

**Paper Reference No. :** PN-227  
**Title of the paper :** Site Selection for Ethanol Plants Using GIS in Nakhonratchasima Province, Thailand  
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### **Abstract**

Ethanol plays an important role in gasohol production which is transformed from agricultural products especially cassava. Many countries have promoted the use of gasohol to reduce the expense from importing crude oil and to reduce the global warming phenomenon. In Thailand, the Ministry of Energy has tried to maximize the use and the production of gasohol from cassava which are mostly grown in Nakhonratchasima Province.

The objective of this paper is to apply Geographic Information System (GIS) for effective site selection of ethanol plants using multi criteria decision analysis through the Analytic Hierarchy Process (AHP), one of the high accuracy methods used for weighting and ranking data. The criterions used for evaluating data are buffering distance from places, conservation area, cassava plantation area, tapioca chip factory, tapioca flour factory, water resources, transportation route and other factors including product data and land cost. Land use was extracted from Landsat-5 TM imagery acquired in December 2008 with 83% accuracy.

The result of this study shows that most of suitable areas for ethanol manufacturing distributed in the center and the northeast parts of the province which are near by the productive areas and locations of tapioca chip factory. Result illustrates that very high suitable area of 113,907 rai (0.88 % of province area) are mostly located in Muang, Non Thai, and Si Khiu district with the area of 45,624, 35,574, and 15,846 rai respectively. High suitable area of 924,106 rai (7.11 % of province area) are mostly located in Non Thai, Dan Khun Thot, and Muang district with the area of 166,170, 121,658, and 121,234 rai respectively. Moderate suitable area of 2,004,364 rai (15.43 % of province area) are mostly located in Dan Khun Thot, Phi Mai, and Non Sung district with the area of 310,428, 221,288, and 150,293 rai respectively. Low suitable area of 1,711,155 rai (13.17 % of province area) are mostly located in Pra Thai, Phi Mai, and Non Sung district with the area of 183,991, 179,211, and 125,228 rai respectively. Very low suitable area of 791,310 rai (6.09 % of province area) are mostly located in Bua Yai, Pra Thai, and Pak Chong district with the area of 165,042, 113,562, and 82,528 rai respectively.

**Keywords :** Site Selection, Ethanol Plants, GIS, AHP

## **1. Introduction**

Thailand has spent about 300,000 million baht per year to import crude oil from foreign countries. The increment of oil price in world market has directly effect the country. One way to solve this problem, is to use an alternative source of energy like ethanol. Ethanol plays an important role in gasohol production which is transformed from agricultural products especially cassava. Many countries have promoted the use of gasohol to reduce the expense from importing crude oil and to reduce the global warming phenomenon. Moreover, Thailand has tried to add value to cassava because cassava market is oversupplied. An excess of 4 million tons of cassava per year can be used to produced approximately 2 million liters of ethanol per day. The Ministry of Energy has acknowledged the important of this issue, therefore has tried to maximize the use and the production of ethanol to 3 million liters per day within the year 2011 especially from agriculture material like cassava which are mostly grown in Nakhonratchasima Province (Department of Alternative Energy Development and Efficiency, 2008). Thus, ethanol produced from cassava plant site selection is beneficial to agriculture of Thailand, and an environment in a long term. In this study, an application of GIS which is an effective tool is used to analyze spatial data and select suitable location for ethanol plants considering physical and economic factors received from Department of Industrial Works (DIW). Result of this study will be a useful information for planning and decision making support for the involved organizations in the future.

## **2. Objectives**

to study suitable ethanol plant site selection using GIS in Nakhonratchasima province, Thailand

## **3. Study Area**

Nakhonratchasima Province, Thailand has an approximate area of 12.99 million rai located between latitude 14° 2' 50" to 15° 50' 31" N and longitude 101° 8' 32" to 102° 57' 54" E. It is composed of 32 districts and 289 sub districts. Most area in the north is flat and plenty of mountain in the southwest and the south of the province (figure 1). It is 100 to 1,300 meters high from mean sea level. There are 3 seasons which are summer, dry, and rainy. The cassava plantation area is approximately 1.98 million rai which is biggest in Thailand (Office of Agricultural Economics, 2009).

