CHAPTER 3
APPLICATION TO SUKHOTHAI

In this chapter, the design of the spatial database for site evaluation will be prepared. After the spatial database were created then apply crisp set and fuzzy set to study the comparison between crisp set and fuzzy set when change the classification range in physical environment factor. Then combined output from both set with infrastructure constraint and environmental law constraint to produce land suitability map of tourism accommodation development in Sukhothai province.

3.1 The study area

Sukhothai province is located in lower northern Thailand located at latitude of $16^\circ 34'$ - $17^\circ 46'$ North and longitude of $99^\circ 24'$ - $100^\circ 1'$ East. Figure 4-1 shows the location Sukhothai province. Sukhothai was the eleventh largest area of Northern Thailand region with an area of $6,596.092$ km^2 or $4,122,557.5$ rai. It is approximately 427 kilometers north of Bangkok. It is one of the most popular destinations in Thailand for both international and domestic tourist. Because of its historical values and beautiful scenic countryside.

The study area in this study did not cover the whole area of Sukhothai province because of the extent of the available satellite data.
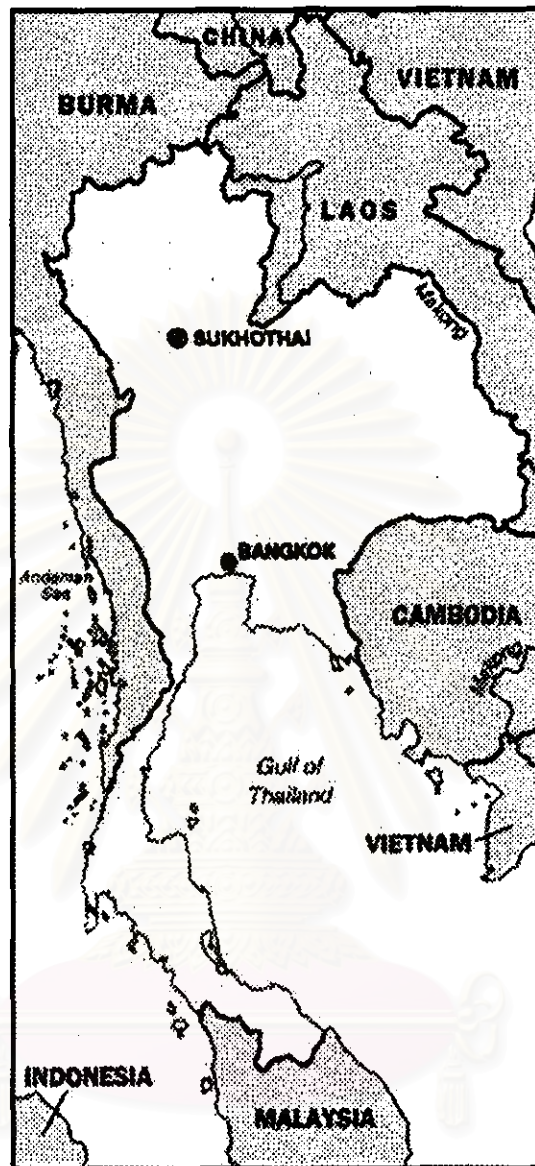
Figure 3-1 Location of Sukhothai

3.1.1 Administrative Setting

Sukhothai is divided into 9 Amphoe, as shown in Figure 3-2 with the total population recorded in 1999 of 631,376 peoples (308,906 male and 322,470 female) Among these, amphoe Muang Sukhothai has the highest population of 113,921 people and has a population density of more than 223.45 people per square kilometer. The amphoe with the least population is Sri Na Khon, which has only 31,198 people and

has a population density of 145.27 people per square kilometer; average population density of this province is 102.74 per square kilometer.

Figure 3-2 Political Boundary of Sukhothai Province

3.1.2 Natural Environment Setting

Forest is the mainly natural resource of Sukhothai province, since 1961 Sukhothai province has the total forest area of 2,719,375 rai or equivalent to 65.96 percents of the total provincial areas. Compared with year 1995, the decreasing rates of the forest area is comparatively high, forest area decrease to 1,432,500 rai or equivalent to 33.13 percents of the total provincial areas. Sukhothai Forest combined

from hill evergreen forest, mixed deciduous forest with teak, mixed deciduous forest without teak, dry dipterocarp forest and teak Plantation.

From the above-mentioned data, Sukhothai is one of the provinces still holding considerable amount of forest areas. The needs for protection and forest conservation are this particular province is rather urgent for actual implement, in order to avoid any encroachments of the remaining forest areas. There are 2 national parks in Sukhothai; one of them is Ramkhamhaeng National Park in amphoe Ban Dan Lan Hoi and amphoe Muang Sukhothai with areas of 341 km^2 or 213,125 rais. The others is Sri Sat Cha Na Lai National Park, in amphoe Sri Sat Cha Na Lai and amphoe Thung Sa Liam with the areas of 133,250 rai or 213.2 km^2. Moreover there is one wildlife sanctuaries, Tam Lom in Tambon Thung Sa Liam amphoe Thung Sa Liam in areas of 11,250 rais which declaration by Government Gazette since 26 January 1993.

Other types of protected area established for the same goals of protecting and conserving forests and their inhabiting wild animals by the Royal Forest Department is Tham Chao Ram non-hunting area areas of 15,875 Rai, which has already incorporated into Pa Mae Mok – Pa. Mae Lam Phan National Park.

3.1.3 Transportation

Sukhothai province has network of roads connecting to other provinces, totaling in length of 863.90 kilometers. It is the most important transportation network of Sukhothai province. Sukhothai has airport, located in amphoe Sawan Kha Loke, which is 30 kilometers away from amphoe Muang Sukhothai. Sukhothai has very short train route, train stop at Sawan Kha Loke and Sri Nakorn stations.

3.1.4 Public Utilities

Sukhothai has 7 provincial offices for water supply. These seven offices locate in amphoe Muang Sukhothai, amphoe Sri Na Khon, amphoe Ban Dan Lan Hoi, amphoe Srisat Chanalai, amphoe Kirimas and amphoe Kong Krailas. The plan in 1994 was to extend water supply limit to 10,781 cu.m. per day.

Sukhothai has network of electricity almost cover all of province, in 1994 there are only 29 houses in province, which not connected to electricity network. Sukhothai has 12 telephone centers. The operating numbers are 8,444. The ratio of telephone number per population is 1.0 telephone number per 100 persons.

3.2 Setting up criteria for analysis and data inventory

Given the study area and objectives of the development, the criteria for analysis are established. These criteria, however, result from the objectives of development planning. They need to be clarified, so that only necessary data for analysis will be collected and organized.

3.2.1 Identification of Site Suitability Criteria

Designing the GIS comprised three stages. The first stage was to investigate the objectives and constraints of the projects. The second stage was to formulate and to evaluate alternative data handling systems capable of meeting the objectives. The third stage was to select the most feasible and cost effective alternative to build the GIS. This section elaborates those processes used in this study.

Physical Environment impact of tourist accommodation development in this study focuses on the potential for soil erosion, potential for runoff, potential for groundwater contamination, potential for flooding and slope constraint. By using a diagrammatic outline of an environmental analysis as show in figure 3-3, potential impacts for Sukhothai province can be analyzed.

Infrastructure facility, which supports tourism accommodation development, is all the utilities and facilities that are necessary for development. This criterion includes transportation facilities such as highways, airport, and waste disposal facilities such as landfills and wastewater treatment plants. This study, focused on a number of constraints that strengthen the tourist accommodation development. The first is transportation accessibility that includes highway and road. The second criteria are water availability, because the accommodation consumes the large amount of water demand for service tourist activities. The third criteria to concern which have

potential to support tourist accommodation is river view scenic, this criteria is more important to concern to selecting tourist accommodation places because the distance from River was an important factor for natural tourism because of the attractive for tourist. Most of Tourist accommodate suited near the river would be quite advantageous. In this study selected the River Yom and major tributaries, because of the volume of water along year, and Yom River is the large River which flow across this province from North to South and have activities of people to interact with this river which make this river lively.

Governmental constraint which included Environmental Impact Assessment guidelines for hotel and accommodation development project and constraint from Environmental law e.g. Enhancement and Conservation of National Environmental Quality Act, B.E. 2535 (A.D. 1992), National Park Act B.E. 2504 (A.D.1961), National Reserved Forest Act B.E. 2507 (A.D.1964), National Reserved Forest Act B.E. 2507 (A.D.1964), Building control Act B.E. 2522 (A.D.1979), Notification of Ministry of Science Technology and Environment issued under the National Environment Quality Act B.E. 2535 (A.D.1992) and Town Planning Act. B.E. 2518 (A.D. 1975), are among the constraints that will be considered for governmental constraint.
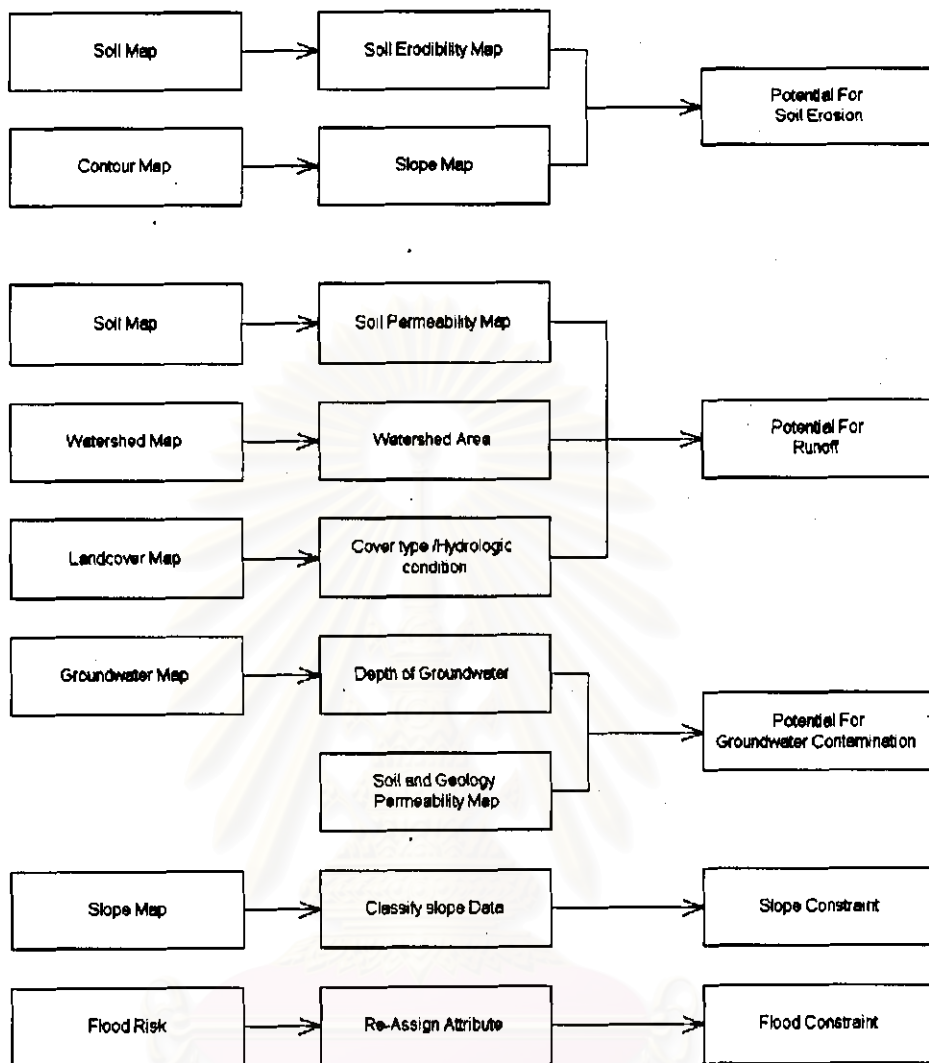
Figure 3-3 Database Development Procedure

Source: Modified from Boonyobhas (1996)

3.2.2 Identification of software to use

Building the GIS in this study required variety type of data, which no software can, operated all of this. A range of software elements was selected based on availability and functionality.

Data in a hard copy format (e.g. topographical, geology, etc) must be captured into the GIS through a digitizing or rasterization process. Contour data must be interpolated by DEM interpolation model. Digital data from remote sensing must be classified for land cover data. Data at different scales must be rectified to a base

reference. Some data elements must be derived from other elements (by apply an appropriate model). Eventually, analytical results must be displayed in an understandable form (Tangjaitrong, 1994). Comparison of the efficiency and accuracy of similar software packages, if they existed, was beyond the scope of this study. Especially for the case of land suitability and applied with fuzzy logic, there have many variable and information to concerned. Summary of software which were used in this study are as following.

a. PC ARC/INFO Version 3.42 and ArcView for Windows Version 3.0a

This software is a product of the ESRI Company. A vector-based GIS comprise several modules for data input, manipulation, analysis, and output purpose. This study uses this software to prepare the GIS data capturing, modeling, and conversion.

b. ENVI version 3.1

This software is a product of Research Systems Inc. This software covers almost of whole range of image processing and images statistics. This study uses this program to prepared 3-D data of Sukhothai and image classification of satellite imageries.

c. PCI Easi+ Version 6.1

This software is a product of PCI Enterprise Inc. This software comprises more than a hundred modules, which cover almost of whole range of image processing and image statistics. This study used the program to prepare some variable of GIS data (e.g. digitized contour line, boundary of historical area, etc.), watershed delineation and image classification of satellite imageries.

d. IDRISI 2.0 for Windows

A research team at Clark University, USA, developed this software. A raster-based GIS comprised all major process for a GIS. This software provides facilities for image processing and image statistics. This study used the fuzzy logic modules of this program in analyzing section.

e. ERODE

This software developed by Dr. Robert Hickey of the Curtin University of Technology, Australia. This program, which calculates cumulative downhill, slope length, maximum downhill slope angle, and flow direction within Arc/Info GRID and IDRISI. In this study used this program to created maximum downhill slope angle, cumulative downhill slope length, and flow direction (aspect).

f. Surfer for Windows version 6.0

This software is a product of Golden Software Inc. It is a grid-base contouring and 3-D surface plotting graphic program. This program interpolates irregular spaced data onto a regular space grid, which used to produce contour map and surface plots. In this study used this program to interpolated rainfall contour lines from which provide from Department of Meteorological and Department of Irrigation and prepared elevation data for ERODE program.

