LAND SUITABILITY ASSESSMENT OF NIPA PALM USING GIS AND ANALYTIC HIERARCHY PROCESS: A CASE STUDY IN PAK PHANANG, THAILAND

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Abstract: Utilization of Nipa palm for ethanol/biofuel production is more advantageous than other ethanol-producing crops for it does not compete or in conflict with the growing demand for food. The study aimed mainly to find suitable area for Nipa palm plantation using the following suitability parameters: water salinity, water pH, soil salinity, soil pH, soil texture, water availability/accessibility, elevation, land use, and slope. Along with this, projection on the production of sap, sugar, and ethanol; and required man-power for the expansion of Nipa palm plantation was also included in the analysis. Analytic Hierarchy Process (AHP) was utilized to assign weights of the different Nipa palm suitability parameters, and then the Nipa palm suitability map classified into four categories: high, moderate, marginal, and low suitable was generated using ArcGIS 9.3 software. The map was then compared with existing Nipa palm for validation purpose. The results showed that around 45% of the Khanap Nak area was highly suitable; and around 98% of the existing Nipa palm area was within the highly suitable category.

INTRODUCTION

In this era of new technologies and industrialization, there is always an increasing demand for fuel, especially for transportation. But the natural sources of these fuels are limited. In many countries, Thailand for example, there is already scarcity of fuels and their rate of energy dependency increases. As a solution, the Thailand's government declared a countrywide campaign in 2003 to promote production and usage of bioethanol by producing local ethanol from renewable agricultural raw material such as sugarcane and cassava (Suksri, et al, 2007).

However, these raw materials are basically food crop continuously utilizing these for ethanol production would be in conflict with the growing demand for food. The use of Nipa palm as a source of bioethanol is more advantageous compared to these crops in terms of yields and sustainability. The potential of Nipa palm to produce sugar (Ekpunobi and Eboatu, 2008), alcohol (Dalibard, 1999), and ethanol (Tamunaidu et al., 2011; Thong-Om 2009) has been already proven and reported. Tamunaisdu et al. (2011) found Nipa palm sap to be a good source and prospect for bioethanol production as it can be easily fermented with high yields of ethanol. Nipa palm is considered to be one of most versatile plant in the coastal areas due to its many uses (Hamilton and Murphy, 1987; Miah et al, 2003; Quimbo, 1991; Wongchan, 1997). In the early days, it has been used for wide variety of purposes, such as thatching, making vinegar, and for alcoholic beverages. Nowadays, it is used as the primary source of ethanol and or biofuel production in some parts of the world like West Africa and Malaysia (Biopact team, 2007; and Tan, 2001).

Unlike other bioethanol raw materials such as sugarcane, conflict with other agricultural land uses will be minimized as Nipa palm grows in wild or mangrove areas (International Center for Research in Agroforesty, 2008; Bamroongrugsa, 1997). Morever, the environment is well protected as well for there are no huge wastes to get rid of such as bagasse (Dalibard, 1999).

Nipa palm is an ethanol-producing tropical plant that grows along the coast, rivers, and estuaries. ICRAF (International Center for Research in Agroforesty, 2008) described the natural habitat of Nipa palm to be 1 to 9 parts per mil (1-9 ppt) as the optimum salt concentration; soil types to be muddy and rich in alluvial silt, clay and humus; high content of various inorganic salts, calcium, and sulphides of iron and manganese; and soil pH to be around 5. Nipa palm can survive at an average minimum and maximum temperature of 20^{o} C and 32-35^{o} C, respectively. In addition, Bamroongrugsa (1997) found that younger Nipa palm seedlings required freshwater while the older ones can tolerate saltwater. However, he also found that watering with 18 ppt salinity water reduced its growth; while 35 ppt salinity impeded the growth and withered its leaf.

The study was conducted to find potential suitable area for Nipa palm plantation and expansion at Pak Phanang, Nakhon Si Thammarat, Thailand particularly in Khanap Nak sub-district. Khanap Nak (or Kanab Nak) is located at 8.20^{o} N latitude and 100.25^{o}E longitude and covers an area around 45 square kilometers. The suitability parameters used where water salinity, water pH, soil salinity, soil pH, soil texture, water availability/accessibility, elevation, land use, and slope. The study also employed Analytic Hierarchy Process (AHP) in assigning weights of different suitability parameters for suitability analysis, and then final suitability map was generated in ArcGIS software. AHP was commonly used with GIS by many researchers to establish relative importance of different parameters by estimating its weights for land suitability analysis (Dai et al., 2001; Carr et al., 2005; Moeinaddini et al., 2010; Chen et al., 2010).

Description of the Khanap Nak, Thailand

Khanap Nak (or Kanab Nak) is the southern-most *tambon* (sub-district) among the eighteen sub-districts of *amphoe* (district) Pak Phanang, Nakhon Si Thammarat, Thailand. Its neighboring sub-districts are Tha Phaya, Pak Phraek, Suea Hueng, Tha Som, and Khopet; while on its east is the Gulf of Thailand. The canal "Klong Rabainam Nhagote" is a man-made distribution canal (around 120-m wide) constructed in 1995 that pumped saltwater from the Gulf of Thailand to the individual shrimp farms of the area.