## **4. Methodology**

The methodology used in an analysis of site selection can be summarized as follows. First, information relating to ethanol plants such as the importance, type, policy, and condition of location were studied and reviewed. Next, data from many sources were collected and layers were created. Then, the weight and rank values were defined with experts. Finally, the analysis used overlay method in GIS to identify suitable areas for ethanol plants. An overview of the analysis concept is shown in figure 2 below.

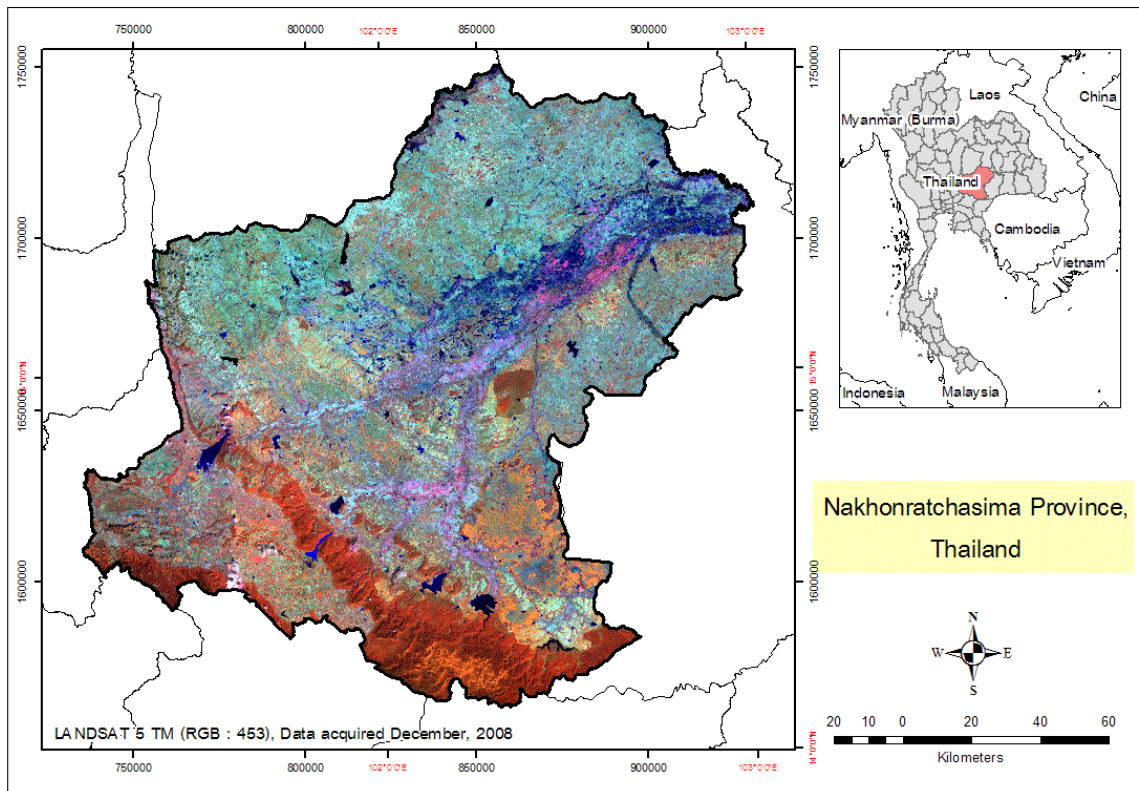


Figure 1. Nakhonratchasima province, Thailand.

