CHAPTER II
LITERATURE REVIEWS

This research was conducted by reviewing all principles and methods of appropriate land classification for sugarcane plantation at Kanchanaburi Province, as well as all other related information as described below.

2.1 Classification of sugarcane cultivation areas using remote sensing

Remote sensing is defined as surveying and checking attributes of materials, objects, areas, or phenomena without touching those targeted objects as perceived from spectral, spatial and temporal data logger recorder. (2) Spectral data is visually registered as light reflected from different wave lengths in pixel characteristics that vary from different materials on earth. Unique pixel values are recorded based upon different brightness value indicating a different wave length value. The unique wavelength values of different materials in the earth's ecosystems are demonstrated in grayscale raster. (3) Synthesis and analysis of remote sensing follows the processes listed below.

2.1.1 Preparation of basic data

1) Selecting satellite imageries on a clear (non-cloudy) day in accordance with the timeframe of that research, and additionally, selecting suitable wave length and band data for expedient and error free.

2) Presenting pictures that interpret the numeral data into pictures by overlapping the wave length (band) to have a single color composite. For example, a false color composite shows plants in red for analysis purposes.

2.1.2 Pre-Processing

This is a process of adjusting defective data and pictures so that visual characteristics become realistic for further analysis.

1) Radiometric correction, which may be wrong due to camera, sun or the electromagnetic spreading passing through the atmosphere, in order to have data in the same area and standard, but it is recorded on different days and seasons.

2) Geometric correction, the errors of picture position may be due to satellite orbital error and inaccuracy of the satellite's photo scanner system depending on confiscation point. Data must be fixed to the correct position consistent with Geographic Coordinate System.

3) Image enhancement, the radiometric level must be adjusted so that the data is consistent with the research objectives and more accurate data analysis. Generally, radiometric images are stretched into narrow mathematically spread lengths:

- Linear contrast stretch is the stretching of radiometric range to more value along a linear equation.
- Histogram equalization is non-linear contrast stretch placing radiometric distribution into normal distribution: this approximates the radiometric pixel numbers.
- Piecewise stretch is the radiometric extension especially parts to get aspiring data.
- Ratio image finds the ratio between image color bands by band's intensity and divides with other bands in the same pixel.
- Principle component transformation (PCT) is a technique that creates a permanent raster by changing duplicate values of radiometric reflection into a new raster at a decreased size. The raster shows complete details and quality such as a PCT 3 raster of MMS which has different details of mangrove forests and land forests.
- Color composite image makes color composite images from satellite images by black and white satellite images in any three wave lengths mixed into a color composite image that has clearer data than black and whites.

2.1.3 Processing

Processing is a process of classification from satellite images. In general, the image classifications may be divided into 2 types:

1) Unsupervised Classification, It is an automatic classification by statistical grouping. It uses the light wave reflection of materials detected in remote sensing. Its drawback is that the analyzer cannot know terrains that cover surface area before when assigning the data groups. This type uses for dissimilar areas.

2) Supervised Classification is classification where the analyzer knows terrains and any materials covered in the analytical areas. This process assigns a sample data for a training area that represent characteristics that appear on satellite images in statistical value analysis including: mean, standard deviation and covariance matrix are represented for area classification data. The popular classifications are these:

- Minimum Distance to Mean Classifier is the data classification by considering the pixel spectral reflectance value in each image that is the least deviant from the center of data.
- Parallelepiped Classifier is the data classification by setting specific types of data that captures variation from the lowest to highest spectral reflectance value on sample data in each band.
- Maximum likelihood classification is the data classification based upon the determined mean vector and covariance matrix data by creating a hypothesis that each type of data has normal distributions to find the probability that each pixel has been classified accurately, but this classification takes more time to process.

2.1.4 Post Processing

Post Processing Classification to get more accuracy by data filter for continuity of reality type of data such as paddy on mountain forest area should be substituted by all forests.

Thaworn et al. (4) studied the classification of in-season and off-season paddy fields in Phitsanulok Province and Chiangmai Province by applying the remote sensing with Color Combination method or 5, 4, 3 Band (IR, NIR, RED) and ISODATA (Iterative Self-Organizing Data Analysis Technique), as well as spectral reflectance for the exploitation of land, and GIS technique to configure values for more accuracy.

Meng Ji-Hua & Wu Bing-Fang (5) studied the classification of agricultural areas by using several methods of remote sensing: 1) classification of satellite images by way of quantitative validation such as supervised and unsupervised classification; 2) classification by more indices such as LAI, TCI, VCI and NDWI; 3) creation of plant classification parallel to growth period; 4) applications of GPS, GIS and RS data. It was found that the agricultural management was important for more efficiency of agricultural area classification because of specific classification types for more accurate classification.

2.2 Classification of sugarcane cultivation areas using Normalized Difference Vegetation Index, Bare Soil Index and Water Index

The classification of plantation areas for alternative energy by using the Normalized Difference Vegetation Index and Bare Soil Index and Water Index is as follows:

2.1.1 The classification of sugarcane cultivation areas with biological index using the Normalized Difference Vegetation Index can be calculated by:

- Normalized Difference Vegetation Index (NDVI) (6) is a value that indicates vegetation proportion on the earth's surface. NDVI is used to estimate the vegetation density or quantity of vegetation cover by using the difference in surface reflectance between wave lengths near infrared and red visible spectrum and then creates the proportion by combining both sum lengths with adjustment to normal distribution with a range between -1 to 1 as follows:

$$NDVI = (NIR - RED) / (NIR + RED) \quad (2\text{-}1)$$

Where NDVI = Vegetation Index

NIR = Near Infrared Wave band (0.76 – 0.90μm.)