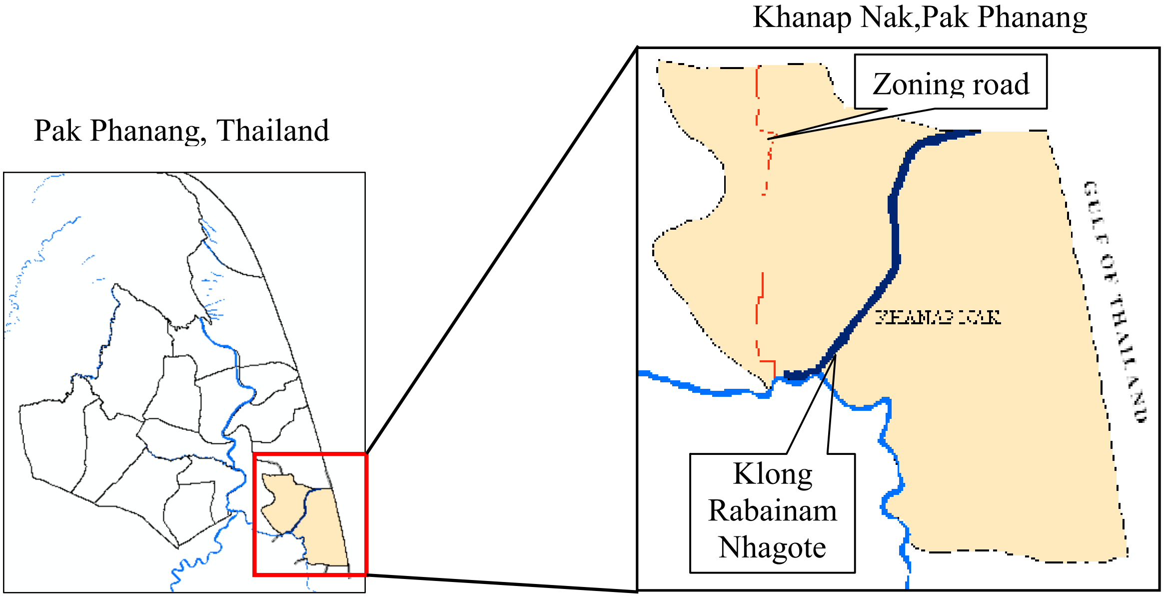

Figure 1. Study Area: Pak Phanang, Thailand

NIPA PALM SUITABILITY MODEL DEVELOPMENT

Figure 2 shows the processes that were performed to create a GIS-based land suitability map for Nipa palm in Khanak Nak, Pak Phanang, Thailand.

Reconnaissance Survey

Reconnaissance survey was executed rapidly and at limited time prior to field survey to provide general information and to become familiar with the study area that will be useful in detailed planning of the field survey. During this process, a subset of the study area from Advanced Land Observing Satellite, Advanced Visible and Near Infrared Radiometer Type II (ALOS AVNIR-2) data (10-m resolution, acquired in March 31, 2009 from Japan Aerospace and Exploration Agency) in natural color composite was used as a reference, and a hand-held Garmin GPS was also used to track routes.

Field Survey

Field survey was conducted to collect water and soil samples of the study area. Areas where to collect soil and water samples were identified in ALOS AVNIR-2 satellite data and using the previous information gathered during the reconnaissance survey. A total of fifty five water and soil samples were collected in the area.

Interview

Although interview was not the main tool for collecting primary data, however, it was conducted to explore the perspectives and idea of the village people, and to seek suggestions about planting Nipa palm. A survey questionnaire guide was prepared by the researcher prior the conduct of in-depth interview. Some follow up questions were also asked during the interview to further get detailed information

Analysis and Interpolation of Water and Soil Parameters

Water and soil samples were sent to laboratory to analyse pH and salinity. And the results were encoded and entered into a GIS database with their corresponding coordinates. Then these parameters/data were spatially interpolated using Kriging method in Geostatistical Analyst tool of ArcGIS 9.3 to derive data over the entire area. Different Kriging models were developed and their prediction errors were checked to choose the best model.

Selection of Criteria

There were nine (9) factors or criteria that were considered as input to the development of Nipa palm suitability model: water salinity, water pH, soil salinity, soil pH, soil texture, water availability, elevation, land use, and slope (table 1).

Weighting of Criteria using AHP

The AHP developed by Saaty (1980) was used to weigh each suitability criterion. Tables 2 to 4 show the pair-wise comparison matrix and the RIW derived for each criterion that belongs to water quality, soil quality, and physical condition, respectively.

The derived water and soil quality models were then assigned weights of 0.60 and 0.40 respectively, to generate a suitability map in terms of environmental conditions.