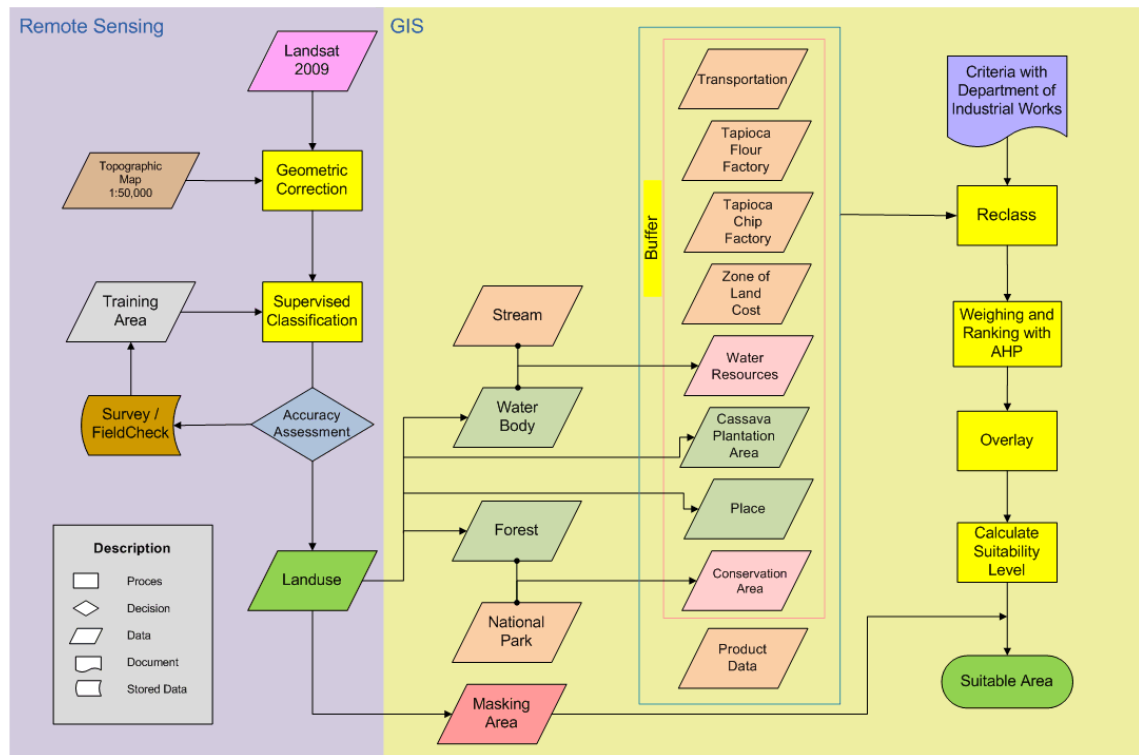


Figure 2. A conceptual model in the analysis of site selection.

#### 4.1 Data

Collected data in various types including satellite imagery, shape file, statistic data, and map, were used to create layers for analysis. Four scenes of Landsat-5 TM imageries including (Path/Row) 128/49, 128/50, 129/49, and 129/50 acquired in December 2008 were supported by GISTDA : Geo-Informatics and Space Technology Development Agency (Public Organization). Layers and their data sources are summarized in table 1.

**Table 1.** Layers and data source.

Layers	Data	Source
1. Place	Place*	GISTDA
2. Conservation Area	Forest Area*	GISTDA
	Conservation Boundary	Royal Forest Department
3. Cassava Plantation Area	Cassava Plantation Area*	GISTDA
4. Tapioca Chip Factory	Report	Office of Agriculture in Nakhonratchasima Province
5. Tapioca Flour Factory	Report	Office of Agricultural Economics
6. Transportation	Topographic Map 1:50,000	Royal Thai Survey Department
7. Zone of Land Cost	Report	Treasury Department
8. Product data	Report	Office of Agriculture in Nakhonratchasima Province
9. Water resources	Water Body*	GISTDA
	Stream	Department of Environmental Quality Promotion

\* Data from Landsat-5 TM in 83% accuracy.