3.2.3 Land cover information from Remotely Sensed Data

The National Research Council of Thailand (NRCT) provides two digital imageries of Landsat 5-TM. The both of satellite imageries were acquired during dry season on the 25 of November 1996 and 25 of January 1997 (path 129 row 48 Scene ID is 47130-30717 and 547130-30717). These images were used as the land use map for the study. Figure 3-4 shows the Landsat TM image scene.

a. Image Rectification and restoration

Geometric Correction of the imagery is necessary for two reasons. First, the image includes geometrical distortions, which need to correct in order to have a more correct representation. Secondly, since image from different seasons will use for classification and change detection, it is necessary to make different image data conform to a common grid. A land cover map, which derived from satellite data, must use the same geographical reference as the other data layers in the geographic database (Tangjaitrong, 1994). Rectifying and resampling the image to the UTM, reference at 25-meter resolution using PCI's image rectification programs did this.

Georeferencing procedure requires the collection of ground control points (GCPs) on both the map and the image. The first step for the geometric correction was to mosaiking the scanned topographic maps in scale 1:50,000 then register it into true positions of the real world. The resulted map is *"registered map."* Then, the satellite coordinates were obtained from the registered map. The coordinate pairs were used to compute a first order transformation matrix that was applied to the entire digital image to compute rectified coordinates for each image pixel. This study selected a number of GCPs from artificial structure (e.g. road intersection and bridges).
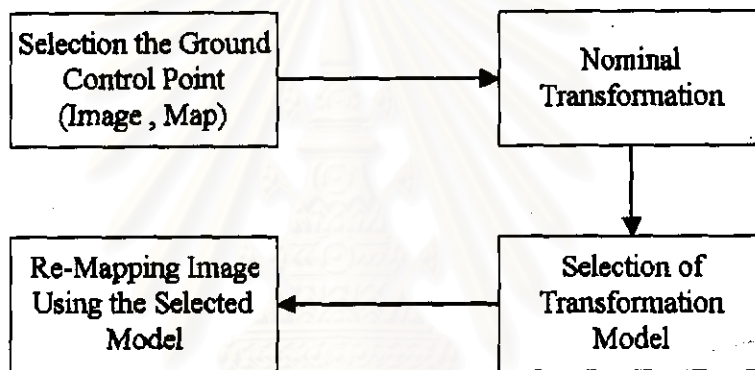
Figure 3-4 Rectification (Geometric Correction) Procedure

The second step was to find a transformation model to map coordinates between the satellites image reference and the map reference. The best fitting model formulated from the two sets of coordinates system (*"Easting, Northing"* from the registered map and *"Column, Row"* from satellite image). That transformation model creates a new corrected image space where interpolates pixel values will later be place during resampling. Then calculated by the rectification program is a polynomial equation is fitted to the GCPs using least square criteria to model the corrections in the image domain without identifying the source of the distortion.

Transformation matrices containing the coefficients for converting coordinates were calculated from the GCPs by the least square regression methods. The best GCPs selected and adjust until the total RMS (Root Means Square) error was less than tolerance level (0.5 of pixel size). The first-order transformation applied and it yields

THE APPLICATION OF FUZZY LOGIC AND GIS
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TOURIST ACCOMMODATION AREA
IN SUKHOTHAI PROVINCE

Notice
False color composite of LANDSAT-5 TM
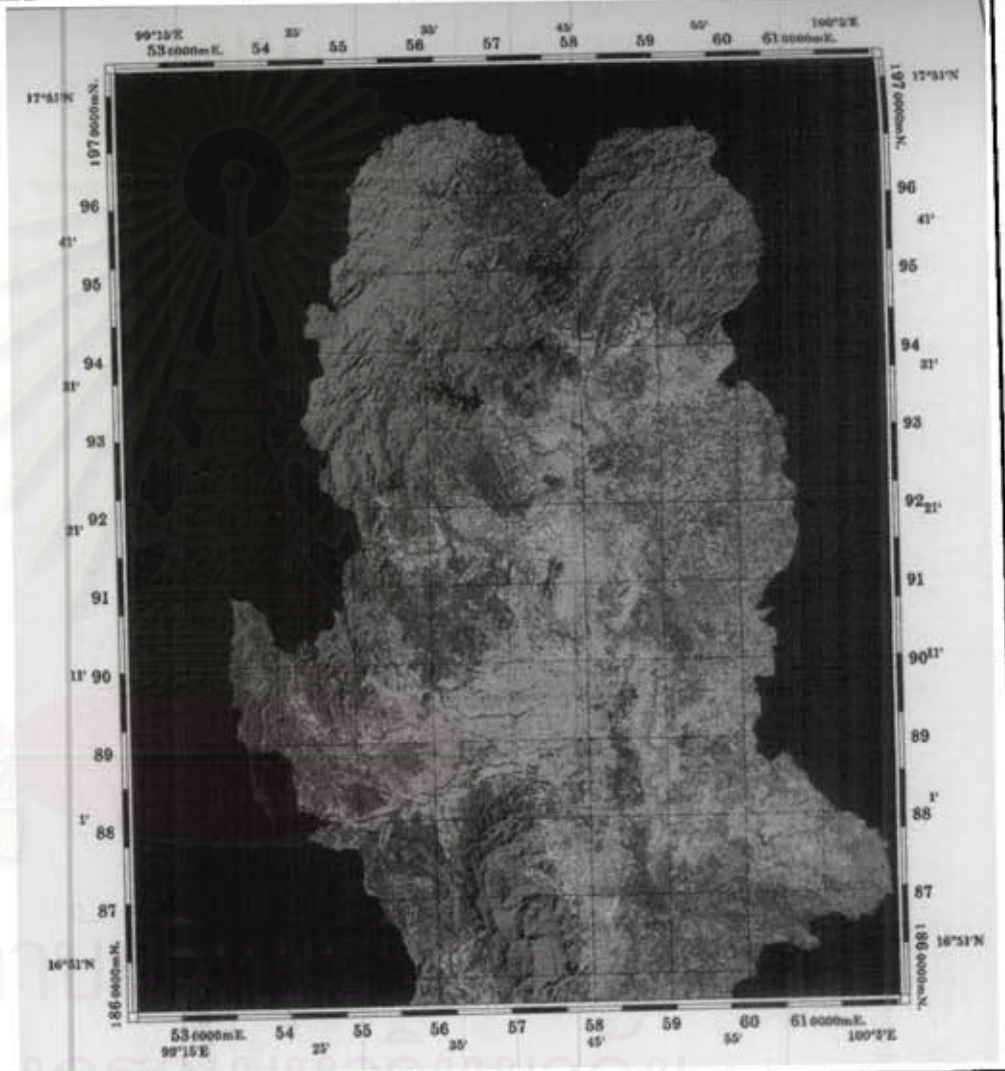acquired on 25 January 1997
Path 129 Row 48

Figure 3-5 LANDSAT 5 TM imagery of Sukhothai Province

adequate result because of flat terrain of study area. Nearest neighboring resampling methods was conducted to retain the original radiometric values of classification.

Result of the rectification programs suggests that only 48 GCPs should be used to create the transforming model. Some selected GCPs were discarded because including them would reduce the overall accuracy of the transforming model.

$$X = X_0 + a_1(x - x_0) + a_2(y - y_0)$$
$$Y = Y_0 + b_1(x - x_0) + b_2(y - y_0)$$

Where

x,y	are the satellites image coordinates
X, Y	are the map coordinates
x_0, y_0	are the coordinate of the center (arithmetic mean) of the GCPs from satellites image
X_0, Y_0	are the coordinate of the center (arithmetic mean) of the GCPs from map
a_i, b_i	are the model constants

Values of x_0, y_0, X_0, Y_0 are dependent on the subset image and the positions of the ground control points. The model constants (a_i and b_i) are dependent on the relative orientation between two coordinate systems. In this rectification, values of the mapping constants as obtained from the selected GCPs were

$$x = 365.125 + 4.785147 \times 10^{-2} (x\text{-}612742.84) - 3.147208 \times 10^{-4} (y\text{-}1898476.25)$$
$$y = 775.371 + 1.674015 \times 10^{-4} (x\text{-}612742.84) - 3.988623 \times 10^{-2} (y\text{-}1898476.25)$$

These formulae were used to rectify the satellite image so that its geographical reference was the same as the other layers in the GIS.

b. Image Enhancement

Image Enhancement encompasses a variety of operations designed to improve the visual interpretability of an image by increasing the apparent distinction between features in scenes. The objective of image enhancement is modifying 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 be a categorized as contrast manipulation.

c. Image Classification

The objective of image classification is to replace visual analysis of the image with automatic techniques for quantitatively identification of features in a scene (Lillesand and Kiefer, 1994). The choice of this approached depends on the nature of the data being analyzed and the intend application.

The goal of supervised classification is to use knowledge of the scene in order to "train" the computer to recognize the spatial signature of each image pixel as belonging to one of a number of learned signatures. The digital satellite images were classified using digital image processing techniques to enable the assignment of land cover classes to areas with similar spectral characteristics. A series of tests was carried out using statistical clustering to derive a set of signatures that was used to classify the images. In the classification or interpretation stage, each pixel in the image data set (must be the same as the list of channel used in generating the signatures) is compared to each training area signature

d. Post Classification Smoothing

This procedure is desirable to smooth the classified image to show only the dominant classification. The procedure used a 3x3 matrix as the filter to replace the center cell of matrix by mode of cell values of the entire matrix.

e. Accuracy Assessment

The accuracy of the classification was determined by field surveys and comparing classified image with previous study (e.g. Onseng (1994), Onseng (1990)). Classified image accuracy consists of three accuracy types, first, overall accuracy that represents 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 the 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.
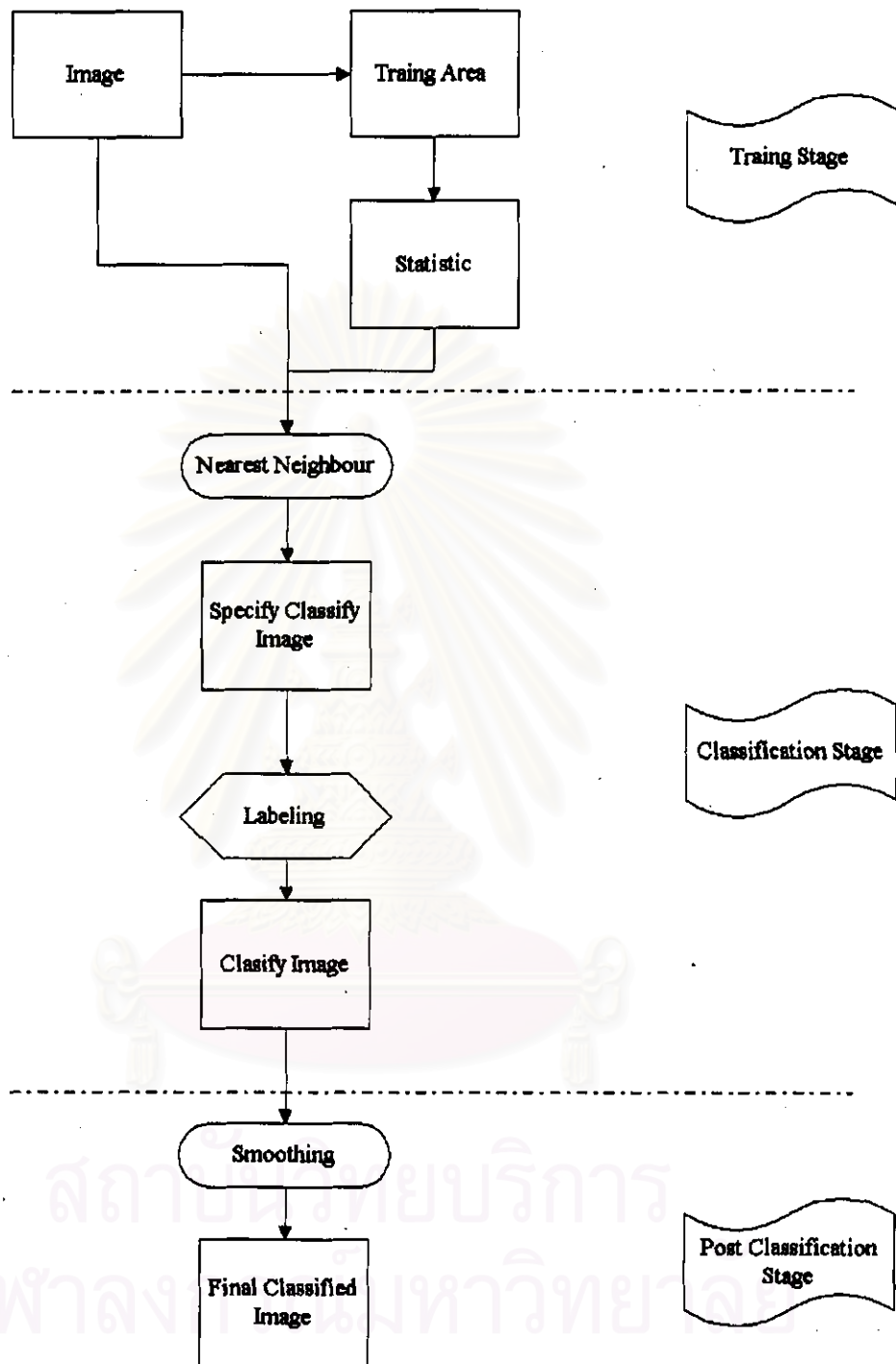
Figure 3-6 Satellite Image Classification Procedures

Classification accuracy's are defines as

Overall accuracy $\qquad$ = $\qquad$ $\sum_{i=1}^{k} X_{ii} / N$

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

User accuracy for classes i $\qquad$ = $\qquad$ $X_{ii} / \sum_{j=1}^{k} X_{ij}$

Where Xij   is a value of the consistency matrix for an element in row i column j

    k   is the number of classes

    N   is the total number of sampling cells

f. Land use Classification Result

The land cover/ land use classification of Sukhothai province is presented in Figure. 3-7. Land cover/land use pattern can be classified into 15 categories. The land use in 1997 was largely agricultural land, which is mainly land for paddy field, forest and filed crops. A small amount of land has been used for residential, commercial and industry.

3.3 Potential Factor According to Soil Erosion

Soil erosion is one of the most serious environmental problem where its remove soils rich in nutrients, increase natural levels of sedimentation in the river and cause flash flood at the construction area. Most of the soil erosion study done by other researchers based on the Universal Soil Loss Equation (USLE) as a method to predict the soil loss.

