CHAPTER III
METHODOLOGY

This research was to apply the geographic information system to classify suitable areas for sugarcane cultivation in Kanchanaburi Province using the principles of satellite imageries analysis with hybrid interpretation, index, and potential surface analysis. The details of research methodology are as follows:

3.1 Materials and data

3.1.1 Hardware and software used in this research

1) Personal Computer
2) Digital Camera
3) GPS Receiver
4) Field Spectroradiometer
5) GIS Software
6) Image Analysis Software

3.1.2 Data of this research was collected from a spatial and non-spatial database along with documents from all related agencies, printing matters, books, journals, pamphlets, reports, and maps. Some data collected was revised for the data accuracy and completeness for further analysis. The details of data are as follows:

Table 3.1 Dataset for this research

Data	Types of Data	Scale	Data Sources	Year
1. Rainfall quantity	Point	1:50,000	Thai Meteorological Department	2001-2010
2. Temperature	Point	1:50,000	Thai Meteorological Department	2001-2010
3. Land utilization	Polygon	1:50,000	Land Development Department	2009
4. Soil -Soil Texture -Soil Drainage -Soil Depth		 1:50,000 1:50,000 1:50,000	Land Development Department	1993
5. Sub-district border, District border, Province border	Polygon	1:50,000	National Statistical Office	2010
6. Landsat 5 TM data -Path 130 Row 50 -Path 130 Row 49 -Path 131 Row 50 -Path 131 Row 49	Raster		Geo-Informatics and Space Technology Development Agency	11 July and 28 August, 2011
7. Spatial database	Point, Line, Polygon	1: 50,000	Department of Environmental Quality Promotion	2004

3.2 Research methodology

3.2.1 Classification of sugarcane cultivation areas in Kanchanaburi Province using the spectral reflectance.

3.2.2 Classification of sugarcane cultivation areas in Kanchanaburi Province using satellite imageries.

1) Classification of sugarcane cultivation areas in Kanchanaburi Province using hybrid interpretation.

2) Classification of sugarcane cultivation areas using various indices, including: Normalized Difference Vegetation Index (NDVI), Bare Soil Index and Water Index Analysis.

3.2.3 Evaluation on potential suitability area and land misutilization for sugarcane cultivation at Kanchanaburi Province.

1) Evaluation on suitable sugarcane cultivation areas using Potential Surface Analysis (PSA).

2) Evaluation on sugarcane cultivation suitability at Kanchanaburi Province in term of economic by means of satellite imageries analysis and Potential Surface Analysis.

3.2.3 Evaluation on suitability of sugarcane cultivation for food and energy aspects.

1) Analysis of sugarcane product in food (sugar).

2) Analysis of sugarcane product in energy (ethanol).

3) Comparing the consumption of sugar in Kanchanaburi Province.

4) Comparing the productivity of sugarcane plantation areas.

