/61	**90**	55/74	**74.32**

Error matrix of land use classification in 1993 provided overall accuracy to 74.8%. The matrix was used to generate categorical accuracies which can be expressed in the form of producer and user accuracy as shown Table 2.5.

Table 2.6 Error matrix for land use classification in 1994

Classified Image	Ground Truth				
	AG	FR	BA	UB	total (point)
AG	**24**	1	1	11	**37**
FR	2	**8**		2	**12**
BA			**7**	2	**9**
UB	1	1	5	**59**	**65**
total	**27**	**9**	**13**	**74**	**123**

Overall accuracy = 98/123 = 79.7%

Table 2.7 Producer and user accuracy for land use classification in 1994

Accuracy	User		Producer	
	Ratio	%	Ratio	%
AG	24/37	**64.9**	24/27	**88.9**
FR	8/12	**66.66**	8/9	**88.88**
BA	7/9	**77.77**	7/13	**53.84**
UB	59/65	**90.76**	59/74	**79.72**

Land use classification accuracy in 1994 showed in Table 2.6. This provided overall accuracy to 79.7%. Similarly 1993, categorical accuracy can be expressed in the form of producer and user accuracy (Table 2.7).

Classification accuracy of 1994 image was higher than 1993 classified image, and 1994 classified image had higher user and producer accuracy than 1993 classified image. Urban class (UB) both 1993 and 1994 has the highest accuracy. The lowest accurate categories was agricultural class (AG) in 1993, and beach class (BA) in 1994.

Discussion

From Figure 2.6, the increasing trend was urban\tourism area (UB). In 1988, tourism area usually located at the beach nearby in the area of Chaweng, Lamai, Bo Phut and Maenam Beach. In 1993 and 1994, the most of distribution was still very near the beach around the island. The less area located in the highland that has beautiful view.

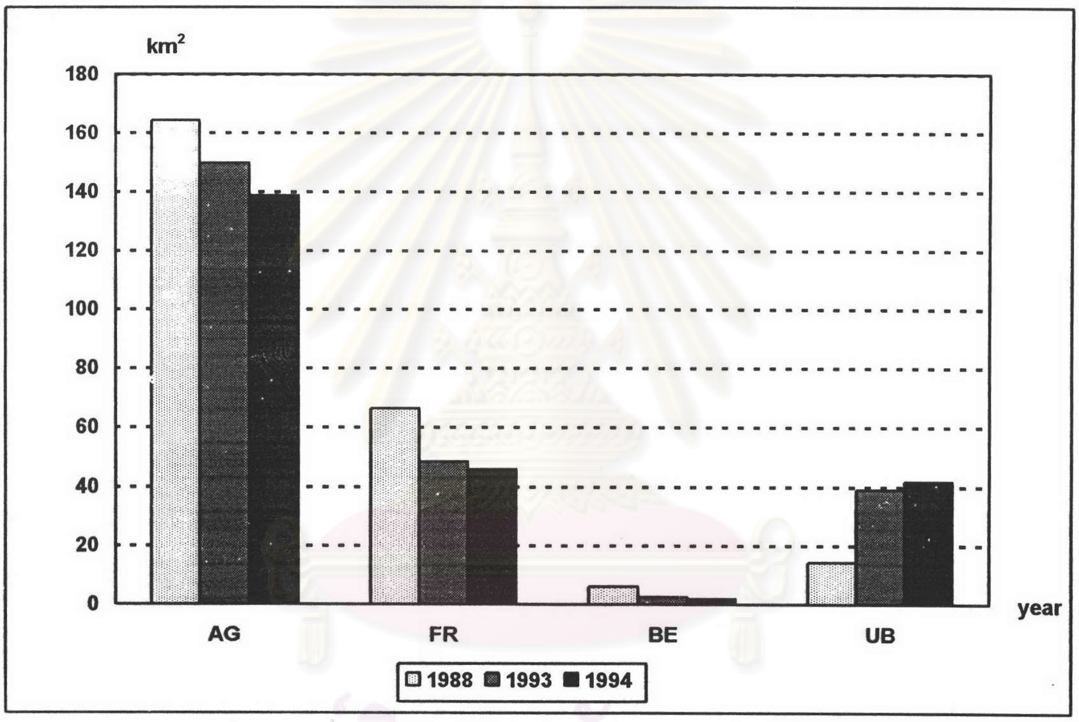

Figure 2.6 Tendency of individual land cover types change

The decreasing tendency was agricultural (AG), forest (FR) and beach (BA) area. For agricultural area, coconut field, paddy field and others, have 164.43, 149.86 and 138.75 square kilometers in 1988, 1993 and 1994 respectively. Agriculture, particularly coconut field in 1988 distributed overall the island. Most absence area was changed to tourism site. Forest area in the past forest located in the highland in the island middle. Recently, this has changed to agricultural and tourism site. Beach around the island relate to tourism expansion because it is the high motivation for development. Therefore, tourism site always locate closely the beach. Whereas tourism area arise, some of Beach area abate.

However, beach area decreasing might occur in the stage of classification. By the cause of a tidal period is deferent in each day, so beach area appearance in satellite image depend on a tide. If satellite sensor recorded the data in flood period, then spectral reflectance was the water body. Contrastly, in ebb period, spectral reflectance was beach area.

Urbanization has expand in area of tourism only during the past six years, Because original communities have been not arise in this time. Population growth have the declining trend (Figure 2.7) because Ko Samui has low of population growth rate (TISTR, 1988). So that the urban area increasing are the tourism area.