The Potential area for soil erosion of Sukhothai Province is prepared by using the ULSE. Wischemeier and Smith (1978) listed the six factors controlling the working of the soil erosion system. These are the erosivity of the rainfall (R), the

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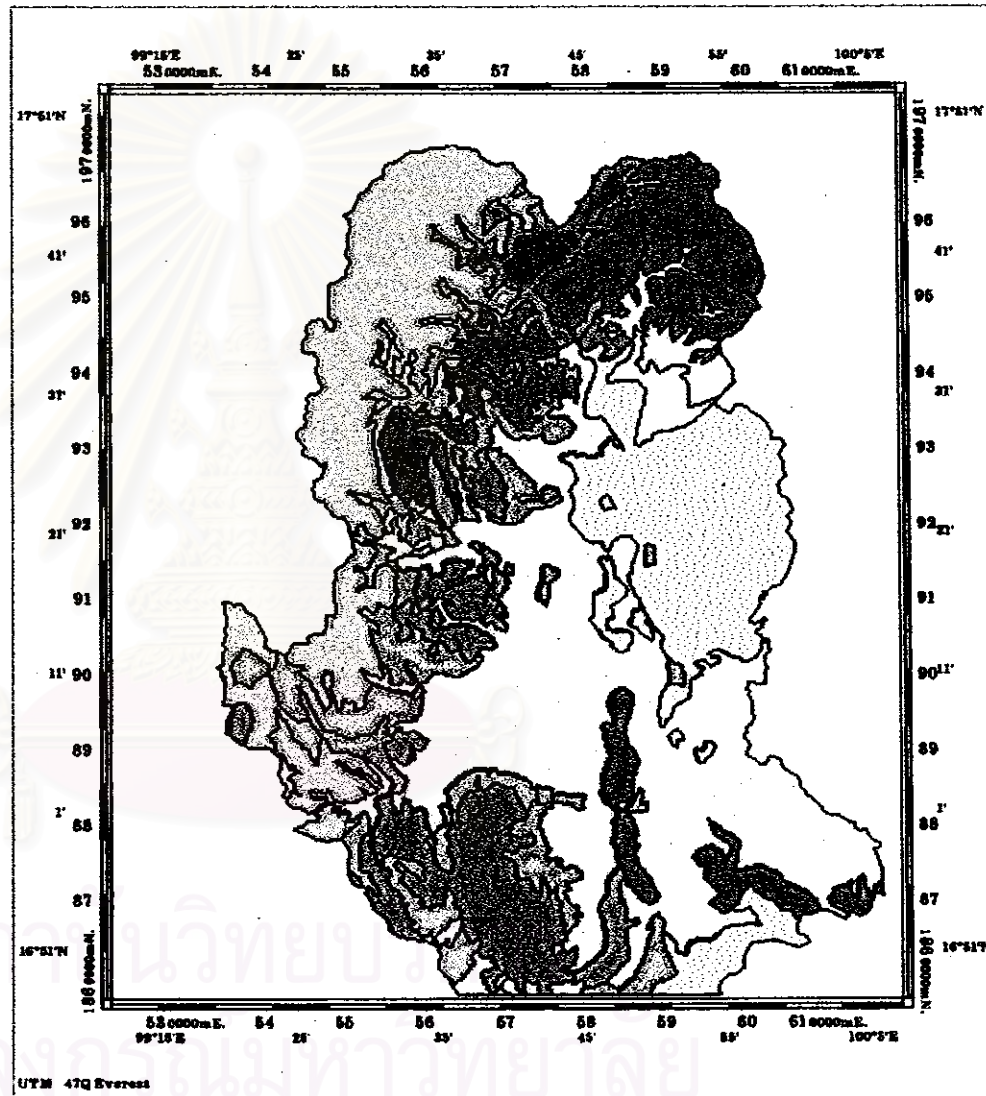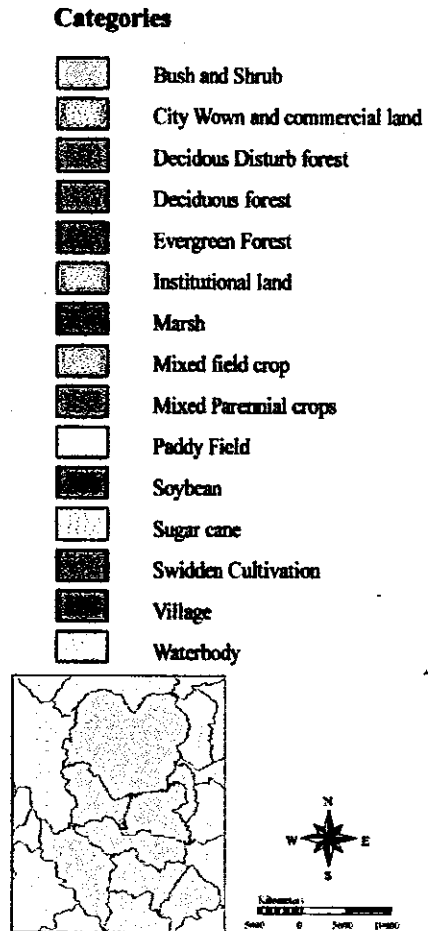### TOURIST ACCOMMODATION AREA
IN SUKHOTHAI PROVINCE

Categories

- Bush and Shrub
- City Wown and commercial land
- Decidous Disturb forest
- Deciduous forest
- Evergreen Forest
- Institutional land
- Marsh
- Mixed field crop
- Mixed Perennial crops
- Paddy Field
- Soybean
- Sugar cane
- Swidden Cultivation
- Village
- Waterbody

Figure 3-7 Landuse classification results of Sukhothai province

41

erodibility of the soil (K), the slope of the land (S), the length of slope (L), the nature of the plant cover (C) and the type of erosion and the type of erosion control practices (P). The product of these six factors would show current soil erosion current soil erosion rates (A). When plant cover was completely removed and no soil conservation measures are practices, soil loss can be high.

The parametric equation of the USLE is

$$S = R\,K\,L\,S\,C\,P$$

Where:

S	Annual soil loss (ton/ha)
R	Rainfall erosivity factor (joule/ha)
K	Soil erodibility factor (ton/joule)
L	Slope length factor
S	Slope gradient factor
C	Crop Management factor
P	Land Management factors

After all of above factor are identified (see appendix A for details of deriving map of the factors), the soil loss can be estimated by inputting the USLE formula and the required factor into the ARC/Info systems. Then the soil loss can be estimated. However, these figures are used only for indicating the potential area for erosion in Sukhothai. Figure 3-8 demonstrates the process diagram of analysis for the potential of soil erosion on Sukhothai, and Figure 3-9. Illustrate location where erosion is most likely take place on this province.
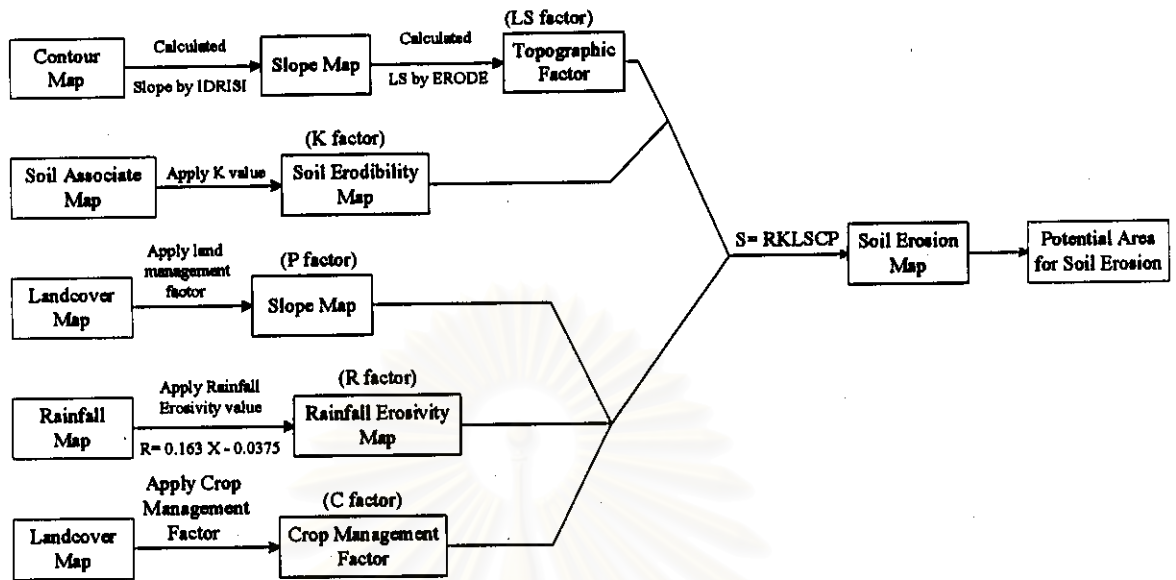
Figure 3-8 Process diagram of analysis for the potential of soil erosion on Sukhothai

Source: Modified from Boonyobhas (1996)

3.4 Factor According to Runoff

When rain falls on catchments, some of it infiltrates and some evaporates. The rest flow as surface water down to valleys to form streams, which then converge into a river. These flows take a finite time to reach any lower point. In heavy storms, the rate of accumulation of water at certain points may exceed the rate at which it can flow to lower points, and the level of water will rise, eventually causing flood. Buildings, crops, and grazing animals in the flood prone area will suffer damage.

The technique of the TR-55 model, which was developed by Soil Conservation Service (SCS), is used in this study to identify the potential for runoff, because the model is less complicated and the required data is simpler to obtain. Since this study intends to identify only the potential area for runoff on Sukhothai Province and not to calculate the actual amount of runoff, the TR-55 is most appropriate.

Erosion Rates

High Erosion

Moderate Erosion

Low Erosion

(tons/ha/yr)

Note

Potential area for Erosion Map created by USLE model

(a) output from USLE model
(b) Soil erosion rates of Sukhothai province
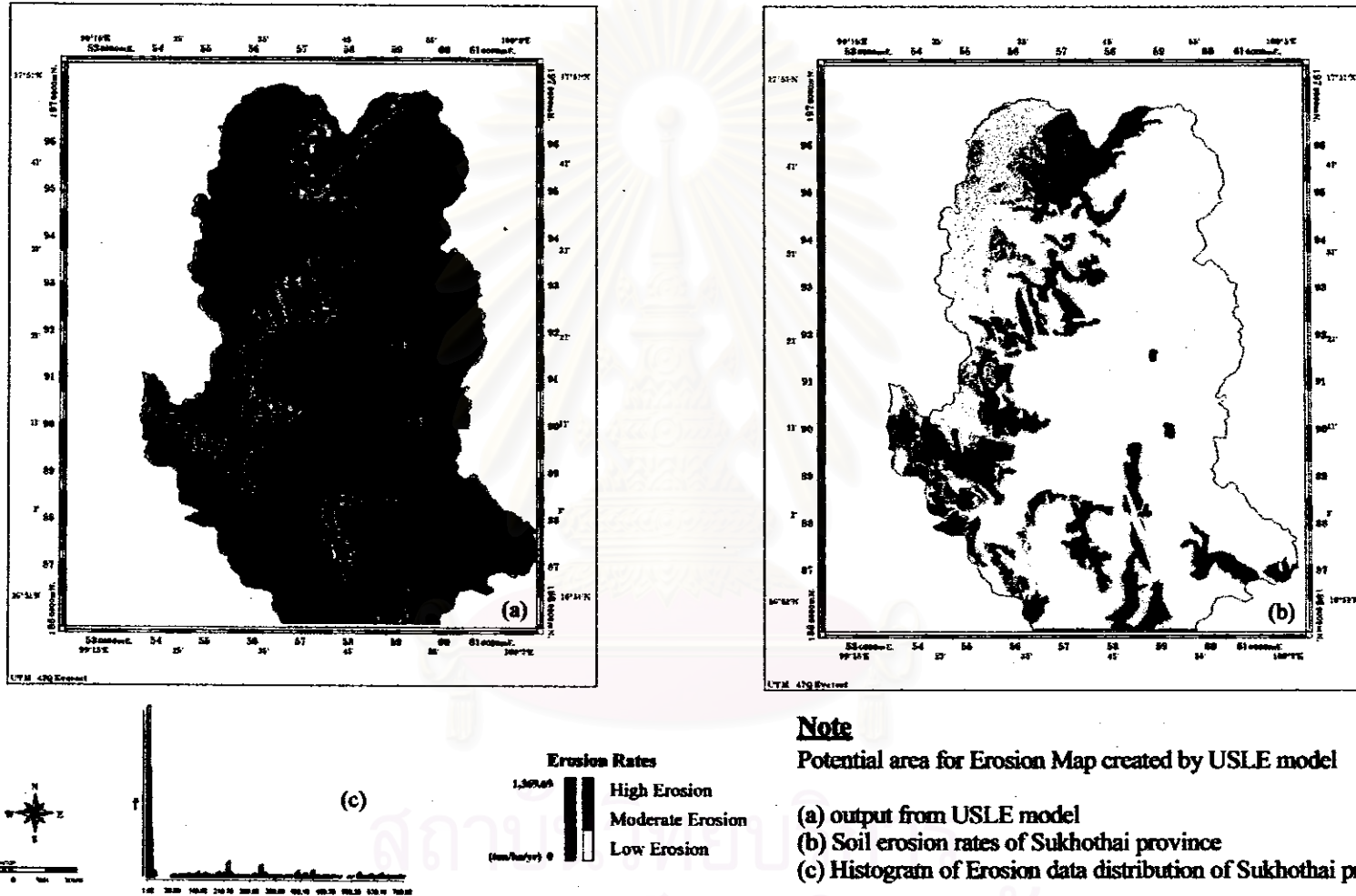(c) Histogram of Erosion data distribution of Sukhothai province

Figure 3-9 Soil erosion rates of Sukhothai province

The technique of the TR-55 model, which was developed by the Soil Conservation Service (SCS), is used in this study to identify the potential for runoff. The SCS runoff equation developed for TR-55 is