RED = Red Visible band (0.63 – 0.69 μm.)

2.1.2 The classification of sugarcane cultivation areas with physical indices using Bare Soil Index and Water Index is calculated as follows:

- Bare Soil Index (BI) is calculated from:

$$BI = \frac{(SIR + RED) - (NIR + BLUE)}{(SIR + RED) + (NIR + BLUE)} \qquad (2\text{-}2)$$

Where BI = Bare Soil Index

SIR = Short Infrared Wave band (1.55 – 1.75 μm.)

RED = Red Visible band (0.63 – 0.69 μm.)

BLUE = Blue Visible band (0.45 - 0.52 μm.)

- Water Index (WI) is calculated from:

$$WI = GREEN/SIR \qquad (2\text{-}3)$$

Where WI = Water Index

GREEN = Green Visible band (0.52-0.6 μm.)

SIR = Short Infrared Wave band (1.55 – 1.75 μm.)

Md. Rejaur (7) studied sugarcane energy reflectance in each period and fertility by using IRS LISS II data and NDVI to classify sugarcane cultivation areas, and to evaluate those areas. The result is a very efficient classification by NDVI in high density fertilized sugarcane plantation areas with 85.25% accuracy.

Ekkarat (8) studied THEOS functions in the classification of agricultural types in Lopburi Province by developing the classification technique of THEOS images in each wave length in order to classify agricultural types, and then by comparing this determined classification with the established LANDSAT data classification. His result indicated that the data classification efficiency of LANDSAT by way of spectral reflectance classification and NDVI was the same to THEOS.

2.3 Classification of sugarcane cultivation areas by spectral reflectance analysis

When solar energy passes through the atmosphere and touches the earth surface, there are three main reactions: reflection, absorption and transmission as shown in Figure 2.1.

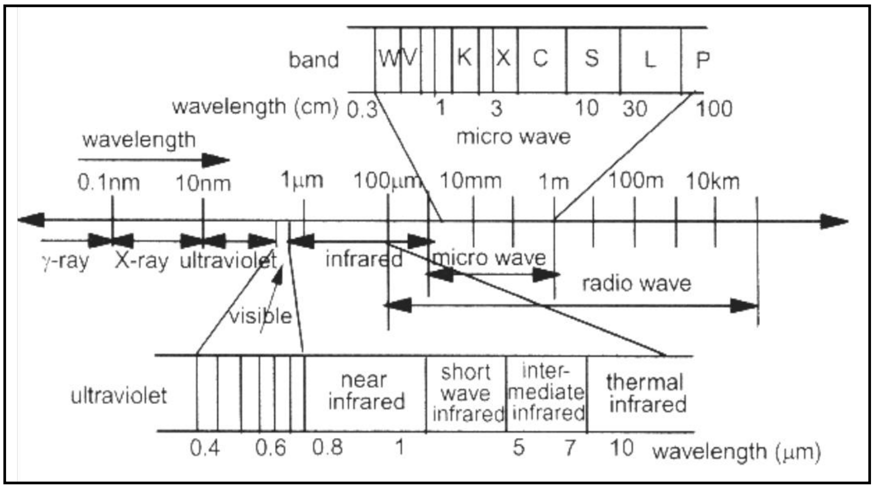

Figure 2.1 Electromagnetic Radiation Wave Length Values
Source: Geomatics Internet Service to Millennium Education

Remote sensing records energy reflected from objects, which deviates by types of surface, surrounding environments, surface reflections rates and capacities. Each object has different solar reflection and absorption in each wave length. Each object classification type (Thaworn, 2005) shows the relation between reflection of each object and its wave length or reflectance that enables the classification of that object. Different objects will differently respond the energy with different wave lengths, which is a spectral characteristic of that object indicating the identity of natural objects and helps select the wave length suitable for data analysis in other fields. For each object, a spectrometer is used to measure spectral signature and spectral reflectance (9).

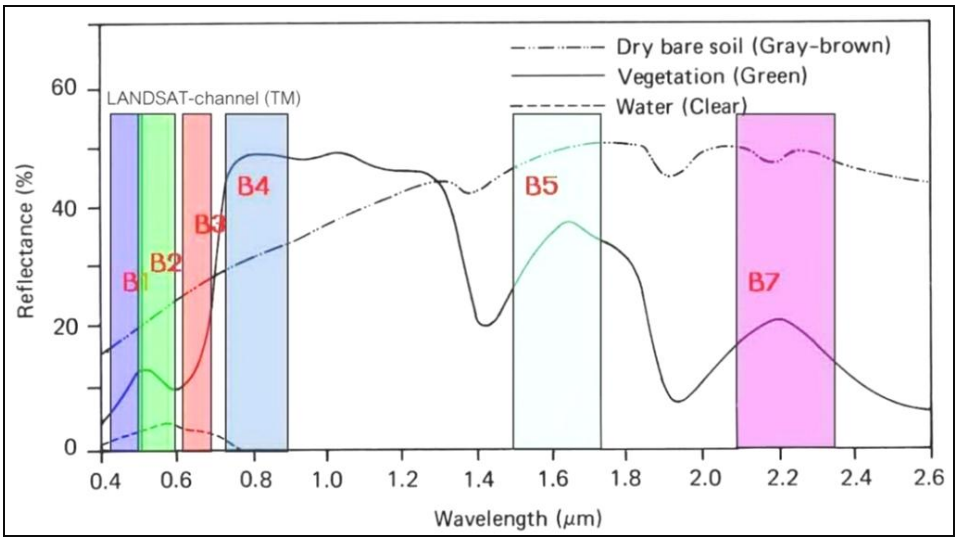

Figure 2.2 Reflection in each wave length between plants, water and soil
Source: Geomatics Internet Service to Millennium Education

Kumar (10) used the remote sensing technique by ASTER's multispectral, spectral reflectance and NDVI to classify the period of sugarcane.