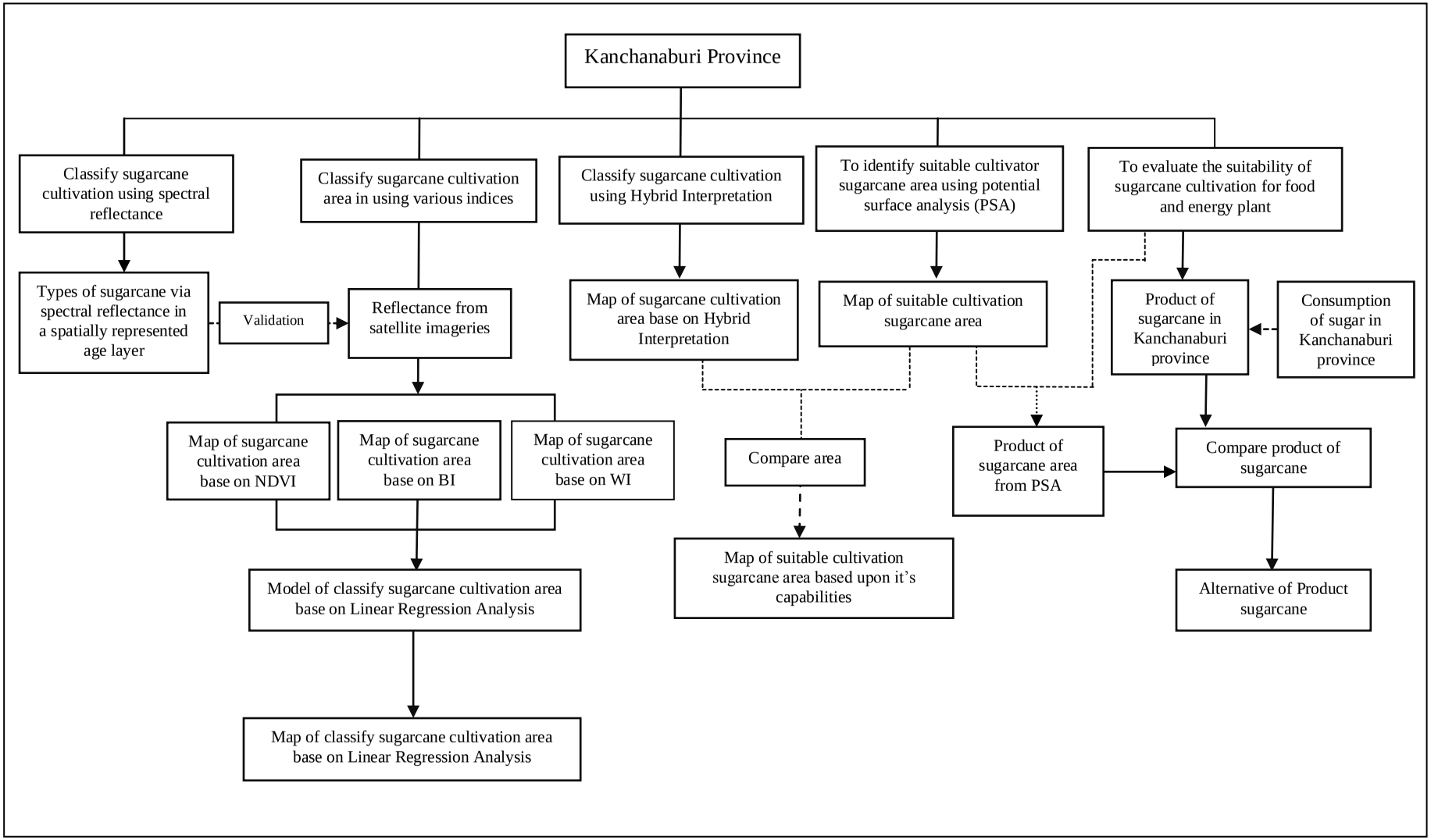

Figure 3.1 Flow Diagram of Classify suitability sugarcane cultivation area using Geo-Informatics in Kanchanaburi Province

3.3 Step of study

3.3.1 Classification of sugarcane cultivation areas in Kanchanaburi Province using the spectral reflectance

1) To find out the spectral reflectance at each plantation period, the sugarcane areas had to be surveyed by way of spectral reflectance analysis by using the Field Spectrometer. The sampling was based on a simple random sampling to cover all studied areas. The data on each sugarcane growth period was collected as follows:

- 1^{st} stage from the beginning of plantation until the sugarcane shoot appears; it usually takes 2-3 weeks.
- 2^{nd} stage when the sugarcane is at the age of 1.5 months and the most tillering phase is after 4 months.
- 3^{rd} stage follows the tillering phase; it starts when the sugarcane is at the age of 3-4 months until 7-8 months.
- 4^{th} stage, At this stage, the sugarcane growth is so slow (after 8 months).

The sample points for sugarcane were collected in 3 phases, including 1) 2^{nd} stage, 2) 3^{rd} stage, and 3) 4^{th} stage. Each stage might be divided into 3 sessions, and 3 samples would be collected at each session. The data on the environment of studied areas was also collected as shown in Table 3.2.