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Where

Q   runoff (in),

P   rainfall (in),

S   potential maximum retention after runoff begins (in), and

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by

$$S = \frac{1000}{CN} - 10$$

Where

CN is the value of the curve number

Unfortunately with limited information in this study to estimate the curve number which is appropriate for Sukhothai conditions. The first assumption is that the hydrological soil groups classified on Sukhothai are the same group as in the SCS categories. The second one is that the cover type listed in the table for runoff curve numbers for other agricultural land, the cover type of woods-grass combination (orchard or tree farm) in poor hydrologic condition, is the selected for Sukhothai condition. Figure 3-10 shows the process diagram for developing the potential for runoff map using TR-55 model, and figure 3-11 shows the potential for runoff map of Sukhothai. These areas are divided into three-category range from low potential to high potential for runoff.
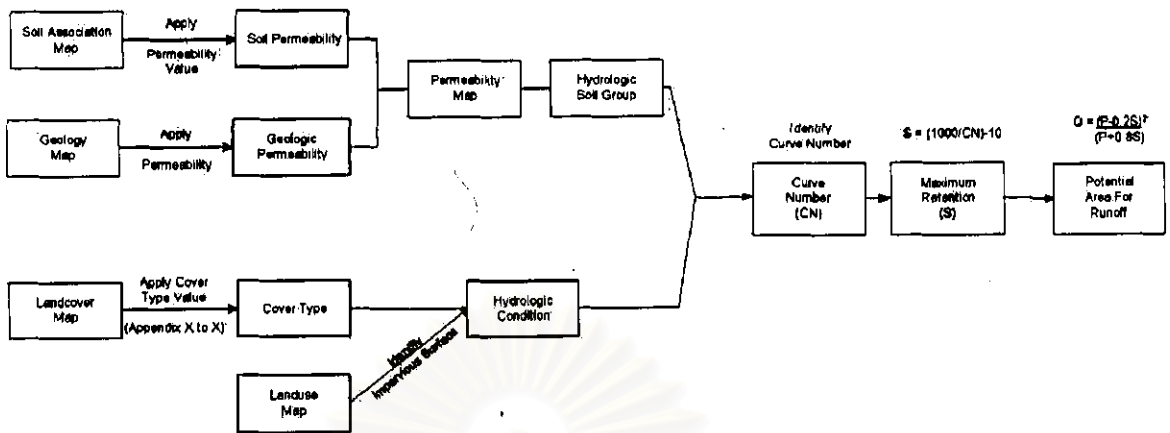
Figure 3-10 Process diagram for developing the potential for runoff map using TR-55 model

Source: Modified from Boonyobhas (1996)

3.5 Potential area according to Groundwater Contamination

Tourism increases wastewater and solid waste, which can be a major problem in some tourist destinations that were not prepared for such problems. Leachate from wastewater treatments and landfills can be major point sources for groundwater contamination while seepage from septic system is non-point source.

The permeability of soil and geology is one of the factors indicating a potential for groundwater contamination, because seepage from waste disposal can penetrate through the strata of soil and geology and contaminate groundwater. In cases where the area also has a high water table, the chance of contamination is higher. Groundwater is very important source of water supply in this province, which is irreplaceable if it is polluted; therefore, protection from contamination is necessary. The factors indicating the potential area for groundwater contamination include the permeability of soil and geology, which allow seepage and leachate to penetrate through the ground. The depth of water tables is other important factor if the area has a high level of water tables, and thus a high potential for contamination.

The groundwater level map is created from the water table level of the subsurface, which is inferred from soil characteristics, and the groundwater map. The area with high groundwater level has potential to be contaminated. The permeability

Figure 3-11 Runoff rates of Sukhothai province

Runoff Rates

High Runoff

Moderate Runoff

Low Runoff
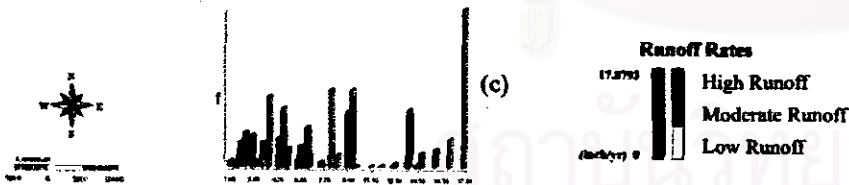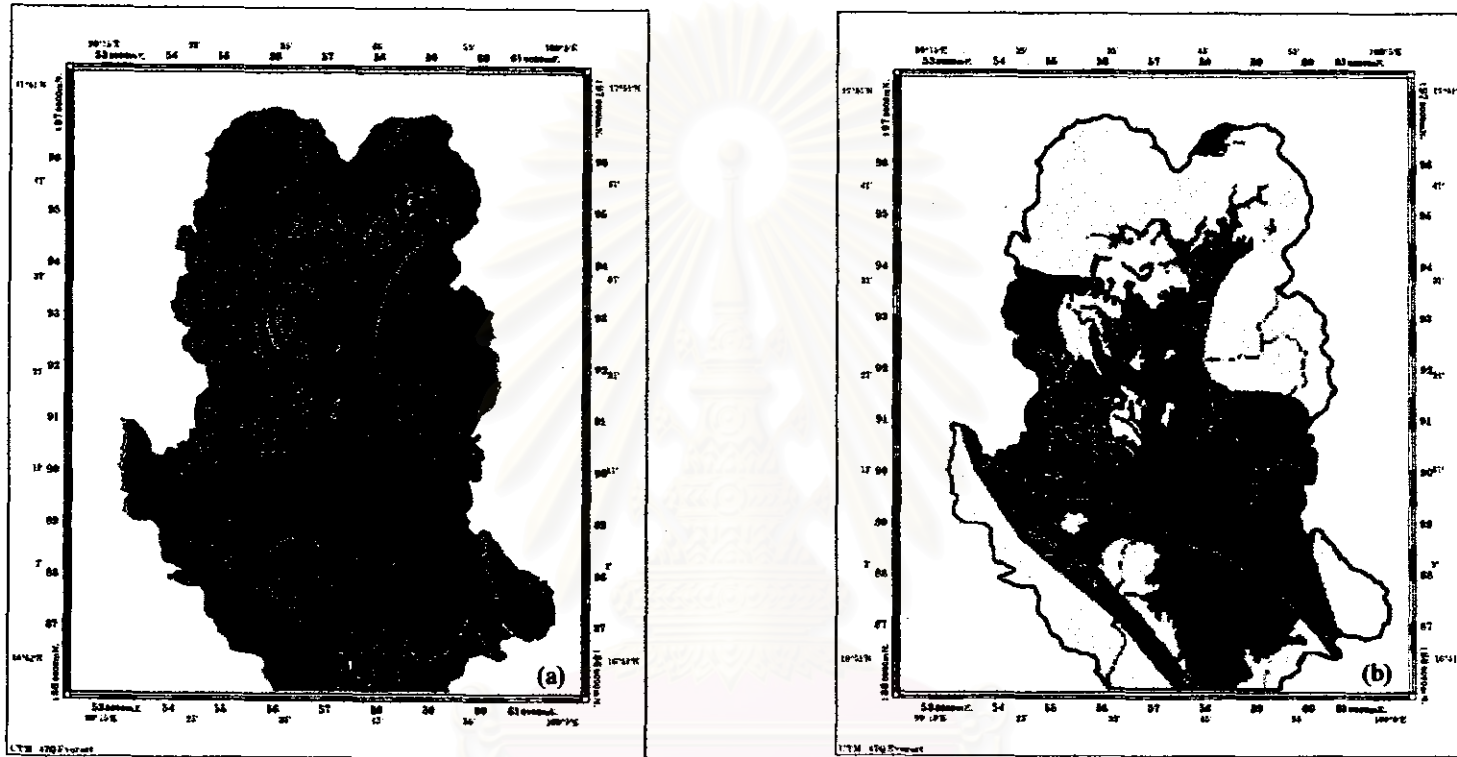
Note

Runoff Map calculated from TR-55 model
(a) output from TR-55 model
(b) grouped to new output
(c) histogram of runoff data before group

map, which is a combination of both soil and geology, indicated the percolation potential of the area, the higher permeability the better the percolation rate. This in turn raises the potential for groundwater to be contaminated.

Figure 3-12 presents the process diagram for indicating the potential area for groundwater contamination and Figure 3-13 shows areas with potential for groundwater contamination of Sukhothai. These areas are classified into three categories from low potential to high potential areas.


Figure 3-12 Process diagram for indicating the potential area for groundwater contamination

Source: Modified from Boonyobhas (1996)

3.6 Factor According to Flood risk

The major cause of flood disaster is the heavy rainfall during monsoon. However, minor factors increase severity of flood such as low lying area, deforestation, and poor land drainage, expanding agriculture land, and missing type of land use. That can seen obviously is the rapid development of urbanization, increase runoff and reducing of infiltration rate that cause the following problem; the reduction

Erosion Rates

High	High
	Moderate
Low	Low
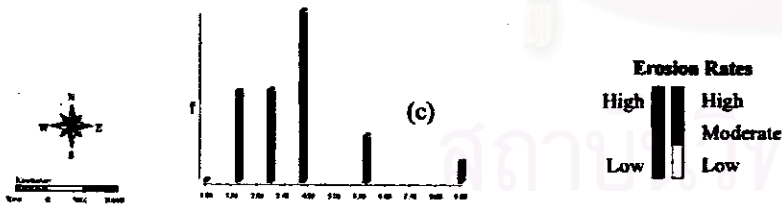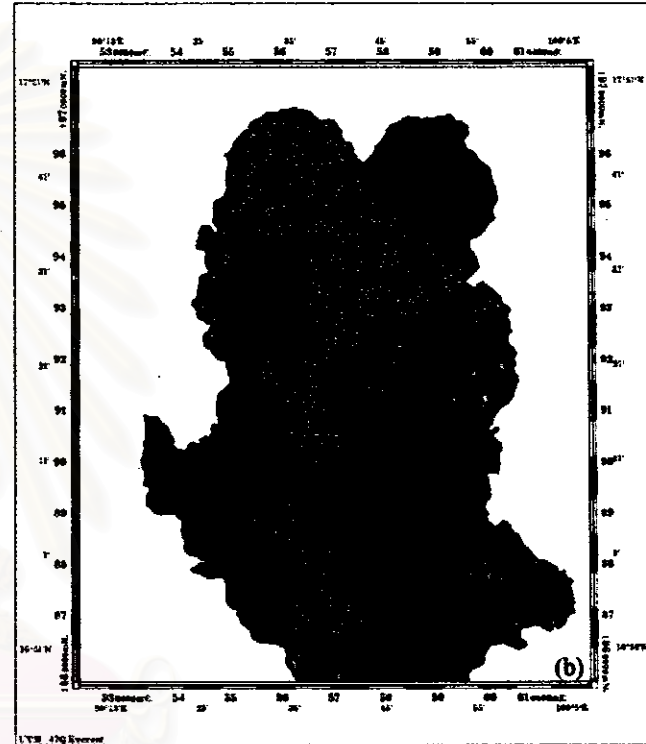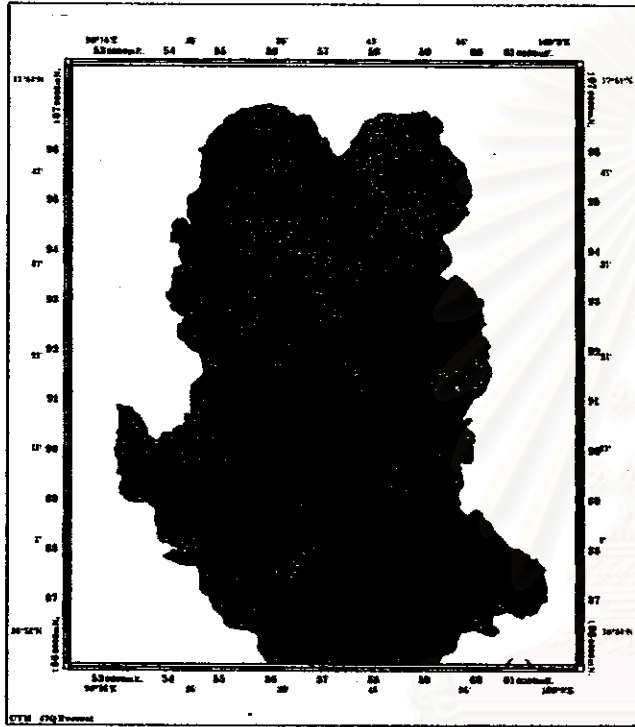
Note

Potential area for Groundwater Contamination Map
created by Overlay technique

(a) output from Overlay technique
(b) Groundwater Contamination risk of Sukhothai province
(c) Histogram of Groundwater contamination data

Figure 3-13 Groundwater contaminant of Sukhothai province

of natural flood storage, reduces the drainage efficiency, and causes the land subsidence. Thus, flooding problems are deteriorated and prolonged.

Damage from flooding has been increasing each year. It results in loss of lives property and production as well as affecting activities in the flooded areas. Large and long duration of flooding can be considered as the economic loss of country. Environmentally, flood affects directly to the people living and working in the flooded area in term of health impairment, risk of life and mental depression. It also affects soil erosion of agriculture land in the flood plain, stream sedimentation, water quality, habitat for fish and animal life, destruction of historical and archeological sites, etc.

The flood risk information, in this study used the result study of Kawinpoomstan (1997) in Yom River Basin include Sukhothai. This study deals with the Rainfall Frequency Analysis procedure which is the application of Rainfall-Runoff model (NAM model) and the Hydrodynamic model (MIKE-11) and the flood risk mapping to determine the inundation area of some importance area on the Yom River Basin.

The flood risk maps are developed base on the results from the hydrodynamic model by estimate the changes in flood plain inundation area for different return period of floods. The flood risk mapping is requiring as the first step of comprehensive flood loss prevention and management.

The Sukhothai flood plain is the large flood storage area. His study prepared on the topographical map of scale 1:10,000. This map represents the location of flooding, the maximum flood depth and duration of the flood. From this study, amphoe Muang Sukhothai, the duration of flooding varies from 31 day to 87 day and the maximum depth if 0.07-0.96 meter above the average bank elevation.