E.M. Abdel et al. (11) studied sugarcane management by using the remote sensing technique to classify sugarcane plantation areas; the period, nutrient and predicted sugarcane production were classified. This study also examined spectrum characteristics or sugarcane reflectance energy in order to check the fertility and nutrient of sugarcane important for farmers' farm management so that the areas appropriate for sugarcane plantation would be selected.

2.4 LANDSAT 5

LANDSAT 5 is the first earth resource satellite launched on 1972. The satellite can record data covering 100 KMs, and such data at the same areas can be re-recorded in each orbit to monitor the changes. The images recorded show the wide visible landscapes on earth. The advantages of LANDSAT 5 are the fact that any changes on earth can be monitored by examining the images recorded at different days and time, which present before and after the changes such as damages by storm, landscape changes because of mudslide, and changes of waterway. Thus, we would know the scope of damages for further remedies quicker than the land survey only. The data from LANDSAT 5 also shows humans' land utilization that provides information for city mapping, research, and analysis, and monitors the urban growth and city physical changes (12).

1) Thematic Mapping data of LANDSAT 5 collects data better than MSS data and has seven bands as follows:

Table 2.1 Particular characteristics in each Band of LANDSAT 5

Band	Wave Lengths (μm.)	Characteristics	Band Types
1	0.45-0.52	Checks the coastal water, the difference between deciduous plants and evergreen plants or classified soils for chlorophyll sensitivity in plants	Blue-green visible spectrum
2	0.52-0.60	Checks the green energy from growing plants	Blue visible spectrum
3	0.63-0.69	Classifies the chlorophyll absorption in plants	Red visible spectrum
4	0.76-0.90	Checks biomass quantities to see the difference between water and non-water	Near infrared
5	1.55-1.75	Checks humidity in plants to see the difference of snow and cloud	Infrared short wave
6	1.04-1.25	Checks the wasted heat in plants to see the heat difference in the studies area and the humidity difference in soils	Infrared heat wave
7	2.08-2.35	Checks the heat in water to classify types of minerals and soils	Mid- infrared

Source: Ministry of Mineral Resources and Environment

Fockelmann (13) checked the types of agriculture present in Neuburg Schrobenhausen district in Bavaria, Germany by using Definiens Ecognition software. This study used LANDSAT 5 TM in three bands i.e. green visible, red, and near infrared. Before the data classification, this study created image objects and then classified them. At first, agricultural and non-agricultural areas were separated; then, the images of agricultural areas were classified such as areas for wheat, oat, barley, and others.

2.5 Global Positioning System (GPS)

GPS is the navigation system to provide location by receiving the radio wave signal from satellites (14). GPS has three main components as follows:

1. Control station segment, it is a data control and command center of GPS system, and it checks the system completeness. This center is located at Colorado Springs, the United States, and it consists of the following stations:

- Five monitor stations located around the world, including Hawaii, Kwajalein, Ascension Islands, Diego Garcia, and Colorado Spring.
- Three ground antennas located at Ascension Island, Diego Garcia, and Kwajalein.
- Master control station located at Schriever Air Force Base, Colorado.

When the stations receive signals from satellites, they would adjust some orbit data and time data of each satellite before sending them back to those satellites. Then, the revised data along with radio waves will be sent from satellites to a GPS receiver.

2. The space segment consists of 24 satellites; each satellite orbits around the earth for 12 hours per day, at an elevation of 11,000 miles from earth. Each satellite has four atomic clocks, which tells time accurately. There are six orbits in each orbit whose four satellites incline to the angle at 55 degrees from the equator. This orbit structure has 5-8 satellites that GPS can monitor and receive the signal at any position always.

3. User segment consists of a receiver that calculates, checks, and decodes signal from satellites. Normally, the data will be processed by programs and be sent to a hand-held GPS screen.

2.6 Field Spectroradiometer

FieldSpec Pro (15) is a tool with functions similar to a Spectroradiometer in laboratories. It weights 8 kg, but has higher accuracy measure than the visible wave length up to the infrared wave. The measurement of this tool is so rapid at the millisecond level through fiber optic. Data is controlled by a notebook with electronic software in the 350-2500 nanometer, which has a 10 nanometer definition at the speed of 10 bands per second. Furthermore, this tool records the wave length in UV/UNIR band (350-1050 nanometers) and SWIR (1000-2500 nanometers). The data wave bands, scanning tools and fiber optic cable may be additionally installed for more efficiency of this remote sensing tool.

Figure 2.3 ADS Field Spectrometer

Kritsakorn et al. (16) studied and analyzed the characteristics of reflectance in some infected sugarcane leaves or white leaves by using the spectroradiometer and chlorophyll meters to measure the spectral reflectance of infected sugarcane leaves, and to put reflectance values in reflectance index such as red edge NDVI, green NDVI, red edge, chlorophyll index (CI Red Edge), chlorophyll index (CI Green), NDVI, and EVI.