Table 3.2 Collection of sugarcane samples at the following growth stages

Stage	Age	Sample Age (Months)
1	0-3 weeks	-
2	1.5-4 months	2,3,4
3	3-4 months to 7-8 months	5,6,7
4	More 8 months	8

After that, the spectral reflectance data would be analyzed by band graph. The spectral reflectance values were selected and such selected values would be calculated to get the average values of each studied point, which represented

the sugarcane at each period. The spectral reflectance values showing as the interfering wave would be eliminated. The final values would be kept in the spectral library to get the spectral reflectance values of sugarcane in each period as shown in Figure 3.2.

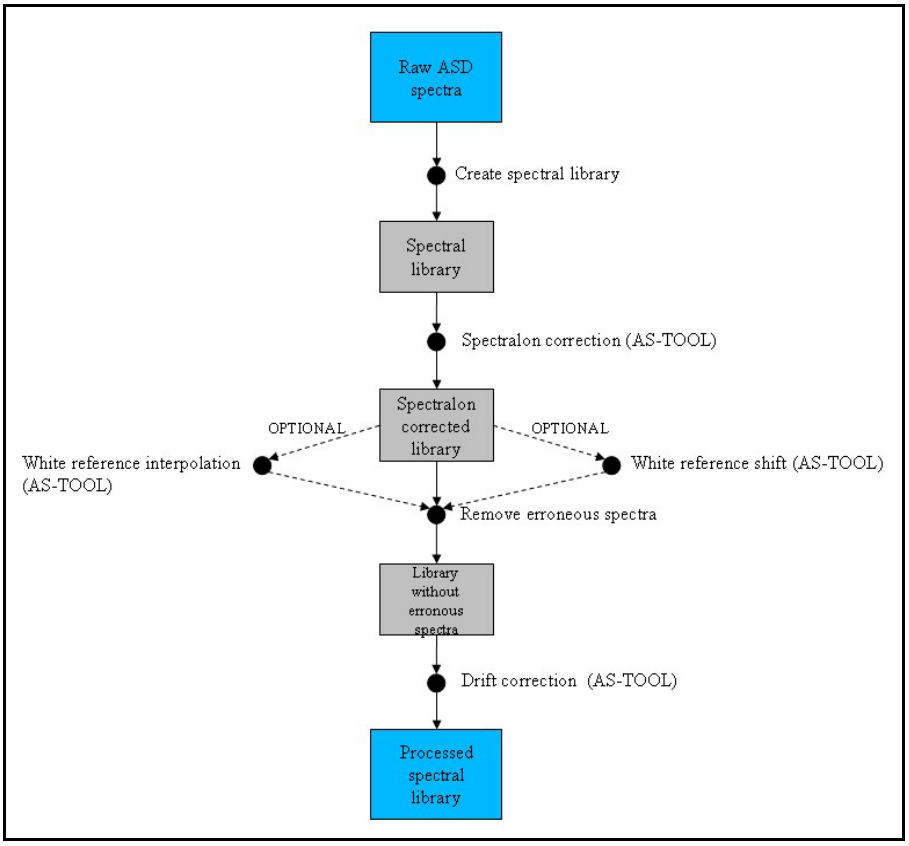

Figure 3.2 Processing of raw spectral data

2) Analysis of correlation between the field reflectance data and satellite reflectance data

The correlation between the field reflectance data and satellite reflectance data was calculated by Correlation Analysis or Correlation Coefficient was calculated to find out the correlation between both types of data. Then, the satellite reflectance data was revised to be the closest or most relevant to the field reflectance data before the analysis of indices in the next step.

3.3.2 Classification of sugarcane cultivation areas in Kanchanaburi Province using the satellite imagery

3.3.2.1 Classification of sugarcane cultivation areas in Kanchanaburi Province using the hybrid interpretation took the following steps:

1) Data Preparation: satellite images taken by LANDSAT 5 in July and August 2011 (Path 130, Row 50), which were in the sugarcane cultivation season and covered the studied areas, were selected. Then, these satellite images were extracted and cropped to show the studies areas only or areas at Kanchanaburi Province for the rapidity in the analysis.

2) Pre-processing based on the following steps:

- Radiometric correction to reduce any unclear satellite images that might have some blurring or confusing lines due to any defects during photo-taking by the satellite or any atmospheric disturbance.