Notice

Flood Risk Map are result from Rainfall - Runoff Model
(NAM Model) and the Hydrodynamic model (MIKE-11)
This map created by estimate the chages in flood plain
inundating area for different return period of floods.
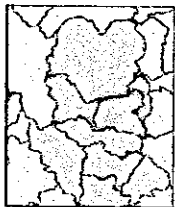
Flood Risk

- 2 Year Flood
- 5 Year Flood
- 10 Year Flood
- 25 Year Flood
- 50 Year Flood
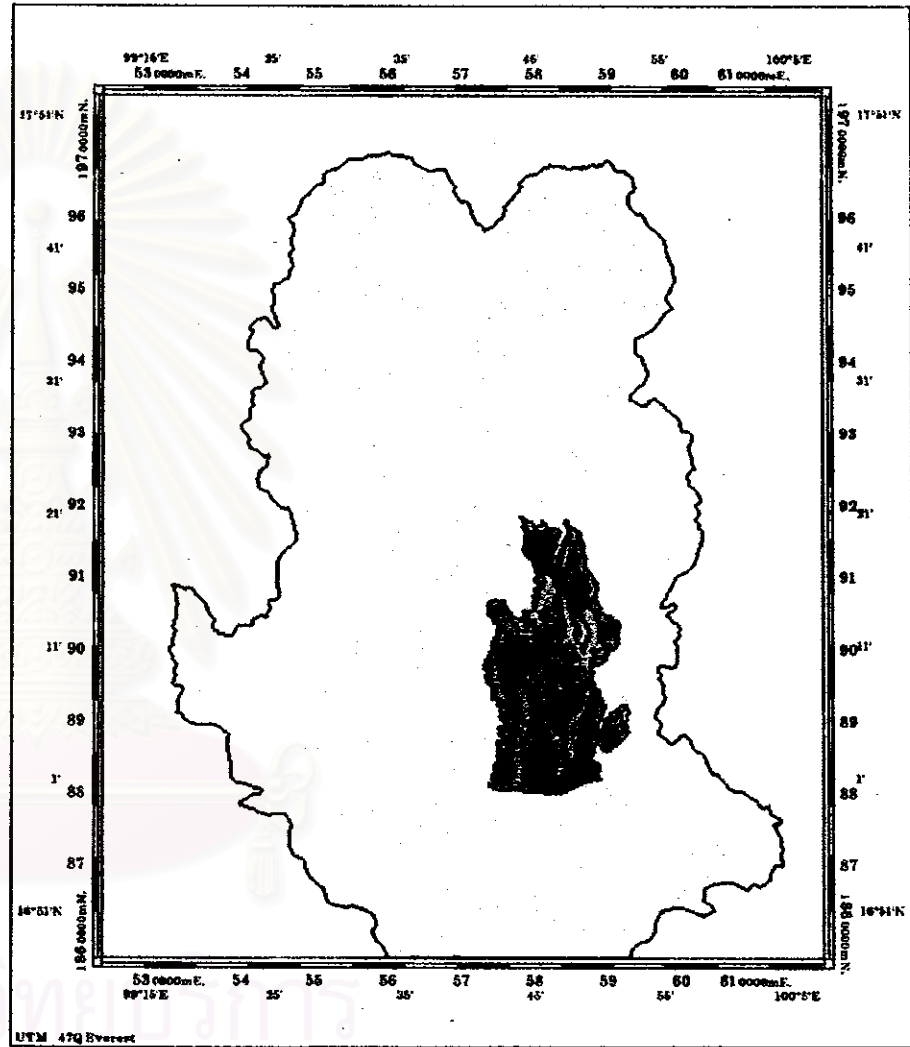- 100 Year Flood
- No Risk

Figure 3-14 Flood Risk Map of Sukhothai Province

3.7 Factor According to Topographic Slope

The need to consider topography in planning is an outgrowth of the widespread realization not only that land uses have slope limitations but also those slopes have been misused in modern land development. The misuse arises from two types of practices: (1) the placement of structures and facility on slope that are already unstable; and (2) the disturbance of stable slopes resulting failure accelerated erosion, and/or ecological deterioration of the slope environment. Marsh (1991) recommended the suitable area for construct building must lower than 18 percent. This study used topographic contour map prepared by the Royal Thai Survey. It then determined the inclination of a slope from the digitized topographic contour map.

3.8 Potential Factor According to Legalistic Constraints

Governmental Constraint and Environmental Law are very important constraint for selecting places to construct tourist accommodation. Governmental constraint which included Environmental Impact Assessment guidelines for hotel and accommodation development project and constraint from Environmental law, e.g. Enhancement and Conservation of National Environmental Quality Act, B.E. 2535 (A.D. 1992), National Park Act B.E. 2504 (A.D.1961), National Reserved Forest Act B.E. 2507 (A.D.1964), National Reserved Forest Act B.E. 2507 (A.D.1964).

There are group of act such as Building control Act B.E. 2522 (A.D.1979), Notification of Ministry of Science Technology and Environment issued under the National Environment Quality Act B.E. 2535 (A.D.1992), Town Planning Act. B.E. 2518 (A.D. 1975).

This study did not concern to build the constraint criteria from Building control Act B.E. 2522 (A.D.1979) because scope of this study provide the provincial scale of suitability area for developing the tourist accommodation. Constraint areas according to such act are very small when make constraint area in provincial scale.

Note

Slope Constrain Map created by reclassify DEM image into 2 class area lower than 18% and area higher than 18%.
(a) output from DEM
(b) grouped to new output
(c) histogram of slope data before group

Slope Constrain
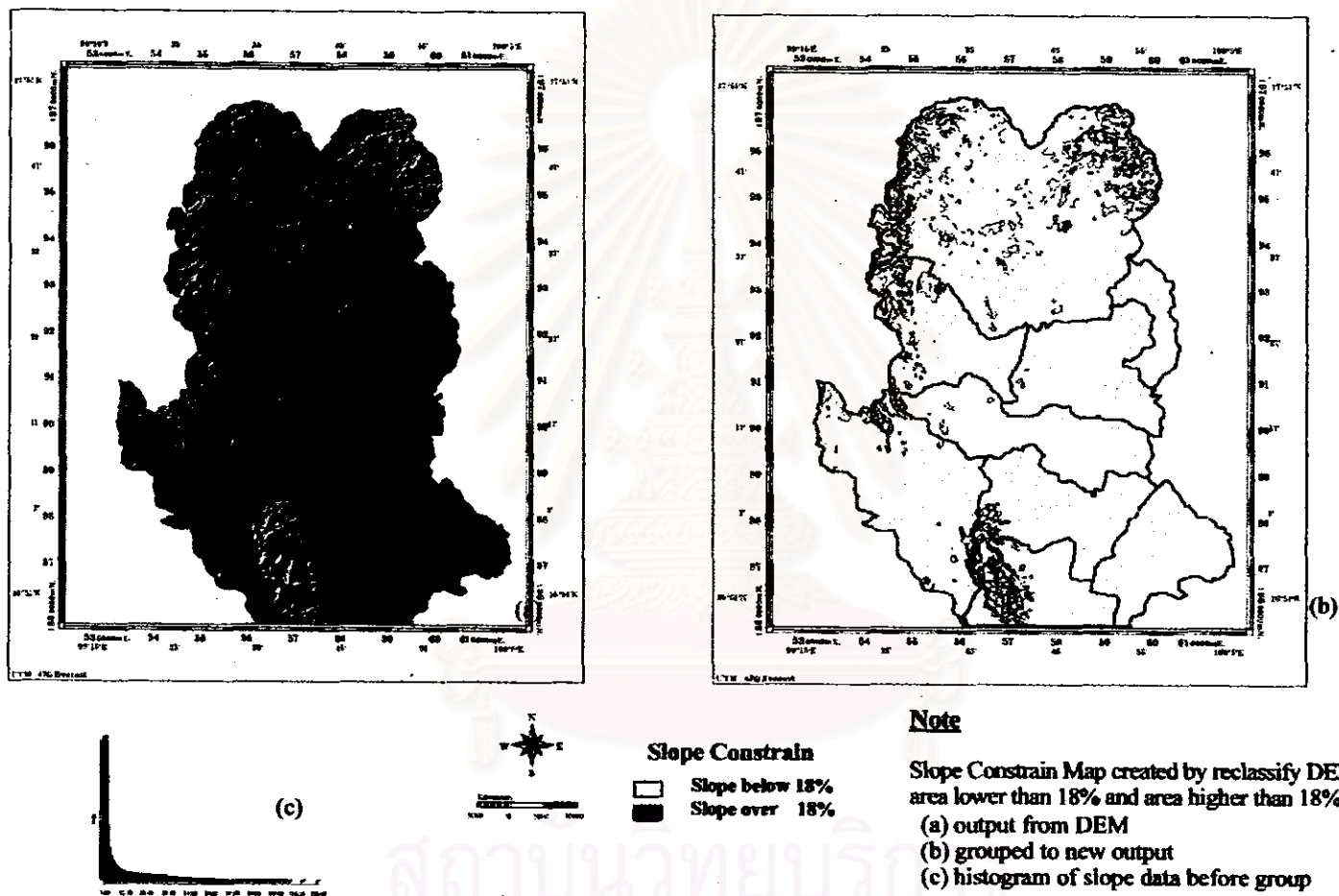☐ Slope below 18%
■ Slope over 18%

Figure 3-15 Slope constraint of Sukhothai province

From the list of Act which list in this section, all of act can be categorized into 3 groups of constraints are forest act constraints, historical act constraint and EIA act, and related notification from various ministry constraints. Figures 3-16, Figure 3-17, Figure 3-18 and Figure 3-19 show the workflow to generate the constraint map and the derived constraint respectively constraint maps.
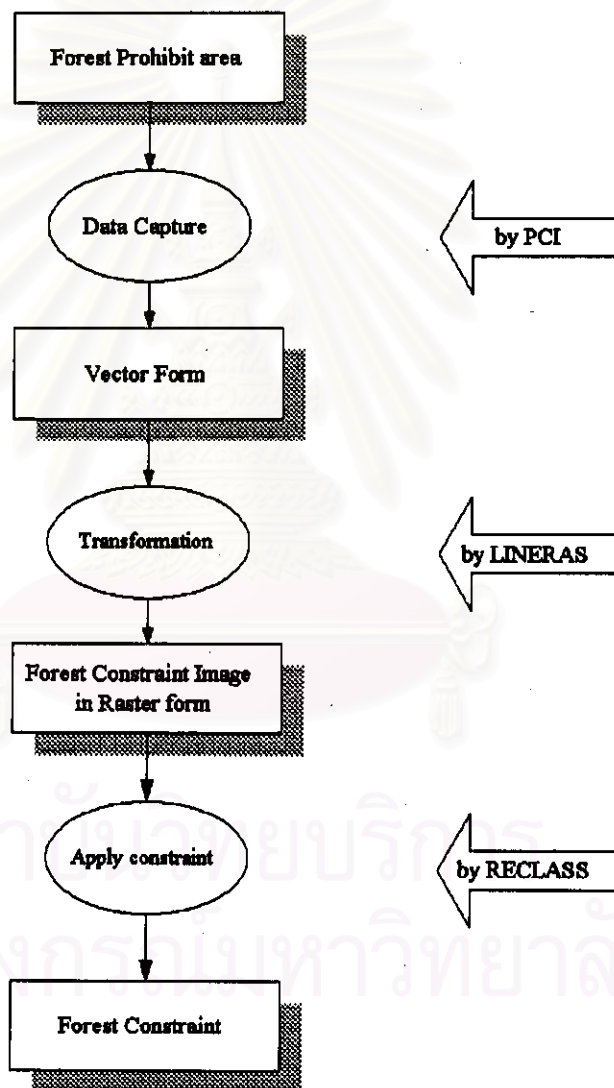