2.7 Geographic Information System

Geographic Information System is a tool or method improved for efficiency in input, storage, preparation, modification, fixing, management, analysis, and presentation of spatial characteristics to be used in various objectives (17). It is composed of two types of data information: spatial data, non-spatial, or attribute data, which is stored by referring to geographic coordinate system and can be sorted by the sequence of input or code determined by a user. This is the relation between spatial data and attribute data in the storage system, which is called the spatial topology, to be used in the analysis in types of GIS as described below.

2.7.1 Spatial Analysis

Spatial suitability analysis is the land suitability ranking that supports land development and land use activities, and it is used as database for assigning land development at each level. This database and analysis can be used for sieve mapping, potential surface analysis, and other spatially based methods such as buffer, overlay, intersect, union, merge, and dissolve. Spatial analysis also needs other coordinating techniques such as statistical analysis and types of data analysis in GIS. Spatial suitability analysis is GIS data management to link the attribute data and related spatial data together. Relations and data storage can be used to analyze the spatial data with the attribute data; so the complicated analysis can be applied suitably.

2.7.2 Analysis of Attribute Data

GIS data processing has the following steps:

- Analysis and editing of attribute data can be retrieved, checked, and changed. These also include linkage and table merging.
- Attribute data query is inter-database retrieving in the database related to the conditioning questions pre-determined by the user.
- Statistical Process is used to calculate statistical values from data tables.

After that, this spatial data can be analyzed with the attribute data so GIS can be more efficient and be used with other programs to make the operation of GIS more complete.

2.7.3 Potential Surface Analysis (PSA)

Potential Surface Analysis is a technique to evaluate the potential surface, to develop each activity systematically, and to be a guideline of selecting locations, potentials and area readiness, which affects that land use. This analysis considers various factors or indices that determine the suitability of rating factors and the importance of weighting factors for particular factors necessary and relevant to determine the location of activities. This analysis is a mathematical method used to average importance and to calculate the average area based upon map border intersection or the combination of map unit; thus, it reduces the duplication of data. The analysis criterion is that the more importance the higher values exist, but the less importance, the lower values exist as per the following equation:

$$S = (R_1 \times W_1) + (R_2 \times W_2) + (R_3 \times W_3) + ... + (R_n \times W_n) \qquad (2\text{-}4)$$

Where	S	=	Potential or suitability of area
	W	=	Important points of factors
	R	=	Suitability points of factor level

After that, these factor values are presented on the area map and PSA analysis is applied by the technique of sieve mapping, which interprets the map digital images from PSA to graphics. The images shown on map will have the different color values so that the potential in each area will be apparent, and the data can be calculated and analyzed more accurately and concretely as per the pre-set objectives.

Kanlaya (18) evaluated the suitability of land used for the plantation of energy plants i.e. sugarcane and cassava in Kanchanaburi Province, by using GIS along with Multiple Criteria Decision Making (MCDM) analysis under FAO framework (1976) for the evaluated suitable areas. The result showed that the suitable areas for sugarcane planting accounted for 52%, and the suitable areas for cassava planting accounted for 45% while the remaining areas were not suitable. Suitable areas for both crops were located at the eastern and southern parts of Kanchanaburi Province where had the fertile soil, water resources, and existing agricultural areas.

Natthaphon (19) studied the suitable plantation system in Nahaew District of Loei Province. In the study, the information about farmer's demands, physical area data, social and economic data, and plant biomass data was collected and analyzed by GIS in coordination with MCDM with fruit specialists, farm plants specialists, vegetables specialists, and flowering-plants specialists, who also used the remote sensing technology to accurately classify land cover areas. The result made us aware that the most suitable plantation system in Nahaew District was the monoculture plantation, which means that only one kind of plant can be grown throughout the year.

Nanthana (20) studied the suitable areas for sugarcane plantation. This study specified sugarcane-trading districts, and also studied places established as sugarcane transfer stations for sugar factories in the eastern region by using GIS and Quantitative Systems for Business plus Version 3.0 (QSB) in the lowest transport value analysis. The result indicated that the most suitable areas for sugarcane plantation were around 14,354.20 km^2 (45.76%). For the established sugarcane transfer stations for sugar factories, it was found that there were potential areas about 15,665.85 (89.86%), 1,119.09 (6.42%) and 647.75 (3.72%) km^2 respectively. From studying the sugarcane transfer stations in the eastern region, it was found that it was unnecessary to establish such sugarcane transfer stations because five sugarcane factories in the studied area have already provided that sugarcane trading service for all sugarcane plantation areas.

2.8 Alternative Energy Plants

Alternative energy plants are plants that are used as raw materials in the process of alternative energy production such as ethanol and biodiesel. Ethanol or ethyl alcohol comes from the fermentation of all carbohydrate plants such as cassavas, sweet potatoes, beetroots, and cereals i.e. rice, corn, millet, or sweet fruits such as sugarcanes, sweet sorghum, lychee, longan, pineapple etc. (21)

Nowadays, Thailand has many sufficient resources for the domestic production of ethanol; those resources include many carbohydrate plants such as rice, corn, millet, cassava, sugarcane etc. This does not include rice that is consumed directly, and corn that is used for animal feeding, which has higher economic value than being used in the ethanol production. Some potential agricultural raw materials that can support the ethanol production industry are exported for several billion baht per year. In 2004, the main agricultural products exported were cassava, sugarcane and molasses. If those agricultural products were processed for the ethanol production, it was estimated that over 5 billion liters of pure ethanol would be produced, amounting to 70 billion baht, with reference to the domestic ethanol price at 12.75 baht per liter, but when these crops were exported, their export values were at 65 billion baht only as they were the primary processing agricultural products (22). Currently, the cassava and sugarcane output per Rai is low; this means that raw materials can be much increased if the plantation is more efficient or the management should be based on the highest efficiency, and the plantation areas are allocated in order to get the best value-based returns.