- Geometric correction to change the geographic coordinate system of satellite images to meet the standard system (UTM zone 47 referred on WGS 1984 Horizontal Base) and to have the image to map correction by selecting the ground point control on the geographic map on the scale of 1:50,000 L0718 Set done by the Royal Thai Survey Department.

3) Hybrid interpretation is the computer-based interpretation along with visual interpretation by using the technique of false color to highlight satellite data, and using Band 4, 5, 3 (NIR, SIR, R) of LANDSAT 5, which are suitable for the interpretation of agricultural areas and forests. The results of such satellite data classified by the computer would be overlay to help decide on the sugarcane classification, that is the land use was classified by digitizing and saving the data in the vector format, or by the types of land use determined by the Department of Land Development in 2009, and determining the land use according to the types of land use at Level 1, 2 and 3 of land use analysis previously done by the Office of Soil Survey and 2009 Land Use Planning, the Department of Land Development such as forest, water source, community, other agriculture and sugarcane.

4) Field surveying to get the latest and more accurate data. In a field survey, the satellite data would be linked with GPS to identify positions of each land use type.

5) Checking of accuracy and preparation of final map from the land utilization from satellite data interpretation, comparison with existing data, and checking of accuracy by the analysis of corrections as follows:

- Classification analysis by comparing the results from satellite data with ground truth data in order to find out an acceptable level of accuracy. In general, the correction probability opportunity (p) is at 80% and the percentage of acceptable error (E) is 10%. Then, the least sample pixels were estimated by using the following equation:

$$n = \frac{Z^2(p)(q)}{E^2} \qquad (3\text{-}1)$$

Where n = Number of least pixels in the random example
p = Probability opportunity that the pixel is probably correct
q = Differences between 100-p
E = Percentage of acceptable error
Z = Standard of normal distribution at the reliability level (95%)

- Checking of accuracy in determining the appropriate sugarcane plantation areas was done by the error matrix to find the overall accuracy, which was calculated by accuracy assessment with the following equation:

$$\text{Overall Accuracy} = \frac{\text{sum of major diagonal tallies}}{\text{total number of samples}} \text{ x } 100 \qquad (3\text{-}2)$$

- Kappa index was used to calculate corrections from changes in numerical checking techniques. The correct point values on the oblique side of the created deviation table were calculated with the total result in columns and rows as per the following equation:

$$\hat{K} = \frac{N \sum_{i=1}^{k} x_{ii} - \sum^{k} (x_{i+} \times X_{+1})}{N^2 - \sum_{i=1}^{k} (X_{i+} \times X_{+1})} \quad (3\text{-}3)$$

Where $\hat{K}$ = Points in rows or types of land utilization and land cover

X_{ii} = Oblique points in of Row i and Column i

X_{i+} = All points in Row i

X_{+I} = All points in Column i

N = Total points

3.3.2.2 Classification of sugarcane cultivation area using various indices

The classification of sugarcane cultivation areas using the Normalized Difference Vegetation Index (NDVI) must pass the atmosphere correct first to eliminate interferences due to atmosphere or satellite bugs. The digital number in satellite image data caused by the differences between electromagnetic spectrum reflected from the same object, azimuth, sun elevation, photographing conditions such as fog, cloud, or aerosol as well as sensor's sensitivity must be converted so that the digital number of image data is arranged to have linear relationship of the digital number and radiation value established by Chavez's COST model (S.M. Skirvin, 1996). The conversion process is as follows:

1) To convert the digital number to be the spectral radiance at database system as:

$$L = [(LMAX - LMIN) / 255] * DN + LMIN \quad (3\text{-}4)$$

Where L = Spectral Radiance

LMAX = Maximum Luminance (DN=225)

LMIN = Minimum Luminance (DN=0)

DN = Digital Number

Table 3.3 TM Post-Calibration Dynamic Ranges for U.S. Processed Data ($Mw*cm^{-2}*ster^{-1}*\mu m^{-1}$)