#### 4.2 Weighting

The weight value defining is importance in this study because it will suggest that which layer has high or low important level in consideration of suitable ethanol plant locations. The important level values were defined in pairwise comparison matrix (Table 2) by 5 experts in soil, forest, water, industry, and ethanol field. The values in this table than were used to calculate weight using eigenvector method. Result of eigenvector values were corrected by which consistency ratio of acceptable values could be no more than 0.1. Hence, the important level of layers in descending order are place, conservation area, cassava plantation area, tapioca chip factory, tapioca flour factory, water resources, transportation, product data, and zone of land cost, respectively.

**Table 2.** Weight value from pairwise comparison matrix.

	Place	Tapioca Flour Factory	Cassava Product	Tapioca Chip Factory	Conservation Area	Cassava Area	Zone of Land Price	Water Resource	Transportation	Eigenvector
Place	1	3	5	2	3	3	7	5	3	0.255
Tapioca Flour Factory	1/3	1	3	1/5	1/5	1/5	3	3	2	0.064
Cassava Product	1/5	1/3	1	1/5	1/5	1/5	3	1/3	1/3	0.030
Tapioca Chip Factory	1/2	5	5	1	1/3	1/3	5	5	6	0.148
Conservation Area	1/3	5	5	3	1	2	7	5	3	0.207
Cassava Area	1/3	5	5	3	1/2	1	5	5	4	0.179
Zone of Land Price	1/7	1/3	1/3	1/5	1/7	1/5	1	1/3	1/2	0.022
Water Resource	1/5	1/3	3	1/5	1/5	1/5	3	1	3	0.051
Transportation	1/3	1/2	3	1/6	1/3	1/4	2	1/3	1	0.044

### 4.3 Ranking

In contrast to weight values, where they were defined for each layer, rank values were defined for each class in a layer. The conditions used in defining classes are of DIW. Each class was assigned a rank based on its suitability for being a plant site. Rank value are ranging from 1 to 5, where 5 is the most suitable site and 1 is the least suitable site. However, for some areas which are not suitable as location for plants such as urban, national park, water resources etc. They were marked and were not considered in the analysis. The reasons used in defining classes in each layer are described below. Table 3 shows classes in each layer and ranks assigned to each class.

4.3.1 Place layer is the most important layer with the weight of 0.255. Place include village, school, hospital, temple, business place, airport, golf field, government place, graveyard, farm, park, housing development, heritage, and tourist attraction. With the concern about health and environmental problems, the ethanol plants should be located far away from place (Justin, 2008). In addition, plant sites should be located further than 500 meters from places. Due to thais regulation. See table 3(a) for classes and their assigned ranks.

4.3.2 Conservation area layer has the weight of 0.207. It includes conservation forest areas and national parks which are important in the environment and natural resource aspects. The plants are then conditioned to locate 1 kilometer further away from these areas. See table 3(b) for classes and their assigned ranks.

4.3.3 Cassava plantation area layer has is the weight of 0.179. The plants should be located near the cassava plantation area because of its advantage in transportation (Stewart and Lambert, 2008). See table 3(c) for more detail in classes and their assigned rank.

4.3.4 Tapioca chip factory location layer has is the weight of 0.148. Tapioca chip can be used to produce ethanol as well (Tunyaporn, 2005). Agriculturist can sell cassava to factory as an alternative to the plants. The plants that are close the factory, have an advantage of transportation. Table 3(d) provides detail about classes and their ranks.

4.3.5 Tapioca flour factory location layer has the weight of 0.064. Tapioca flour is also a material used to produce ethanol. However, the production cost is higher than using cassava or tapioca chip. The plants that are close the factory having the advantage of transportation. Table 3(e) shows classes and their assigned ranks.

4.3.6 Water resources layer has the weight of 0.051. Water resources are important in the production process of liquefying with amylase. The plants that are

close to water resources, have more advantage. However, water should be perennial so it will not affect water usage of people lived near by. If the distance is less than 500 meters, wastewater treatment ponds are need lining. Table 3(f) shows classes and their assigned ranks.

4.3.7 Transportation layer has the weight of 0.044. The plants should be located near the roads with more than 2 lanes due to its easy accessibility. Roads wider than 2 lanes, are used for the analysis. classes and their ranks are shown in table 3(g).