Table 2.2 Export quantities and value

Kind of plants	Domestic uses (million ton)	Exports (million ton)	Export Values (million baht)	The Potential of Ethanol Production (million liter)	Ethanol Values (million baht)	Different Values (million bath)	Values when produce ethanol (%)
Cassava	7.0	11.4	18,345	2,057	26,227	7,882	43
Sugarcane (Sugar)	21.5	43.0	44,560**	3,010	38,378	-6,182	-14**
Molasses	1.6	1.3	1,963	338	4,310	2,347	120

**When sugar price on the global market rises by more than nine baht per kilogram, it is not economically viable to use molasses as the alternative energy resource.

Source: The Department of Customs, 2004 referred in the Department of Alternative Energy Development and Efficiency, Ministry of Energy; 2010

Table 2.3 Overseas Ethanol production with other plants

Kind of plants	Products per hectare(ton)	Alcohol production per hectare (ton)
Sugarcane (Brazil)	54.2	3630
Sweet Sorghum (U.S.A.)	46.5	3554
Corn (U.S.A.)	5.7	2200
Cassava (Brazil)	11.9	2137
Cereals (U.S.A.)	3.5	1362
Wheat (U.S.A.)	2.1	773

Source: Brown (1980) referred in the Department of Alternative Energy Development and Efficiency, Ministry of Energy; 2010

2.8.1 Ethanol's General Situation

Ethanol is used in three main industries, i.e. beverages, cosmetics, pharmaceutical, and paints industry, and fuel industry, which consume 80% of all quantities distributed and produced around the world. The main factor that makes ethanol industry more popular and growth is its support for environment as it is the natural gas, produced from plants; so the production helps distribute income to people in rural areas, reduce the import of petroleum, and support the wide research and knowledge base expansion. The future of ethanol industry seems better as the demand on ethanol has grown continually whereas the opportunities for research and development for production efficiency and use are still wide. In addition, the production technologies can be studied and tested by small-sized up to large-sized industries. The production of ethanol is also important in social dimensions. Therefore, the project to be initiated for further sustainable management must be supported by the State to enable the development of local technologies.

Nowadays, the ethanol industry has expanded. About 23 ethanol factories are supported by the government with the total capacity of 4.06 million liter per day. Three of such factories already started their production with the total capacity of 350,000 liter per day. PTT Plc. announced its plan to replace Benzene 95 with gasohol (ethanol to be mixed with 10% gasohol), which would be implemented quicker within 1 year. Additionally, Thai Oil Co., Ltd., a large national oil refinery, announced that it would invest in an ethanol project supplied by cassava to produce one million liter of ethanol per day. The waste from that ethanol production would be utilized for the electricity generating.

2.8.2 The utilization of ethanol

C_2H_5OH, a clear flammable object, is an organic substance that comes from the fermentation of carbohydrate plants. Ethanol, also known as ethyl alcohol, can be mixed with liquor or any alcohol for consumption. Anhydrous has a boiling point at 78.5 °C. Ethanol can be used as an octane additive in gasohol, which is mixed with gasohol extensively as a substitute in the currently popular Methyl Tertiary Butyl Ether (MTBE). It was found in the research that MTBE can harm the environment when it leaks out into public water resources, and contaminates the drinking water in the U.S.A. If MTBE is prohibited to be mixed in the fuel, the ethanol demand would increase.(23)

At present, the global ethanol production volume is about 31 billion liters; two thirds of this volume is produced in America, especially the U.S.A. and Brazil. Another half of ethanol output is produced in the Asia Pacific, Europe and others. About 60% of ethanol is produced from sugar plants, 35% from seeds and flour plants, and 5% from synthesis.

Ethanol could benefit the agricultural sector because the farmers have more sources for selling their raw materials; ethanol production plants could be built and located across the country so that the ethanol could be produced in our country and it is not exhaustible; commercialized ethanol production in Thailand creates more jobs for farmers, which helps reduce the national unemployment, and spatially distribute jobs to rural areas; Thailand has more diverse sources of energy; the values of farm crops are increased; the energy prices are stable; the air pollution caused by MTBE production is reduced as it is replaced by ethanol; transportation fees and insurance costs of exporting farm crops to the international markets and importing the petrol are reduced; and more revolving capital exists in our economic cycle (Jiraporn, 2001).

2.8.3 Sugarcane

Sugarcane (*Saccharum officinarum* L.) is a kind of grass like rice and corn. Sugarcane is planted in tropical countries i.e. Brazil, Cuba, Australia, India, Philippines and Thailand. The general varieties include sugarcane, red sugarcane, black sugarcane, and bitter sugarcane. (24)

1) Botanical Characteristics

- Sugarcane is a Monocotyledon like rice; it has light green leaves. The back of leaf sheath has hair and fat and each grown sugarcane plant has 8-12 duty leaves.
- Sugarcane stem is large and erect with color ranging from light green to dark purple almost black, which its white fat covered. Each stem is composed of nodes and sections.
- Sugarcane root system is fibrous and spread radially around the stem about 50-100 cm and ranges from 100-150 cm depth. Sugarcane is not taproot if cultivated by seeds.
- Sugarcane flower, which is visible more in older plants, blooms like a white arrowhead bunched at the top of the stem and it has an integrated androecium and gynoecium. When the pollination occurs, it has a seed that can be grown.