Band	Prior to August 1983		Prior to 15 Jan 1984		After 15 Jan 1984	
	$LMIN_\lambda$	$LMAX_\lambda$	$LMIN_\lambda$	$LMAX_\lambda$	$LMIN_\lambda$	$LMAX_\lambda$
TM1	-0.152	15.842	0.000	14.286	-0.15	15.21
TM2	-0.284	30.817	0.000	29.125	-0.28	29.68
TM3	-0.117	23.463	0.000	22.500	-0.12	20.43
TM4	-0.151	22.432	0.000	21.429	-0.15	20.62
TM5	-0.037	3.242	0.000	3.000	-0.037	2.719
TM6	0.200	1.564	0.484	1.240	0.123	1.560
TM7	-0.015	1.700	0.000	1.593	-0.015	1.438

Source: Markham and Barker, 1986

2) Conversion of spectral radiance to be the spectral reflectance to decrease luminance of the sun because of factors like elevation and distance from earth to the sun by calculating the elevation of the sun the same as the zenith on the same day that data was recorded. The seasonal influence on spectral radiance values and the distance from earth to the sun can be analyzed by using the following equation:

$$\rho_p = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda . \sin\theta_s} \quad (3\text{-}5)$$

Where ρ_p = Reflectance

L_λ = Radiance

d = Distance from earth to sun as in table 3.3

$ESUN_\lambda$ = The average of Solar Exoatmospheric from Markham and Barker (1986) as in table 3.4

θ_s = Solar Zenith Angle

Table 3.4 Distance from Earth to the Sun (Astronomical Unit)

Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance
1	0.9832	74	0.9945	152	1.0140	227	1.0128	305	0.9925
15	0.9836	91	0.9993	166	1.0158	242	1.0092	319	0.9892
32	0.9853	106	1.0003	182	1.0167	258	1.0057	335	0.9860
46	0.9878	121	1.0076	196	1.0165	274	1.0011	349	0.9843
60	0.9909	135	1.0109	213	1.0149	288	0.9972	365	0.9833

Source: Markham and Baker, 1986

Table 3.5 TM solar exoatmospheric spectral irradiances $ESUN_{\lambda}$ $(mW \cdot cm^{-2} \cdot \mu m^{-1})$

BAND	LANDSAT4	LANDSAT5
TM1	195.8	195.7
TM2	182.8	182.9
TM3	155.9	155.7
TM4	104.5	104.7
TM5	21.91	21.93
TM7	7.457	7.452

Source: Markham and Baker, 1986

3) The process of finding NDVI and physical index is as follows:

3.1) NDVI is calculated by taking a wave range of each band to have the mathematic analysis to get the data in form of raster, which may be illustrated in form of map, and helps classify plants from other objects.

- Normalize Difference Vegetation Index (NDVI) is calculated by inputting the satellite data in the Red band and Near Infrared band of LANDSAT 5 as per the following equation:

$$NDVI = (Band\ 4 - Band\ 3)/(Band\ 4 + Band\ 3) \quad (3\text{-}6)$$

3.2) Physical Index can be analyzed as follows:

- Bare Soil Index (BI) can be found by inputting satellite imageries in Blue band, Red band, Near Infrared band and Short Infrared band of LANDSAT 5 as per the following equation:

$$BI = \frac{(SIR + RED) - (NIR + BLUE)}{(SIR + RED) + (NIR + BLUE)} \quad (3\text{-}7)$$

- Water Index (WI) can be found by importing satellite data in wave lengths in the Green band and Short Infrared band of LANDSAT 5 with this following equation:

$$WI = (Band2/Band5) \quad (3\text{-}8)$$

4) The correlation between NDVI and plant community can be found by putting NDVI, BI and WI into regression analysis to find out the correlation between these three indices.

5) Accuracy checking is done by comparing NDVI and physical indices with field surveys.