4.3.8 Product data layer has the weight of 0.030. The plants located near areas of high production capability of cassava have more chance to get continuous material. These production capabilities are different in each district. Its average is between 2.5 to 5 tons/rai. Table 3(h) shows detail about classes and their ranks.

4.3.9 Zone of land cost is the lowest important with the weight of 0.022. Even though, land cost isn't much important but it will be used in case there are many very high suitable locations. The cheaper land cost has more advantage especially in case of land for rent. Land cost used in this study are estimate overall cost in each district and some zones along main road in Nakhonratchasima province. Classes and their ranks are shown in table 3(i).

**Table 3.** Rank value in layers.

(a) Distance from Place				(b) Distance from Conservation Area			
No.	Buffer (km)	Ranking	Class	No.	Buffer (km)	Ranking	Class
1	> 5	5	Very High Suitable	1	> 9	5	Very High Suitable
2	3 - 5	4	High Suitable	2	7 - 9	4	High Suitable
3	1 - 3	3	Moderate Suitable	3	5 - 7	3	Moderate Suitable
4	0.5 - 1	2	Low Suitable	4	3 - 5	2	Low Suitable
5	0 - 0.5	1	Very Low Suitable	5	1 - 3	1	Very Low Suitable

(c) Distance from Cassava plantation Area				(d) Distance from Tapioca Chip Factory			
No.	Buffer (km)	Ranking	Class	No.	Buffer (km)	Ranking	Class
1	0 - 1	5	Very High Suitable	1	0 - 10	5	Very High Suitable
2	1 - 3	4	High Suitable	2	10 - 20	4	High Suitable
3	3 - 5	3	Moderate Suitable	3	20 - 30	3	Moderate Suitable
4	5 - 7	2	Low Suitable	4	30 - 40	2	Low Suitable
5	> 7	1	Very Low Suitable	5	> 40	1	Very Low Suitable

(e) Distance from Tapioca Flour Factory				(f) Distance from Water Resources			
No.	Buffer (km)	Ranking	Class	No.	Buffer (km)	Ranking	Class
1	0 - 10	5	Very High Suitable	1	0 - 0.5	5	Very High Suitable
2	10 - 20	4	High Suitable	2	0.5 - 1	4	High Suitable
3	20 - 30	3	Moderate Suitable	3	1 - 3	3	Moderate Suitable
4	30 - 40	2	Low Suitable	4	3 - 5	2	Low Suitable
5	> 40	1	Very Low Suitable	5	> 5	1	Very Low Suitable

(g) Distance from Transportation				(h) Product Data			
No.	Buffer (km)	Ranking	Class	No.	Product (tons/rai)	Ranking	Class
1	0 - 1	5	Very High Suitable	1	4.5 - 5.0	5	Very High Suitable
2	1 - 3	4	High Suitable	2	4.0 - 4.5	4	High Suitable
3	3 - 5	3	Moderate Suitable	3	3.5 - 4.0	3	Moderate Suitable
4	5 - 7	2	Low Suitable	4	3.0 - 3.5	2	Low Suitable
5	> 7	1	Very Low Suitable	5	2.5 - 3.0	1	Very Low Suitable

**Table 3.** Rank value in layers. (cont.)

(i)

Zone of Land Cost			
No.	Cost (million baht)	Ranking	Class
1	< 0.05	5	Very High Suitable
2	0.05 - 0.5	4	High Suitable
3	0.5 - 1	3	Moderate Suitable
4	1 - 3	2	Low Suitable
5	> 3	1	Very Low Suitable