2) Climate and weather

- Sugarcane likes 27-32 °c with suitable humidity. If sugarcane is planted in cooler temperature for a length of time, its sweetness will increase.
- Rainfall should be approximately 800-1,500 millimeter per year with regular rain distribution. If less rain occurs, an irrigation system should be used to support the plantation.
- Additionally, sugarcane likes the strong sunlight.
- Sugarcane should be planted in highlands, which are not flooded, with the slope gradient not more than 3%. Soil for sugarcane plantation should be the incoherent or sandy loam. Soil fertility should be medium up to good and there should be a good drainage, and ground should have a depth at least 50.8 cm, ph 5-7.7 with organic matters no less than 2%.

3) Plantation season

The plantation season is very important because it results to the preparation of soil, sugarcane growth and output, and harvesting that involves other control factors in the plantation. But, in any irrigated areas, the sugarcane can be planted at any seasons. Most sugarcane plantation in Thailand usually relies on rain. The sugarcane plantation periods may be divided into 3 sessions:

- Plantation in the beginning of rainy season (May-July): at northern, central, and northeastern regions of Thailand, sugarcane is usually planted during this time. The plantation in this season may encounter the problem of weeds that makes the plantation costs higher. Sugarcane plantation at the beginning of rainy season does not allow the use of rainwater completely because, at the first 1-3 months, sugarcane stems are small so they want a little amount of water. Sugarcane wants more water at the age of 4-8 months when it falls on the end of rainy season. When the period of watering is short or there is the water shortage, the sugarcane will not gain a full growth so the output is low. Moreover, for sugarcane plantation during this season, the sugarcane cannot be harvested at the beginning of sugarcane crushing season because sugarcane are still young, and then it must be cut at the end of sugarcane crushing season.

- Plantation at the end of rainy season (December-February): at the eastern region such as Chonburi and Rayong and the plantation has been increasing at the central region of the country. The advantages of planting at this period are fewer weeds, more available rainwater, and more growth time resulting to more products. The sugarcane can be cut at the beginning of crushing season. However, the plantation at this time needs better preparation of soil than that at the beginning of rainy season.

- Plantation in the dry season (February-April): This type of plantation must be in capillary areas with sufficient humidity or irrigation. On this method, soil is prepared by deep planting and bushy covering to expose the breeding stem to humidity, which has problems later in the dry season. This plantation period is especially lucrative in the central and western areas of Thailand and usually gets the 8-12 month sugarcane.

4) Utilization

Sugarcane plantation and harvest takes about 8-12 months. The farmers should know what kind of sugarcane to be planted by considering soil types and local weather, and determining the sugarcane mature for the crushing process. The highest sweetness of sugarcane must be in line with law. The sugar plants usually start the crushing season from November to May. In Thailand, most sugarcane is planted for the production of sugar. The wastes from the sugar production are bagasses and molasses. Bagasses can be used in the production of hardboard, fertilizer, fuel, feed, and paper pulp. Molasses can be exported and used in domestic industries such as alcohol production industry, monosodium glutamate production industry, soy sauce production industry, animal feed industry, and citric acid production industry, etc.(25)

5) Sugarcane and sugar situations in Thailand

Sugarcane and sugar industry is very important to the social and economic development of Thailand. It could create income for over 1,000,000 grassroots people and other 1,000,000 labors. The income from domestic sugar distribution and export in production season 2010/2011 amounted to 180 billion baht. (26)

It is estimated that, in the 2010/2011 production season in Thailand, the sugarcane production was approximately 65.69 million tons and the sugar production was about 6.9 million tons. However, Thailand's sugarcane production in this season, 2010, was 95.35 million tons and the sugar production was at 9.64 million tons. This means more products than forecasted for 39.20% and 39.11% respectively, which are the highest historic sugarcane and sugar output. On average, the efficiency of Thailand's sugarcane plantation and sugar plant production are still low about 9-10 ton per Rai with sugar sweetness about 11 CCS. and sugar production about 100-105 kg. per ton sugarcane while Brazil and Australia have engaged the sugarcane production at 13-15 tons per Rai and sugar production about 110-115 kg. per ton sugarcane.

There are some limitations of use sugarcane as ethanol; however, the ethanol production from other sources other than sugarcane is possible, which is determined by sugar prices. That is the sugar factories' choice if the farmers do not want to expand plantation areas. The production per Rai is raising, depending on weather and funding to the sugarcane production for ethanol because sugar has an advantage of the low cost on the ethanol production. (27)

Table 2.4 Thailand's sugarcane and sugar production

Production Seasons	Sugarcane (million tons)	Sugar (million tons)	Sugar (kg./ sugarcane tons)	C.C.S.
2001/2002	59.49	6.13	103.22	11.72
2002/2003	74.07	7.28	98.36	11.17
2003/2004	64.48	7.01	108.71	12.09
2004/2005	47.82	5.17	108.22	12.17
2005/2006	46.69	4.78	103.50	11.61
2006/2007	63.79	6.72	105.33	11.91
2007/2008	73.31	7.80	106.63	12.10
2008/2009	66.46	7.19	108.13	12.28
2009/2010	68.49	6.93	101.17	11.58
2010/2011	95.35	9.64	101.10	11.72