3.3.3 Evaluation of potential suitability area and land misutilization for sugarcane cultivation at Kanchanaburi Province

3.3.3.1 Evaluation of suitable sugarcane cultivation areas at Kanchanaburi Province by using Potential Surface Analysis (PSA)

The evaluation of suitable sugarcane cultivation areas in Kanchanaburi by Potential Surface Analysis applies GIS along with Potential Surface Analysis and Overlay Technique to evaluate suitable plantation areas for sugarcane in Kanchanaburi, and to classify suitability levels by using statistical methods as follows:

1) Determining factors

The fundamental factors affecting the sugarcane cultivation were determined with reference to research papers of the Department of Agriculture, Land Development Department, as well as other related state and private agencies responsible for agriculture. In this research, 10 factors were determined, including annual rainfall, soil drainage, soil depth, soil texture, temperature, slope, pH, distance to irrigation, distance to water resources, and land use.

2) Data collection and preparation

The spatial and non-spatial fundamental factors affecting the plantation of sugarcane area in Kanchanaburi Province were compiled from reports, research documents and maps made by related agencies. Such data was corrected to have accuracy and data format ready for further analysis by GIS.

3) Weighting factors and rating factors

Weighting factors and rating factors are used in the spatial analysis that determines suitable plantation areas for sugarcane with reference to the criteria of weighting factors and capacity of factors from the Department of Agriculture, Land Development Department, and other related agencies, as well as an interview with soil management specialist, Associate Professor Chalee Navanukroh. Weighting factors are then put into an analytic hierarchy process (AHP) by using the direct comparison between factors, which were shown in form of weighted factors as per the following table:

Table 3.6 Rating factor of each factor used to evaluate suitable cultivation areas for sugarcane

Types of data	Weighting level types of data			
	4	3	2	1
Annual Rainfall	1,200 – 1,500 mm.	1,500 - 2,500 mm.	2,500 - 4,000 mm.	< 900, > 4,000 mm.
Soil Drainage	Very Good, Good	Moderate	Rather Good	Bad, Worst
Soil Depth	> 150 cm.	100 - 150 cm.	50 - 100 cm.	< 50 cm.
Soil Texture	C<65%,L,SCL,SiL,Si,CL,L	SiCL, SL	SiC, LS	C(>65%),G,SC,AC,S
Temperature	25 - 29 ℃	30 - 32℃, 14-24℃	33 - 35℃, 10 -13℃	> 35℃, <10 ℃
Slop	0-5%	6-10%	11-15%	>15%
pH	6.1-7.3	7.4-7.8, 5.1- 6.0	7.9-8.4, 4.0-5.0	>8.4, <4
Distance to Irrigation	In	-	Out	-
Distance to water resource	<500 m.	500–1000 m.	1000–1500 m.	>1500 m.
Land utilization	Agricultural area	Communities & Buildings	Forest & Water Resources	Others

Notes: Weighting factors and factor capacity are in the study process only.

How the weighting factors are rated to evaluate factors suitable for sugarcane cultivation.

High suitable	4
Moderate Suitable	3
Low Suitable	2
Non-suitable	1

Table 3.7 Weighting factors used to evaluate suitable areas for sugarcane cultivation in Kanchanaburi Province

Types of data	Annual Average Rainfall	Temperature	Slop	Land use	Soil Texture	Soil Drainage	Soil Depth	pH	Distance to Irrigation	Distance to Water Resources	Total	Weighting Factor
Annual Rainfall	0	3	3	3	3	3	3	3	3	3	27	0.152
Temperature	1	0	3	3	1	1	1	3	3	3	19	0.11
Slop	1	1	0	3	1	1	1	3	3	3	17	0.095
Land use	1	1	1	0	1	1	1	1	1	1	9	0.05
Soil Texture	1	3	3	3	0	2	1	3	3	3	22	0.123
Soil Drainage	1	3	3	3	2	0	3	3	3	3	24	0.134
Soil Depth	1	3	3	3	3	1	0	2	3	3	22	0.123
pH	1	1	1	1	1	1	2	0	3	3	14	0.079
Distance to Irrigation	1	1	1	3	1	1	1	1	0	2	12	0.067
Distance to Water Resources	1	1	1	3	1	1	1	1	2	0	12	0.067
Total	9	17	19	25	14	12	14	20	24	24	178	1

Notes: Weighting factors and factor capacity are on the study process only.

How weighting factors are rated to evaluate suitable factors for sugarcane cultivation.