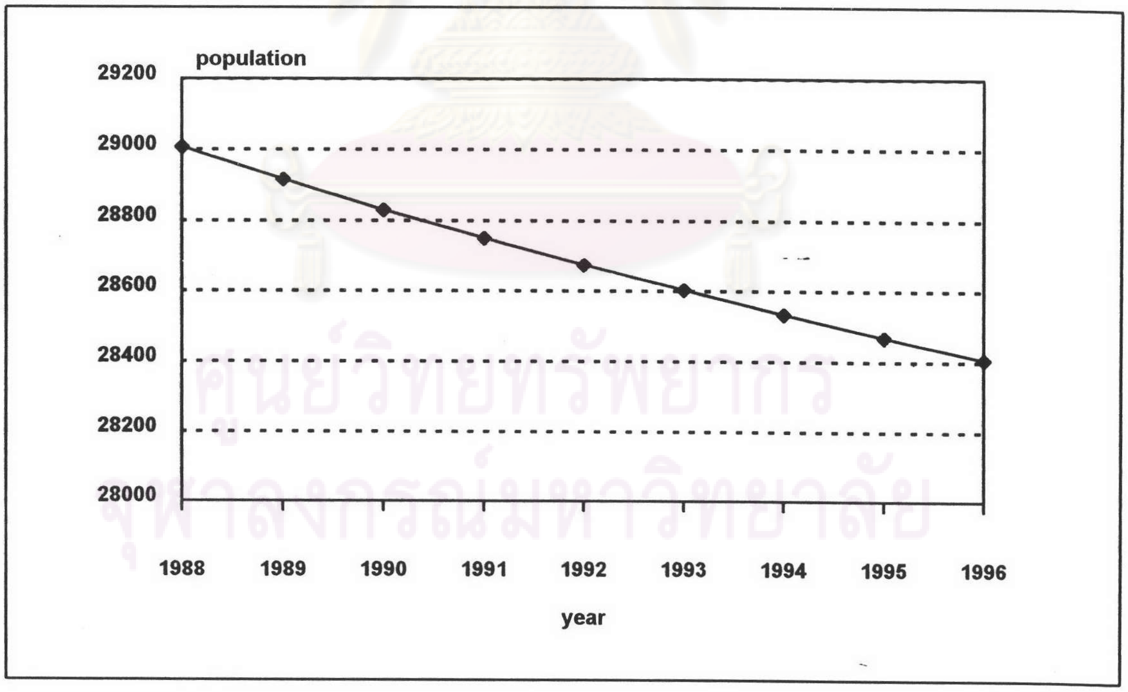

Figure 2.7 The tendency of Ko Samui population growth

Most of decreased agricultural areas have changed to area for tourism and the open area. In recent year, the new career that relate to tourism are interested for people more than others career because of the higher income (from interviewed in the field). Therefore, the distribution of income still being like this, agricultural area will have the depletion tendency in the future. Forest decreasing in former year were due to change into agriculture, but now these changes are for tourism development. An other public area, sandy beach, around the island was clearly encroached for tourism from 6.12, to 2.6 and 2.05 square kilometers in 1988, 1993 and 1994 respectively. Chaweng Beach is the example trespassed of tourism area on the public beach.

Table 2.8 Annual rate of land use change

Class	1988-1993 (%)	1993-1994 (%)	1988-1994 (%)
AG	-1.77	-7.14	-15.62
FR	-5.38	-5.51	-30.93
BA	-11.50	-21.15	-66.50
UB	12.69	6.53	65.86

Consideration from annual rate of area change (Table 2.8) showed that from 1988 to 1994 tourism area has arisen to 65.85%. Highly increasing rate has occurred in 5 years from 1988 to 1993 that arise to 12.69%. For others land use, all of them have the depletion tendency, particularly beach area has the highest decreasing rate followed by forest, and agricultural area. Beach area has the highest decreasing rate because it has the highest potential and motivation for development. Since Ko Samui is an island, so there is limitation of land activities. Whenever area of some land use increases, some other land use types must decrease.

Classification accuracy from error matrices (Table 2.4 and Table 2.6) provided the overall accuracy as 74.8% in 1993 and 79.7% in 1994. It should be noted that ground truthing has been done only in 1994 but used in the both two images (1993 and 1994). This could contribute to the higher accuracy in the 1994 image to the 1993 image.

For the individual land use categories, the numbers of ground truthing data are not equal. Urban area category (UB) is the aim of this study so ground truthing were concentrated in this class. Furthermore, many tourism resorts are under coconut fields, they cannot be clearly classified from the satellite image. Satellite image can see only coconut field, thus it reduces the classification accuracy. The high accurate of urban category was done by collected many of ground truthing data. While others categories have minority therefore, data were collected less than the UB category

.

Major problem of image classification was unclearly classified for urban area that located in the coconut shading. Because satellite sensor can record only coconut spectral reflectance. It can not identify either urban area or coconut field. Other reasons were the complexities and relative small sized of surfaces produce a heterogeneous image. This means that many classification a difficult task (Howarth, 1983).

Error matrices (Table 2.4 and 2.6) illustrate the urban area ground truth 74 points of data, but can correct in classified image only 55 and 59 points in 1993 and 1994. The less points are 15 and 11 points and were classified as agricultural class (coconut field).

In 1993 the producer's accuracy for the urban area category classification is 74.32%. While the 16% of those areas miss identified from urban were urban under the coconut shading that was classified as coconut field category (AG). However, those areas identified as urban area has a 90% chance to actually urban. This mean that the probability of urban area was identified in this image as an urban area is 74%, actually might be an urban area 90%.

The 1994 image is similar to the 1993 image, the producer's accuracy for the urban area category classification is 79.72% while actually of urban area identified should be 90.76% (user's accuracy).