## 5. Result and Conclusion

Result of analysis is a map showing suitable sites selected for ethanol plants (figure 3). It is obtained from the overlay operation of layers. Weight value defined for each layer, is multiplied by the rank values given to the classes of that layer. Every value of map (M) is calculated by using a following equation

$$M = \sum WR$$

where

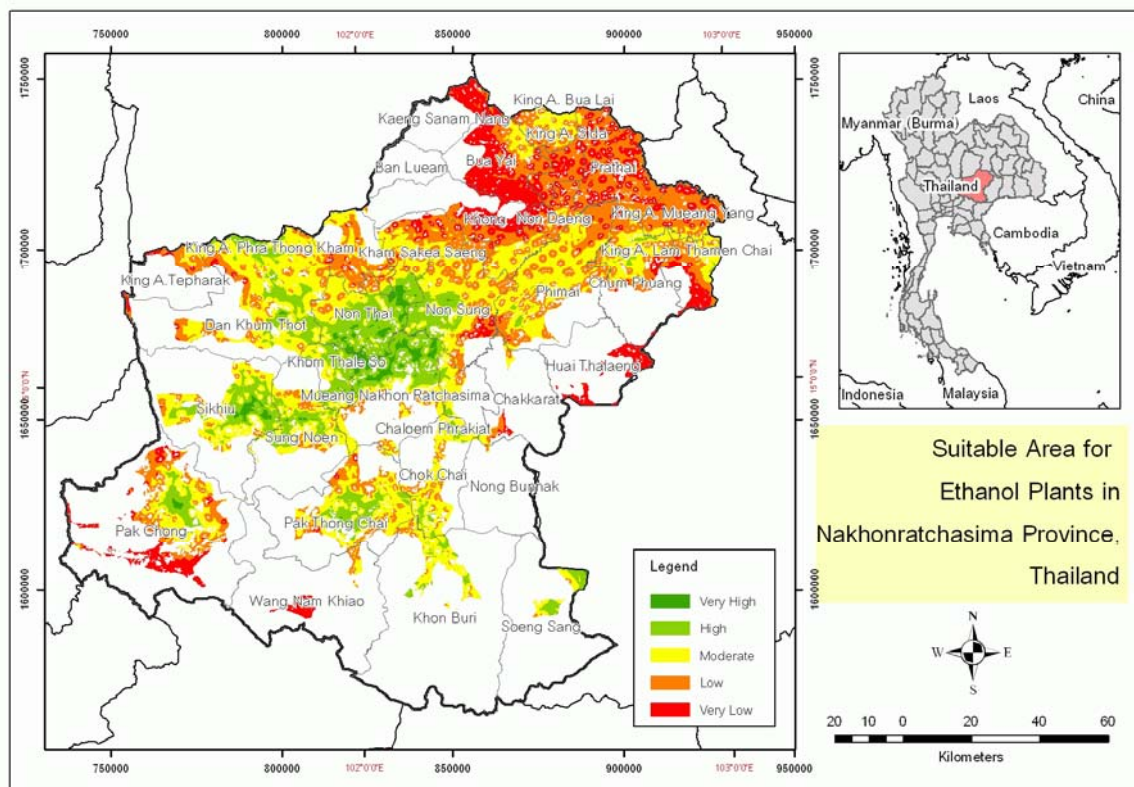
W = weight value of layer

R = rank value of class

The statistic values obtained from the calculation include, the minimum value of 1.264, the maximum value of 4.336, the average value of 3.000, and the standard deviation of 0.505. Five suitable levels and interval show in table 4.

**Table 4.** Interval of suitable level

Suitable Levels	Interval
Very High	> 4.010
High	3.506 – 4.010
Moderate	3.001 – 3.505
Low	2.496 – 3.000
Very Low	≤ 2.495



**Figure 3.** Suitable area for ethanol plants.

The total suitable area in site selection for ethanol plants is 5,544,842 rai (42.68 % of province area) and marking area is 7,445,510 rai (57.32% of province area). Suitable areas are distributed in the central and the northeast.

Very high suitable area of 113,907 rai (0.88 % of province area) are mostly in Muang, Non Thai, and Si Khiu district with areas of 45,624, 35,574, and 15,846 rai respectively.

High suitable area of 924,106 rai (7.11 % of province area) are mostly in Non Thai, Dan Khun Thot, and Muang district with areas of 166,170, 121,658, and 121,234 rai respectively.

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