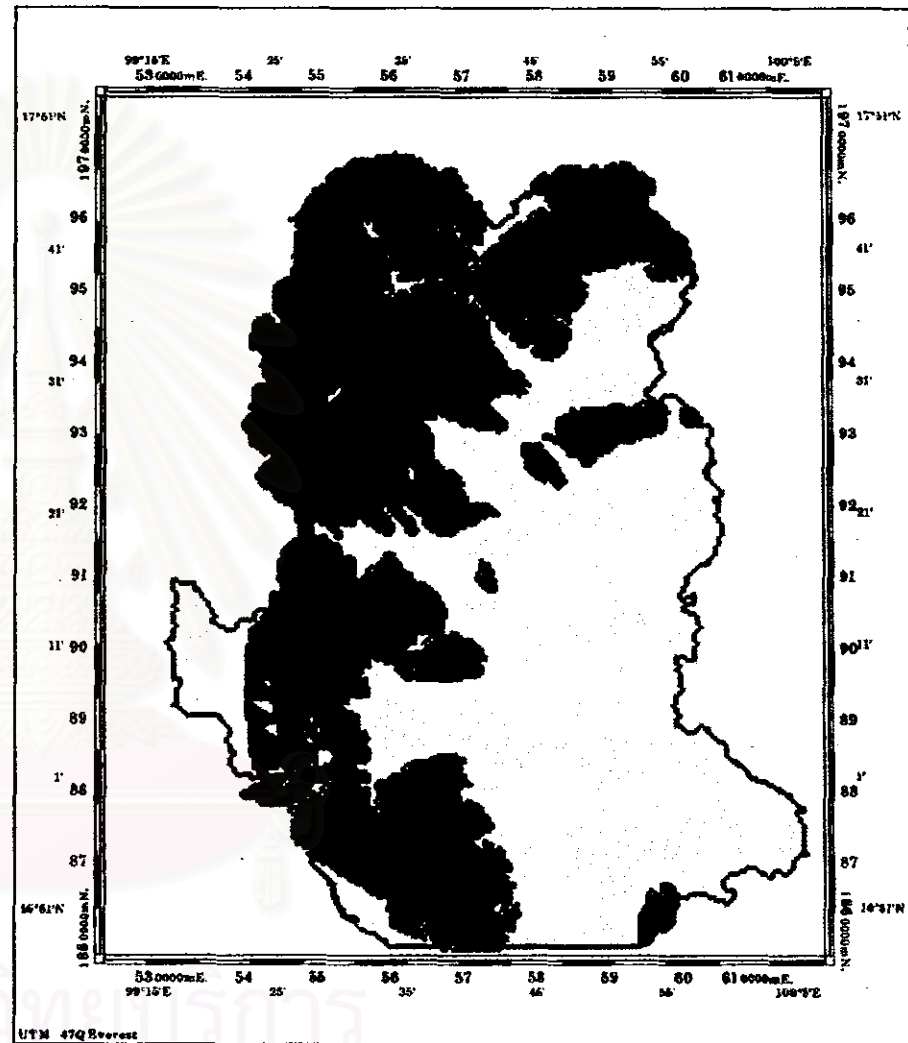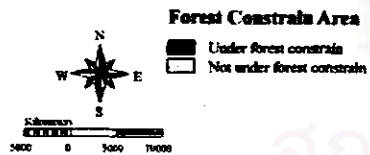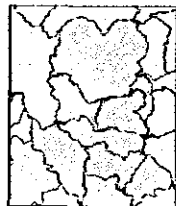**Figure 3-16** Database Development Workflow for Forest and Protected Area
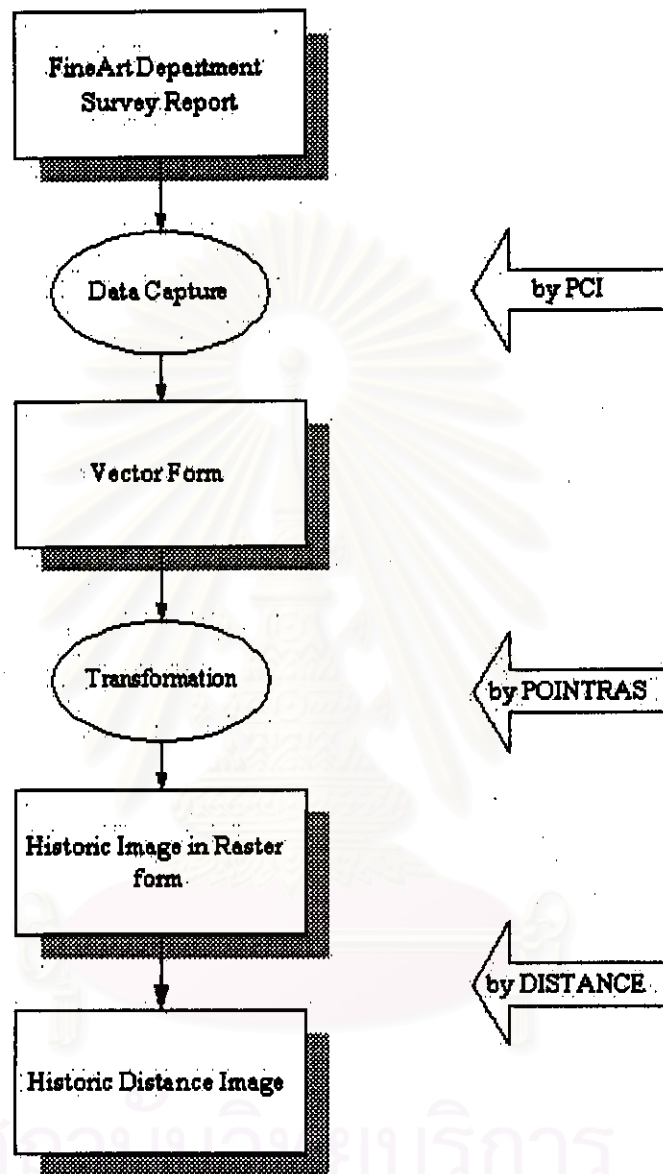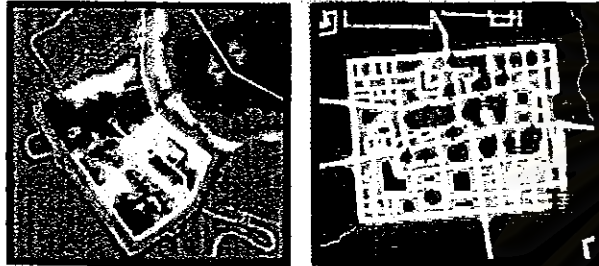
Figure 3- 17 Forest prohibit area of Sukhothai province

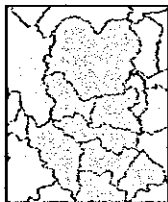**Figure 3-18** Database Development Workflow for historical Constraint Area

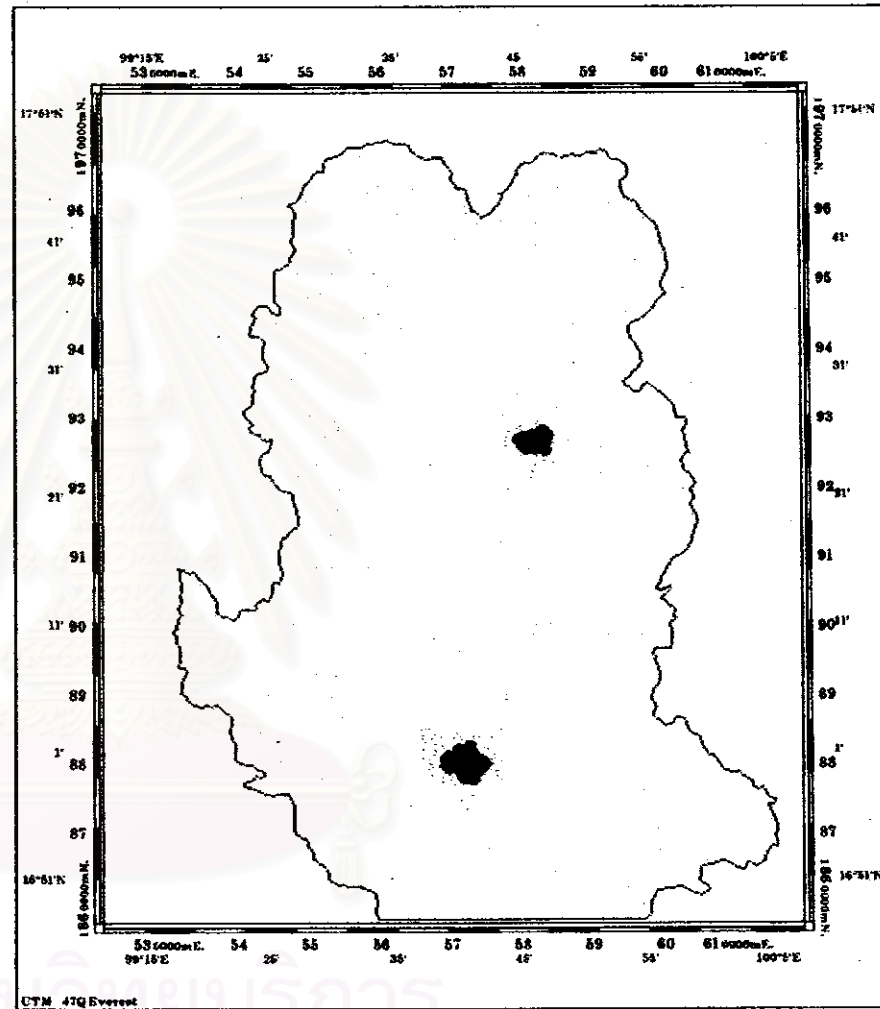Source: Modified from Boonyobhas (1996)

Figure 3-19 Historic constraint of Sukhothai province

3.9 Factor according to Infrastructure Facilities and Scenic supports

These factors are considered as supporting conditions for accommodation development. These are water supply, distance from existing transportation system and river view scenic spots.

3.9.1 Water Supply

The distance from natural water supply was an important factor for tourist accommodation development because of the stability of water to supply the tourist demand and cost of water from natural water supply were cheaper than municipality water work. These constraints are the alternative source of water supply when selected area not have municipality water supply. To obtain this factor, river and surface water were digitized into vector format from the scanned 1:50,000 topographical map of the study area by PCI and registered to the UTM reference. The vector data were transformed into a raster from by IDRISI software.

In this analysis, a simple overlay technique is used. The data maps required for this analysis is the groundwater availability, and distance from river and inland water reservoir. In this study, set up arbitrarily distance from both side of river bank 500 meters and 100 meters from inland water reservoir. Data on each map are rated according to scale of 1 to 10. The groundwater volume and groundwater depth are overlay together; then overlay with distance from river and water reservoirs then grouping result map into the water supply constraint map.
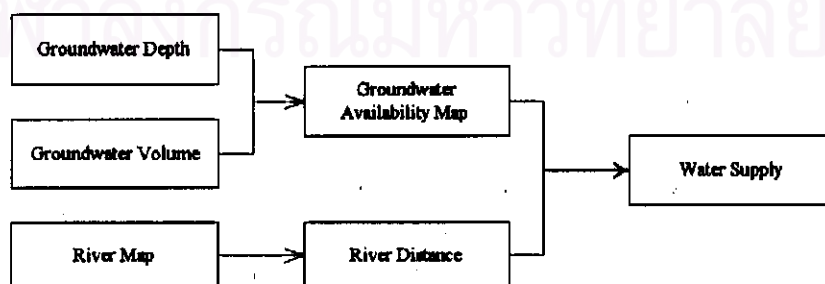
Figure 3-20 The Process Diagram of Water Supply Constraint

Note

Potential area for water supply create from Overlay data from groundwater availability. distance from river and inland water and area in public waterwork support.
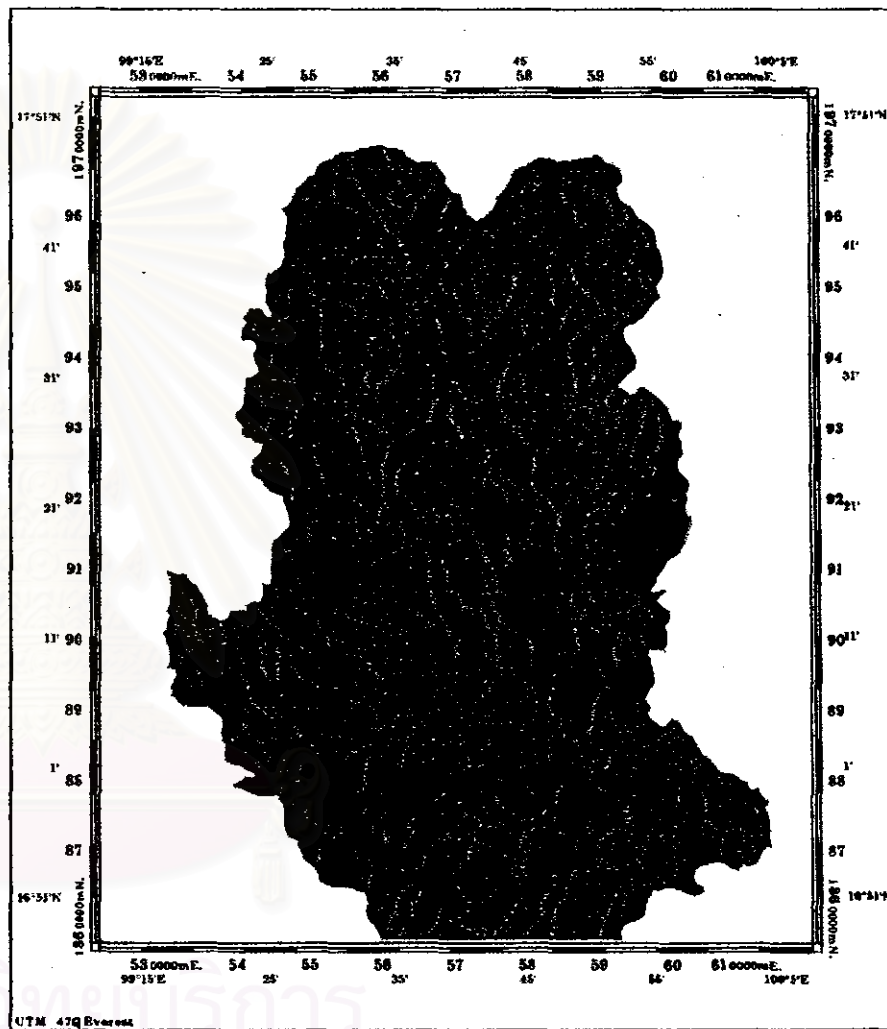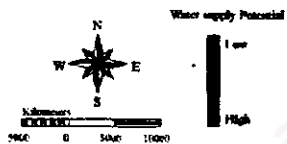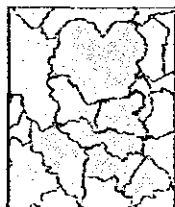
Figure 3-21 Water supply constrain of Sukhothai province

3.9.2 Transportation Facility

The distance from Transportation facility was an important factor for tourist accommodation development because of the accessibility to tourism area depends on the road distance. The accommodation place that exists near the road would have the potential for development. In this study set up arbitrarily distance to concern about transportation accessibility is 500 meter both side from the road.

To obtain this factor, major transportation system (1 or more lane wide) as digitized into a vector from the scanned 1:50,000 topographical map of the study area by PCI and registered to the UTM reference. The vector data were transformed into a raster from by IDRISI software (Figure 3-23).
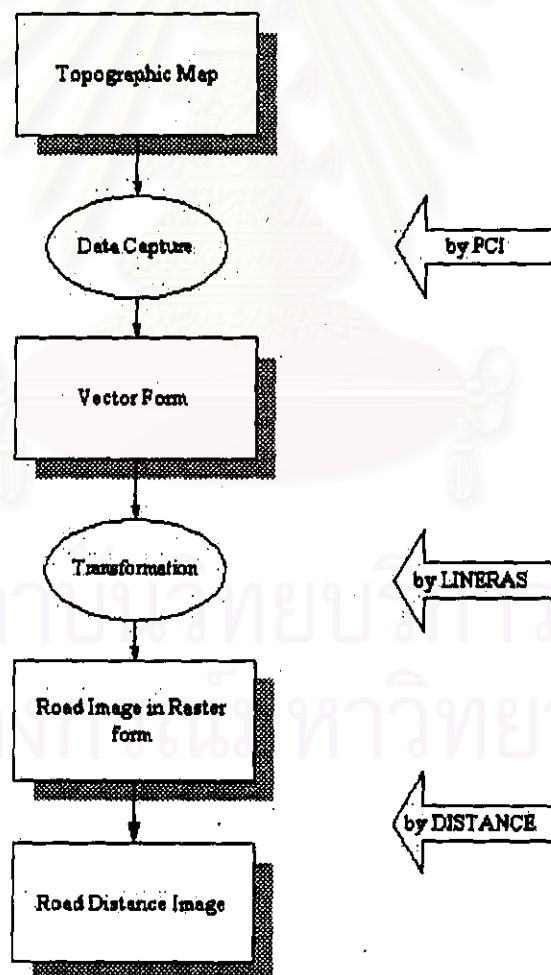
Figure 3-22 Database Development Workflow for Transportation accessibility factor

3.9.3 River Scenic Distance

The distance from River was an important factor for natural tourism because of the attractive for tourist. Most of Tourist accommodate suited near the river would be quite advantageous. In this study only the River Yom was selected, because of the volume of water along the year, and Yom River is the large River which flow across this province from North to South and have activities of people interacting with this river which make it lively. The study had set up an arbitrarily distance to concern about river scenic distance is 100 meter both side from the river.