Source: The Cane and Sugar Board, 2011

6) Sugar Consumption

According to the surveys of domestic sugar consumption, Thai people's sugar consumption has been gradually increasing, from 4.3 kilograms/person/year in 1958 to 11 kilograms/person/year in 1975, and from 11.0 kilograms/person/year in 1983 to 12.7 kilograms/person/year and 28.5 kilograms in 1997 and 29.2 in 2001, until it reaches 39 kilograms/person/year in 2010. (28) From such data if calculated in the number of teaspoon, it was found that Thai people consume sugar higher for 2 times or from 8.7 teaspoons per day to 20 teaspoons per day. In addition, from a survey of food status and nutrition in Thailand by the Division of Nutrition, the Department of Health, Thai people drink general beverages, excluding fresh water and milk, higher for 6.8 times per person. Most general beverages contain a high amount of sugar, and they are widely distributed in the market. The rising amount of sugar consumption and higher favor for beverages containing the high quantity of sugar are shown in Table 2.5. (29)

Table 2.5 Quantity of sugar in Thailand

Year	Quantity of Sugar (Kg./People/Year)
2501	4.3
2518	11.0
2526	12.7
2540	28.5
2544	29.2
2553	39

Source: Department of Health, 2011

7) Ethanol production from sugarcane

There are two methods to produce ethanol from sugarcane:

- Cane juice from fresh sugarcane: cane juice is fermented with yeast. One ton of fresh cane can get 70 liters of ethanol. If using sugarcane as the raw material in the ethanol production, this raw material may not be adequate. There is also a limitation that the sugarcane plantation and harvesting to be supplied to sugar plants can be done within 5 months per year; as a result, there will be a problem of producing the ethanol from sugarcane only. In addition, using sugarcane as a raw material must encounter the problem of interest sharing between sugarcane farmers and sugar plants. (30) It is apparent that there are some limitations in using sugarcane as a raw material for the ethanol production. However, the ethanol made from sugarcane may be considered whenever the sugar prices drop, which deems another solution of sugar plants. If the farmers don’t want to expand their plantation areas, the increase of product per planting areas is another solution to get the adequate quantity of sugarcane for the ethanol plants, and to have lower cost for the ethanol production. (31)

- Molasses: molasses and yeast are fermented together. One ton of molasses could get 260 liters of ethanol. Molasses is a by-production of the sugar industry. In general, 1 ton of sugarcane gets molasses about 45-50 kilogram per ton. However, the sugarcane production at each year is unstable, depending on the sugarcane quality and quantity. The quantity of molasses in 2005-2006 was 2.11 million tons. Produced molasses are consumed domestically or exported. Most domestic consumption of molasses is in liquor, alcohol, yeast, soy sauce, and monosodium glutamate industries.

Table 2.6 Comparison of ethanol quantity produced from various crops

Crops (1 ton)	Ethanol (liters)
Molasses	260
Sugarcane	70
Fresh Cassava	180
Millet	70
Cereals (Rice, Corn)	375
Coconut Oil	83

Source: Thai Ethanol Manufacturing Association, 2010

8) Strategic Plan for the cane and cassava production development

The sugarcane and cassava production development strategy is that sugarcane and cassava are the energy plants used for the ethanol production, but such production must not affect the domestic consumption and the plantation of other crops. Sugarcane and cassava plantation areas remain unchanged, but the productivity per rai must be increased for another 10%. The guidelines are to improve the breed of energy plants to be sufficient and appropriate for the needs of farmers, to use appropriate production technologies, and to promote the production and manufacturing management.

Nowadays, the sugarcane and cassava produced at each year are sufficient for the domestic consumption and ethanol production. Other remaining quantity may be exported. In 2009, about 73.2 million tons sugarcane was produced to get 20 million tons for our domestic consumption and other 50 million tons sugarcane was exported. The output of cassava totaled 27 million tons; 8 million tons of them was consumed in the country, which may be divided into 7 million tons of cassava chips and cassava flour while 0.78 million tons was used for the production of ethanol.

About 19 million tons of cassava was exported. If such sugarcane and cassava exported is produced to get ethanol, our country can reduce the huge quantity of imported fuel. (32)

For the policy of alternative energy plants, the sugarcane is produced for the household consumption and ethanol production, that is, it must be sufficiently produced as food before being produced as ethanol. At present, the sugarcane quantity is adequate for the domestic consumption and ethanol production. If the demand on ethanol increases, the exported amount may be moved to produce the ethanol. This is the same to cassava, which will be first produced for the demand on food; the remaining quantity will be produced as ethanol. If the cassava output is great, but the price is low, it will be more produced as ethanol. (32)

2.9 Study Area

2.9.1 General Characteristics

Kanchanaburi is located in the center of Thailand. It consists of 19,483.18 Sq.km. or 12,176.967 rai and far from 129 km. Bangkok. Its connected borders are:

North, connecting with Tak, Uthaithani, Suphanburi, and Republic of the Union of Myanmar.

East, connecting with Suphanburi, Nakhon Pathom, and Ratchaburi.

South, connecting with Ratchaburi.

West, connecting with the Republic of the Union of Myanmar by Tenasserim Range is international border.