Column factors are less important than row factors	1
Column factors are important equal row factors	2
Column factors are more important than row factors	3
Cannot compare	0

4) Analysis and evaluation of the potential areas suitable for sugarcane cultivation

The analysis and evaluation of the potential areas suitable for sugarcane cultivation in Kanchanaburi Province were applied by using the geographic information system together with Potential Surface Analysis, and Overlay Analysis as

well as fundamental factors data compiled earlier. The analysis was based on the following equation.

$$S = (R_1 \times W_1) + (R_2 \times W_2) + (R_3 \times W_3) + \ldots + (R_9 \times W_9)$$

Definition:

S	=	Capacity or area suitability
R_1	=	Rating of annual rainfall
W_1	=	Weighting of annual rainfall
R_2	=	Rating of temperature
W_2	=	Weighting of temperature
R_3	=	Rating of slope
W_3	=	Weighting of slope
R_4	=	Rating of land use
W_4	=	Weighting of land use
R_5	=	Rating of soil texture
W_5	=	Weighting of soil texture
R_6	=	Rating of soil drainage
W_6	=	Weighting of soil drainage
R_7	=	Rating of soil depth
W_7	=	Weighting of soil depth
R_8	=	Rating of pH
W_8	=	Weighting of pH
R_9	=	Rating of distance to irrigation
W_9	=	Weighting of distance to irrigation
R_{10}	=	Rating of distance to water resources
W_{10}	=	Weighting of distance to water resources

5) Classification of level suitability for sugarcane cultivation

The level of suitable sugarcane cultivation areas can be classified by using statistic methods. The suitability levels may be divided into 4: highly suitable, moderately suitable, slightly suitable, and not suitable by mainly using

the means of data set. Then, the Standard Deviation values are used to determine the width of each range as follows.

$$(I_1) = (\overline{X}) - SD$$
$$(I_2) = (\overline{X}) - SD \leq S \leq (\overline{X}) + SD \quad (3\text{-}3)$$
$$(I_3) = (\overline{X}) + SD$$

When I_1 = Slightly suitable area
I_2 = Moderately suitable area
I_3 = Highly suitable area
$\overline{X}$ = Mean
S.D. = Standard Deviation

6) Data presentation

The results of analysis and evaluation of sugarcane cultivation areas were presented in form of map with the scale of 1:50,000 for the suitability levels of sugarcane cultivation.

3.3.3.2 Analysis of suitability of sugarcane cultivation areas and land misutilization based on area potential

The suitability of sugarcane cultivation areas based on area potential was analyzed by comparing those sugarcane cultivation areas from satellite imagery analysis got from the Potential Surface Analysis in order to demonstrate the appropriate levels of sugar cultivation based on area potential.

3.3.4 Evaluation on suitability of sugarcane cultivation at Kanchanaburi Province in term of food and energy

1) Analysis of sugarcane productivity in term of food is sugar by comparing the sugarcane cultivation areas as classified by the GIS and the results of sugarcane productivity analysis done by Offices of The Cane and Sugar Board, that is, sugarcane productivity was approximately 9-10 tons per Rai with the sweetness about 11 C.C.S. to get the sugar about 100-105 kilograms/ton sugar.

2) Analysis sugarcane product in term of energy is ethanol by comparing the sugarcane cultivation areas as classified by the GIS and the results of sugarcane productivity analysis done by Thai Ethanol Manufacturing Association, that is, 1 ton of fresh sugarcane be produced for 70 liters of ethanol or 1 ton of molasses can produce 260 liters of ethanol. Molasses is the by-product of the sugar industry. In general, 1 ton of sugarcane can produce molasses for 45-50 kilograms per ton.

3) Comparing the demand of sugar in Kanchanaburi Province with sugarcane productivity in sugarcane cultivation areas got from the analysis of satellite imageries. This is used to check whether the yield of sugarcane grown in Kanchanaburi Province is sufficient to meet demand within the province or the excess of sugarcane production can be used in other areas.

4) Comparing the productivity of sugarcane cultivation areas using satellite imageries with the productivity of sugarcane cultivation areas using the Potential Surface Analysis to show alternative areas between sugarcane cultivation areas and sugarcane productivity.