To obtain this factor, digitized into a vector from the scanned 1:50,000 topographical map of the study area by PCI and registered to the UTM reference. The vector data were transformed into a raster from by IDRISI software.
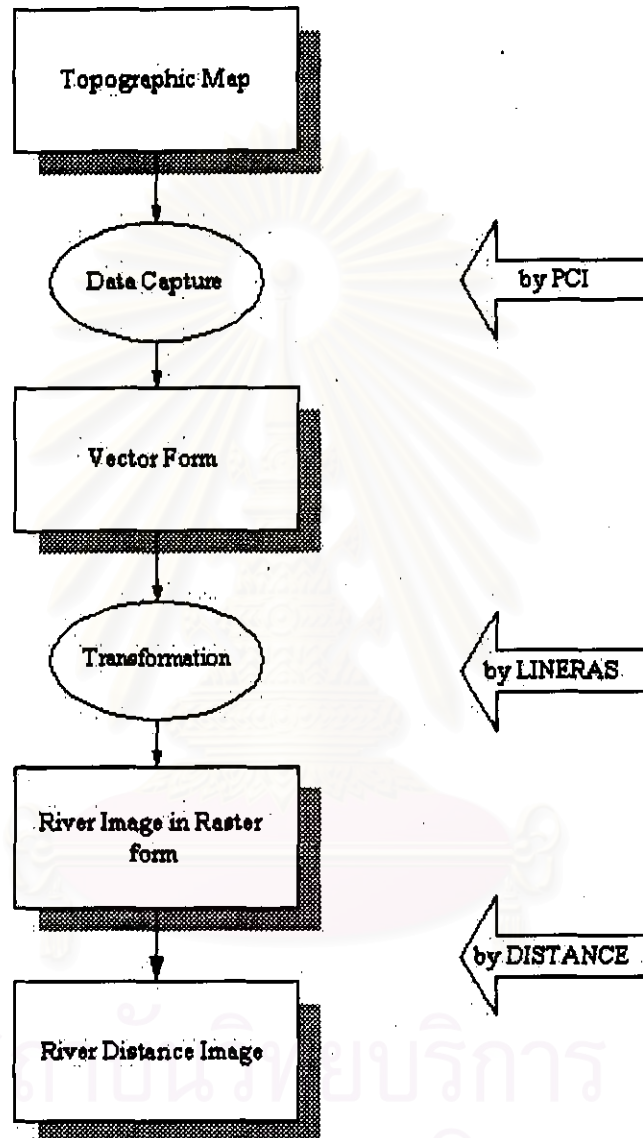
Figure 3-23 Database Development Workflow for River Scenic Distance

Note

River scenic distance created by buffer 100 meter from river Yom

River Scenic Distance

River Yom buffer 100 m

Study area
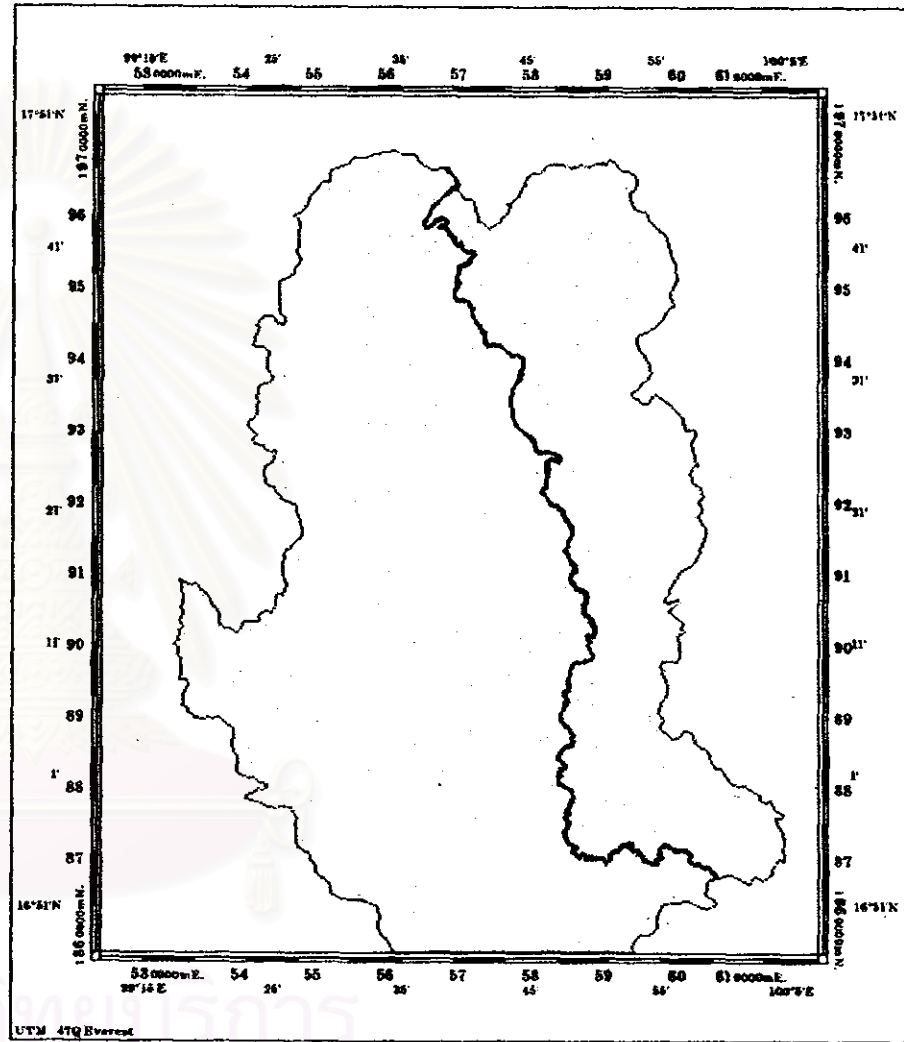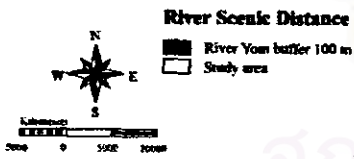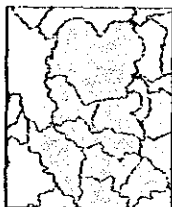
Figure 3-25 River scenic distance of Sukhothai province
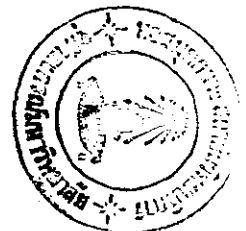
3.10 Criteria Decision Procedure

This objective of this process is to combine, factors into a single decision image, which can be called a suitability or potential map. Factors were combined in the form of a weighted linear combination. This procedure can be done as follow.

3.10.1 Standardizing Criteria to a common scale

Before criteria combination, it is necessary that factors be standardized because of the different scales. This mean that the worst criterion score will always have a standardize score of 0, and the best a score of 1 (Eastman et al., 1995). To standardize to the same scale, we can apply a simple linear stretch (e.g. IDRISI module STRETCH, the dame that is applied to images). STRETCH procedure re-scales image values to fall within a range from the data values. It is used to standardize multiple criteria image to a common scale before combining them with Multi Criteria Evaluation.

$$x_i = \frac{(r_i - r_{min})}{(r_{max} - r_{min})} * m$$

Where r is the raw scores in the original units of measure and m is an arbitrary multiplier.

Through standardization, criterion scores will be expressed according to a consistent numeric range (e.g., 0-99, 0-255, etc). In the case of IDRISI, the stretch

3.10.2 Fuzzy set building

Fuzzy Sets are sets (or classes) without sharp boundaries; that is, the transition between membership and non-membership of a location in the set is gradual (Zadeh, 1965). A Fuzzy Set is characterized by a fuzzy membership grade (also called a possibility) that ranges from 0.0 to 1.0, indicating a continuous increase from non-membership to complete membership. In this study selected, the sigmoidal ("S-shaped") membership function was selected, as it is the most commonly used function in Fuzzy Set theory. It is produced using a cosine function, which requires the positions (along the X-axis) of 4 points governing the shape of the curve. These are

indicated in the figure below as points a, b, c, d, and represent the inflection points of the curve as follows:

a	membership rises above 0
b	membership becomes 1
c	membership falls below 1
d	membership becomes 0
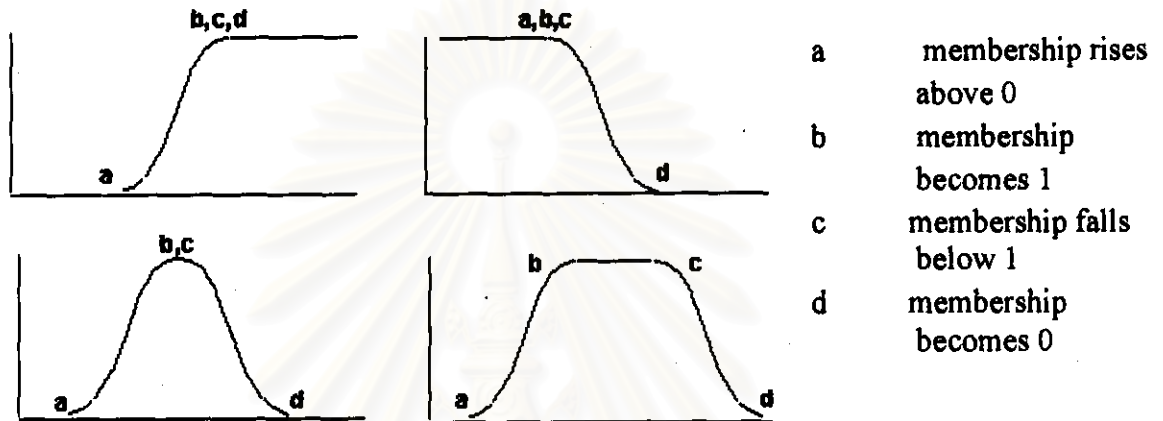
Figure 3-25 Sigmoid shape of Fuzzy set

The Sigmoidal Membership function figure below shows a monotonically increasing, monotonically decreasing, and two symmetric membership curves at the upper left, upper right, lower left and lower right respectively. In the monotonically increasing case, the value given for inflection point's b, c, and d are identical. Similarly, in the monotonically decreasing function, a, b and c have identical values.

3.10.3 Assign Criterion Weights

Many tickers are how to weight the criterion. This is often a subjective decision. For example, how much more important is 'gentle slope', compared to 'bedrock geology', when deciding where to locate a new accommodate site? Weights or criteria priorities refer to specify the important of individual factors relate to the others included in the evaluation. The development of weights technique for this study used pair-wise comparison, which in the context of decision-making process

know as Analytical Hierarchy Process that compares each factor in pair until a self-consistent set of weights is found. The experts assign an importance to each criterion, on the following scale:

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very strong	Strongly	Moderately	Equally	Moderately	Strongly	Very strong	Extremely

Less Important   More Important

Then, a matrix is created (actually, only one half of the symmetric matrix must be filled in) containing $n^2/2$-n comparisons (the diagonals are always 1, i.e., a factor is equal in importance to itself).

Principle component of this matrix gives the principle eigenvector of the matrix, which is exactly the best estimate of the factor ratings to be used in the multi criteria evaluation. The weights will sum to one. At the same time, the other eigenvectors can indicate how consistent are the pairwise comparisons given by expert.

3.11 Setting up GIS for study effects when changing classification range

3.11.1 Setting up classes for physical environment factors

This study apply previous criteria classification range from previous study e.g. soil erosion and runoff criteria classification key from Boonyobhas (1996), groundwater depth and groundwater volume to created groundwater contamination potential from the study of Chula-Unisearch, Chulalongkorn University (1997), flood risk from Kawinpoomstan (1997) to make the flood constraint in Sukhothai province and slope suitable for developing tourist accommodation from Marsh (1991). Calculating the suitability area requires evaluating whether a pixel falls into the set describing each criterion. There are two major types of sets in the classification range; crisp set and fuzzy sets. Set with a well-defined boundary (Crisp Sets) and sets with a vague defined boundary (Fuzzy Sets). Table 3-2 summarizes the criteria used.

Table 3-1 Original physical environment criteria use in this study

Physical Environment Categories	Classification Range	Source
Soil Erosion	Severe Erosion (> 50 ton/ha. /yr) High Erosion (26-50 ton/ha. /yr) Moderate Erosion (15-26 ton/ha. /yr) Low Erosion (< 15 ton/ha. /yr)	
Runoff	High Runoff (> 15 inch/yr) Moderate Runoff (10-15 inch/yr) Low Runoff (<10 inch/yr)	
Groundwater Depth	Deep (> 110 meters) Medium (50-110 meters) Shallow (< 50 meters)	Chulalongkorn-Unisearch (1997)
Groundwater Volume	High (> 80 m^3 /hr) Medium (40-80 m^3 /hr) Low (< 40 m^3 /hr)	Chulalongkorn-Unisearch (1997)
Slope	Suitable (not more than 18 %) Unsuitable (more than 18 %)	Marsh (1991)

Each factor is of equal importance to itself. For setting up the pairwise comparison matrix in this study setting the arbitrary weighting importance between each categories. Flood Risk was highly importance. Slope was high importance than soil erosion, runoff and groundwater contamination.

Table 3-2 Pairwise Comparison Matrix for calculated physical environment potential area for tourist accommodation development

Categories	Flood Risk	Slope	Soil Erosion	Runoff	Groundwater Contamination
Flood Risk	1				
Slope	1/3	1			
Soil Erosion	1	4	1		
Runoff	1/5	2	1/7	1	
Groundwater Contamination	1/3	2	1/3	4	1

The factor score was calculated into the weights by WEIGHT module in IDRISI. The formula for factors weighting calculation were defined as:

$$W_i = \frac{\sum_{j=1}^{k} S_i}{\sum_{j=1}^{k} \sum_{i=1}^{k} S}$$

Where W_i =   factors weighting

     S   =   factor score

     i   =   row i^{th} of matrix

     j   =   column j^{th} of matrix

     k   =   the number of row and column of matrix

Then provided the result in Table 3-4.