2.9.2 Geographical Features

Kanchanaburi is a province in the western region of Thailand. Its physical features include mountains and ranges from the north. These ranges are the Thanon Thongchai, and Tenasserim. The Thanon Thongchai range comes from Maehongson and passes through Tak until Three Pagodas in Kanchanaburi. The west of this province is a narrow valley resulted by land subsidence and land consolidation. The features eroded into single mountains can be seen widely. The piedmont plateau consists of rock waste and soil, which are carried by water from the high plains. The structure and soil texture are different from the alluvial soil in the central plain. The east consists of plains and the south consists of rolling plains with short rivers from Thanon Thongchai and Tenasserim ranges. These Piedmont plateaus and rolling plains are fertile and used for planting many plants such as sugarcane, cassava, corn, and other economically lucrative plants. The river plain soil is less suitable for rice farming. Rice plantation is clustered on the lower basin near the delta that connects the central plains. The Kwaeyai River, the Maeklong River's branch flows to join with Kwaenoi River at Muang District which then flows out to the Gulf of Thailand at Samutsongkram. Most water resources in this province are used for electricity generating and irrigation. In this province, there are many barrages and dams such Sri Nagarindra Dam, Vajiralongkorn Dam, Maeklong Dam etc.

2.9.3 Weather

Kanchanaburi is a tropical savanah climate: AW in Koppen Style. It is dry during the winter and predictably humid during the rainy and dry seasons. In May-October, the region is affected by the Southwest Monsoon that comes from Andaman Sea, which brings rainfall and high humidity. The spreading of rain in this province is different; the upper areas at Saiyok District, Thongpaphum District, and Sangklaburi District face more diffuse rainfall than lower areas. Rainfall averages about 1,086.2 millimeter per year.

2.9.4 Temperature

Kanchanaburi is mostly highland with mountains that act as a physical border. High elevation creates during the summer. April is the hottest month of the year. In winter, it is not exceptionally cold, except in the bordering ranges, where the lowest average temperature is 26.5 °c and the highest average is 39.39 °c.

2.9.5 Forest Resources

Forests in Kanchanaburi include mixed deciduous forests and dry dipterocarp forests.

Mixed deciduous forest is more or less sparse forest that consists of coordinated small, medium, and large perennial plants, where the deciduous dipterocarp forest does not exist. In both types of forest, there are some species of bamboo growing in crowded and high clusters. Soil in both forest types in Kanchanaburi is sandy loam, which has medium humidity and moisture content. If soil decomposes from limestone or alluvial soil accumulated on the river banks, the combined soil type creates ideal conditions for lucrative teak forest.

Deciduous dipterocarp forest can be found in plains and 1,000 meter downhill slopes; this forest type grows on sandy soil or lateritic soil, which is shallow and dry. Deep sandy soil cannot maintain moisture content until the dry season, while lateritic soil is shallow and rather dark red.

2.9.6 Population

Kanchanaburi has 835,308 people: 420,244 men and 145,064 women. (33)

2.9.7 Agriculture

Kanchanaburi has 2,877,161 Rai of agricultural areas with overall agricultural production about 11,542,567.43 tons. The main important crops are corn, cassava, sugarcane, rubber, maize, sweet corn, asparagus, and pineapple. (34)

Kanchanaburi has 561,633 Rai of sugarcane plantation with the total sugarcane production at 6,049,023 tons. These figures show an increase of areas and plantation from the last year, and indicate that the sugarcane plantation quantity is higher than that of corn feed and cassava.

Table 2.7 Economically important plants of Kanchanaburi

Types	Plantation Area (Rai)	Production(ton/year)	Average (Kilogram/Rai)
1. sugarcane	561,633	6,049,023	10,660.00
2. In-season rice	487,177.00	289,477.41	621.63
3. Off-season rice	224,251.00	201,137.07	900.95
4. Cassava	641,911	1,890,980.20	3,390.66
5. Pineapple	36,085.00	133,415.15	3,950.47
6. Feed Corn	134,332.25	100,533.50	750.20
7. Sweet corn	37,672.00	66,646.64	1,770.30
8. Baby corn	131,733.00	202,644.44	1,561.52
9. Eucalyptus	62,207.00	382,364.00	11,107.81
10. Rubber	124,527.50	12,030.35	275.39

Source: Kanchanaburi Agricultural Extension Office, 2009

Table 2.8 Forecast report of sugarcane plantation areas and sugarcane production on 2010/2011 in the central region

No.	Provinces	Sugarcane Plantation Area (Rai)	All Sugarcane Production (Ton)	Areas of Sugarcane Plants (Rai)	Pressing Sugarcane Quantity (Ton)	Average Production (Ton/rai)
1	Uthaithani	214,747	2,596,788	234,421	2,492,121	10.63
2	Chainat	108,511	1,156,264	105,266	1,110,120	10.55
3	Singburi	61,349	656,651	59,482	630.103	10.59
4	Lopburi	497,005	5,281,706	479,747	5,045,487	10.52
5	Saraburi	92,783	996,648	89,796	954,597	10.63
6	Angthong	12,944	144,487	12,480	137,865	11.05
7	Suphanburi	486,484	5,281,474	469,406	5,043,261	10.74
8	Kanchanaburi	561,633	6,049,023	542,249	5,779,762	10.66
9	Nakhonpathom	73,352	795,637	70,689	758,799	10.73
10	Ratchaburi	149,281	1,592,126	144,114	1,521,100	10.55
Total		2,356,173	25,271,605	2,277,155	24,170,547	10.61

Source: The Office of Cane and Sugar, 2010 (35)