Table 3-3 Weighting from pairwise comparison Matrix for Calculate physical environment potential area for tourist accommodation development

Factors	Weighting
Flooding	0.3296
Slope	0.0736
Erosion	0.3704
Runoff	0.0711
Groundwater Contamination	0.1552
Total	1.0000

3.11.2 Weights combination

The WEIGHT procedure is used to develop a set of relative weights for a group of factors in a multi-criteria evaluation. Providing a series of pairwise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated develops the weights. These pairwise comparisons are then analyzed to produce a set of weights that sum to one. The factors and their resulting weights can be used as input for the MCE module for weighted linear combination or ordered weighted average. Weighted linear combination was performed by the Multi Criteria Evaluation (MCE) module in IDRISI with 5 factors and their weights and indicated the 2-parameter constraints. These constraints were Forest constraint and Historic Area constraint.

In this study, the Weighted Linear Combination (WLC) option where criteria may include both weighted factors and constraints was used. WLC starts by multiplying each factor by its factor/tradeoff weight and then adding the results; constraints are then applied by successive multiplication to "zero out" excluded areas. The result was a suitability map. The weighted linear combination could define as

$$S = \sum W_i X_i C_j$$

Where

S   suitability

W_i weight of factor I

X_i criterion score of factor I

Cj   criterion score (0,1) of constraint j

The weights generated by this module are produced by means of the principal eigenvector of the pairwise comparison matrix. This procedure is characterized by full tradeoff between factors and average risk. In this case, the higher the factor-weight the more influence that factor has on the final suitability map. Along with full tradeoff, an average level of risk characterizes this combination procedure, as it is exactly midway between the minimization (AND operation) and maximization (OR operation) of areas to be considered suitable in the result.

3.11.3 Varying the classes of physical environment factors

In order to understand the effect of class-boundary variation, which could occur when decision making are carried out without an exact criteria, criteria in the previous section were systematically varied. In this study setting arbitrary level to verify the classification ranges for each physical environment were categorized into 17 scenarios. This study set different level to verified effect of changing weight range by changing 5% of ordinary classification range to make the range systematic value to compare effects would occurred. Details of these scenarios are shown in Table 3-5.

3.11.4 Potential Site Selection

Selecting the potential area for tourist accommodation development in Sukhothai province was determined from technical grounds and environmental concerns. The study proposes that areas suitable for developing accommodation area must meet the following conditions.

- It must not be in historical area

- It must not be in forest constraint area cover by forest law

- It must not be in flood risk area

- It must not be in high potential of erosion area.

- It must not be in area high potential for surface water runoff area

- It must not be in high potential for groundwater contamination area

- It must not be in area which have slope more than 18%

- It should be located in area which have infrastructure support

- It should be easy to access

- It should be located near river

The study did not include socio-economics factors for the selecting suitability area process. Although these factors can affect the site selection, but this study scope on effect when apply varies set theory; fuzzy set and crisp set into various physical environment classification. Persons who want to use this study for selecting suitable area for tourist accommodation development will concern the limitation of this study.

Table 3-4 List of criteria to study effect when changing classification range

Criteria	Soil Erosion	Runoff	Groundwater Level	Groundwater volume	Slope	Remark
1						Use ordinary level as describe in Table 3-2
2						Use ordinary level and apply fuzzy set
3	+5%					Change soil erosion level by increasing 5 % of ordinary range
4	-5%					Change soil erosion level by decreasing 5 % of ordinary range
5	+10%					Change soil erosion level by increasing 10 % of ordinary range
6		+5%				Change runoff level by increasing 5 % of ordinary range
7		-5%				Change runoff level by decreasing 5 % of ordinary range
8		+10%				Change runoff level by increasing 10 % of ordinary range
9			+5%			Change groundwater depth level by increasing 5 % of ordinary range
10			-5%			Change groundwater depth level by decreasing 5 % of ordinary range
11			+10%			Change groundwater depth level by increasing 10 % of ordinary range

Table 3-4 (contd.) List of criteria to study effect when changing classification range

Criteria	Soil Erosion	Runoff	Groundwater Level	Groundwater volume	Slope	Remark
12				+5%		Change groundwater volume level by increasing 5 % of ordinary range
13				-5%		Change groundwater volume level by decreasing 5 % of ordinary range
14				+10%		Change groundwater volume level by increasing 10 % of ordinary range
15					+5%	Change slope level by increasing 5 % of ordinary range
16					-5%	Change slope level by decreasing 5 % of ordinary range
17					+10%	Change slope level by increasing 10 % of ordinary range

Note: Blank value means use ordinary classified range.

After the environmental impacts potential that are potentials for soil erosion, runoff, groundwater contamination, surface steepness, EIA guidelines, and infrastructure supports are defined, the integration of these impacts potential is necessary. This integration is required because most of the time the impacts occurs simultaneously to each other within an area; in fact, one impact can increase the severity of the other. Prior to the integration, each impact potential map needs to be evaluated, and the potential need to be grouped into three categories; high potential, moderate potential and low potential.

From the conditions for selecting tourist accommodation development, degree of the appropriateness can be calculated. Suggestions from environmental decision-making, environmental expert, forest scientist, investor and land planner valued the contributing levels of each condition. The information and the criteria were used to calculate degree of appropriateness using the following equation.

$$Poss = S_{\neg_H} \bullet S_{\neg_F} \bullet [W_P S_P + W_T S_T + W_R S_R + W_W S_W]$$

Where $S_{\neg_H}$ = 1 if the area <u>is not</u> a historical area

            = 0 if the area <u>is</u> a historical area

    $S_{\neg_F}$ = 1 if the area <u>is not in</u> a forest conservation area

            = 0 if the area <u>is in</u> a forest conservation area

    S_P = 1 if the area <u>has</u> low physical environment effect

            = 0 if the area <u>does not has</u> low physical environment effect

    S_T = 1 if the area <u>is close</u> to a road

            = 0 if the area <u>is not close</u> to a road

    S_R = 1 if the area <u>is close</u> to river

            = 0 if the area <u>is not close</u> to river

    S_W = 1 if the area <u>has</u> high water supply

            = 0 if the area <u>has</u> low water supply

$W_H, W_F, W_P, W_T, W_R, W_W$ = weights assigned to each contributing factors, and

    Poss   = appropriateness level for developing tourist accommodation

The relation shows that any area situating in a historic area ($S\neg_H = 0$), in a forest conservation area ($S\neg_F = 0$) is not suitable for tourist accommodation development (since it will have $Poss = 0$).

For areas not in the prohibit zone, values of $Poss$ depend on degree that the areas meet the proposed criteria. If all the criteria are met, value of $Poss$ will equal to ($W_P + W_T + W_R + W_W$).

a. Evaluating the criteria

Calculating the $Poss$ value requires evaluating whether a pixel fall into the set describing each criterion. There are two major types of sets in the classification range; crisp set and fuzzy sets. To estimate a membership level of x in set A, a sigmoid function has the following from

$$\mu_A(x) = \cos^2 \alpha$$

Where $\alpha = \pi/2*(x-x_2)/(x_2-x_1)$ if μ_A is a monotonically increasing function

Where $\alpha = \pi/2*(x-x_2)/(x_1-x_2)$ if μ_A is a monotonically decreasing function

x_1 and x_2 ($x_1 < x < x_2$) are estimated (crisp) point where x is certainly not a member of A if $x < x_1$ or $x > x_2$

b. Calculating Poss

Procedures to calculate the suitability values comprise three steps. First, calculating distances from subjects. The distance is defined as a minimum orthogonal length between the considering point and the considering subjects. The seconds are calculating membership value by using stepwise function (for crisp sets) and sigmoid function (for fuzzy sets) and the last step is calculating values of $Poss$.

This study considered that the effect of physical environment effects such as soil erosion, surface water runoff, groundwater contamination risk, flooding are the most significant factor of tourist accommodation development in Sukhothai

province. Following significant factor is the distance from road, distance from river and water.

To select the best site uses RECLASS module from IDRISI. Its primary application is in decision-making where a specific area (or number of cells) is required that contains the best, or worst, cells according to some index. By grouping cells and then reclassifying the result into new category, a specific number of the best or worst ranks can be determined. This stage generated output image, which has a 25-meter cell size then reclassified the image by using RECLASS module. Its reclassifies the data stored in images or attribute values files into new integer categories.

The calculated *Poss* ranges from 1 to 255. Areas having the *Poss* = 1 meet all the suggested conditions. *Poss* increased, as fewer criterions are met degree of satisfactory increase. This study assigned five levels of suitability to the areas as:

Most Suitability $(1 \leq Poss < 100)$

Moderately Suitability $(100 \leq Poss < 150)$

Least Suitability $(150 \leq Poss \geq 200)$

Table 3-5 Determination of sets in the proposing criteria

Set	Meaning	Consideration
$S_{\neg H}$	Not in Historic Area	Use Historic Constraint map and apply distances from historical sites an area is "not" quite far if x < 1,000 m an area is certainly "too" far if x > 10,000 m
$S_{\neg F}$	Not in Forest Constraint Area	Use Forest Constraint map
S_P	Low physical environment effect	Use result from physical environment criteria which study in previous section
S_T	Close to a road	Use distance from roads an area is certainly close if x < 500 m an area is certainly "not" close if x > 5,000 m
S_R	Close to river	Use distance from river and tributary an area is certainly close if x < 100 m an area is certainly "not" close if x > 2,500 m
S_W	Have sufficient for water supply	Use distance from inland water (well, reservoir, etc.), groundwater supply availability and area within public waterworks service area

3.12 Establishing the Factor weight for each criteria

In the nature of a focus group, the GIS analyst works with decision makers as a group to fill out a pairwise comparison matrix. Each decision maker was asked in tern to estimate a rating and then to indicate why he or she felt that way. The group would then be asked if they agreed. Further discussion would ensure, often with suggestions for different ratings. In many areas of decision-making depend upon the accumulated knowledge and experience of experts. It was very difficult to extract knowledge from expert to make the most suitable essential indicator as the criteria and weighting of parameter to find the suitable area using GIS. In the same situations, experts give the weight of environment factor is very different.

In this study, weighting and rating suitability were categorized into 11 scenarios. It aimed to determine the effect of using crisp and fuzzy set and the effect of setting up criteria, which represent weight to concern when selecting area to developed to tourist accommodation development. It also aims to find the way

to decreased effect of different source of environment expert which giving different weight on same environmental criteria. Table 3-6 show list of weight importance for 11 scenarios.

Table 3-6 Weighting importance for each scenarios.

Categories	Weighting Importance for each criteria (percent)										
	1	2	3	4	5	6	7	8	9	10	11
Physical Environment	25	100	10	70	10	10	10	40	20	20	20
Transportation Accessibility	25	0	30	10	70	10	10	20	40	20	20
River Scenic Distance	25	0	30	10	10	70	10	20	20	40	20
Water Supply Facility	25	0	30	10	10	10	70	20	20	20	40
Weight Summation	100	100	100	100	100	100	100	100	100	100	100

- **Scenario 1**

This scenario was set up environmental weighting criteria by giving same weighting for all criteria that contains physical environment, transportation accessibility, river scenic distance and municipality water and natural water supply. Each factor has same degree of important (weight = 25%). These combinations represent the decision-makers who concern all of factor which occur when developing any project.

- **Scenario 2**

This Scenario was set up so that it concerns about physical factor only. This criteria given full scale of weight (weight = 100%) to environment physical criteria and apply not concern to select tourist accommodation development (weight = 0%) to other three factors residual which are transportation accessibility, river scenic criteria and water supply criteria. This scenario concern about environmental factor only when developed new project in Sukhothai province. This combination represent the environmental scientist who always

concern about environmental quality and give the environmental are main criteria to setting up any project.

- **Scenario 3**

This Scenario was set up so that it concerns about infrastructure support which is the main criteria to selecting anywhere to build-up a project. This criteria assign three of infrastructure facilities support, e.g. Transportation Accessibility, River scenic distance and water supply (weight = 30%) then assign the less weight score to physical environment criteria (weight = 10%).

- **Scenario 4**

This Scenario was set up so that it concerns about physical factor as the major criteria. This criteria given highest scale of weight (weight = 70%) to environment physical criteria and apply lower weight to select tourist accommodation development (weight = 10%) to other three factors residual which are transportation accessibility, river scenic criteria and water supply criteria.

- **Scenario 5**

This Scenario was set up so that it concerns about transportation accessibility as the major criteria. This criteria given highest scale of weight (weight = 70%) and apply lower weight to select tourist accommodation development (weight = 10%) to other three factors residual which are physical environment, river scenic criteria and water supply criteria.

- **Scenario 6**

This Scenario was set up so that it concerns about river scenic distance is major criteria. This criteria given highest scale of weight (weight = 70%) and apply lower weight to select tourist accommodation development (weight = 10%) to other three factors residual which are physical environment, transportation accessibility and water supply criteria.

- **Scenario 7**

This Scenario was set up so that it concerns about water supply facility is major criteria. This criteria given highest scale of weight (weight = 70%) and apply lower weight to select tourist accommodation development (weight = 10%) to other three factors residual which are physical environment, transportation accessibility and river scenic criteria.

- **Scenario 8**

This Scenario was set up so that it concerns about physical environmental criteria is major criteria to concern. This criteria given high scale of weight (weight = 40%) and apply lower weight to select tourist accommodation development (weight = 10%) to other three factors residual which are transportation accessibility, river scenic criteria and water supply criteria.

This combination group (Scenario 8, 9 and 10) are setting up to determined change between increase or decreased importance of each criteria e.g. physical environment, transportation accessibility, river scenic distance and water supply facility.

- **Scenario 9**

This Scenario was set up so that it concerns about transportation accessibility is major criteria to concerned. This criteria given high scale of weight (weight = 40%) and apply lower weight to select tourist accommodation development (weight = 10%) to other three factors residual which are physical environment, river scenic criteria and water supply criteria.

- **Scenario 10**

This Scenario was set up so that it concerns about river scenic distance is major criteria to concerned. This criteria given high scale of weight (weight = 40%) and apply lower weight to select tourist accommodation development (weight = 10%) to other three factors residual which are physical environment, transportation accessibility and water supply criteria.

· **Scenario 11**

This Scenario was set up so that it concerns about water supply is major criteria to concerned. This criteria given high scale of weight (weight = 40%) and apply lower weight to select tourist accommodation development (weight = 10%) to other three factors residual which are physical environment and transportation accessibility and river scenic criteria.