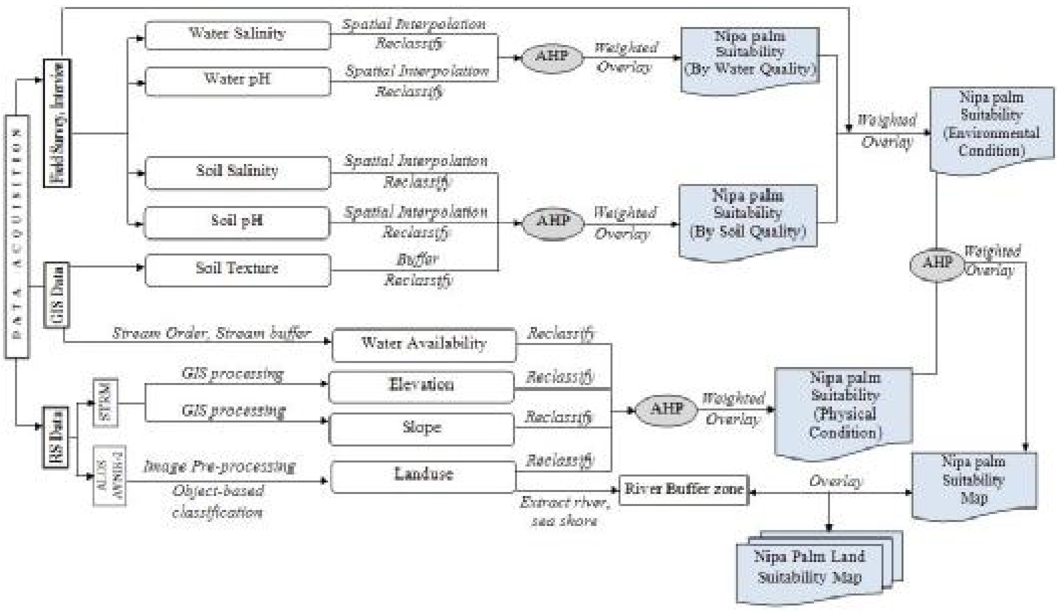

Figure 2. Nipa Palm Suitability Model Development Workflow

Table 1. Suitability Criteria for Nipa palm

No.	Criteria	SUITABILITY			
		High (1)	Moderate (2)	Marginal (3)	Low(4)
1	Water salinity (ppt)	3 - 7 ppt	ge 2 & lt 3 gt 7.0 & le 8.0	ge 1 & lt 2 gt 8.0 & le 9.0	lt 1 gt 9 0
2	Water pH	7.0 - 7.5	ge 6.0 & lt 7.0 gt 7.5 & le 8.0	ge 5.0 & lt 6.0 ge 8.0 & le 8.5	lt 5.0 gt 8.5
3	Soil salinity	1 - 4 ppt	gt 4 & le 6 lt 1	gt 6 & le 8	gt 8
4	Soil pH	5 - 6.5	gt 6.5 & le 7.0	gt 7.0 & le 7.5	gt 7.5 <5
5	Soil texture	sandy-clay-loam; clay and humus	loamy-sand; clay-loam	silt-loam; loam	clay; gravelly-clay; sand
6	Stream buffer 1 (m)	200	400	600	800
	Stream buffer 2 (m)		100	200	300
	Stream buffer 3 (m)			100	200
	Stream buffer 4 (m)				200
7	Elevation (m)	< 3	ge 3 & le 6	gt 6 & le 9	gt 9
8	Landuse	Wetlands Pine tree Nipa palm Aquaculture pond	Mixed vegetation Wet to dry land	Paddy field	Bareland River seashore
9	Slope (degree)	le 5	gt 5 & le 10	gt 10 & le 20	gt 20

le – lesser than and equal *ge - greater than & equal*

lt – lesser than *gt – greater than*

Table 2. Pair-wise Comparison Matrix and RIW for Water Quality

	Water salinity	Water pH	RIW
Water salinity	1	2	0.67
Water pH	1/2	1	0.33

RI = 0 *CI = 0* *CR = 0*

Table 3. Pair-wise Comparison Matrix and RIW for Soil Quality

	Soil salinity	Soil pH	Soil texture	RIW
Soil salinity	1	2	3	0.539
Soil pH	1/2	1	2	0.297
Soil texture	1/3	0.5	1	0.164

RI = 0.58 *CI = 0.0046* *CR = 0.0079*

Table 4. Pair-wise Comparison Matrix and RIW for Physical Condition

	Water Availability	Elevation	Land use	Slope	RIW
Water Availability	1	2	3	4	0.460
Elevation	½	1	2	4	0.294
Land use	1/3	½	1	2	0.157
Slope	½	¼	½	1	0.089

Data Integration and Manipulation

The nine (9) factors were reclassified and weighted according to the result of AHP defined in the previous step, these forms the thematic layers (soil quality, water quality, and physical condition) that were used then in suitability analysis. Since the raster data type was used in all of the analysis in this study, overlay of themes were done using the ArcGIS raster calculator. Operations from the simple addition and multiplication to the creation of complex logical/conditional statements of raster data were performed to generate the final suitability map. Each pixel size was 10m x 10m.

Generation of Nipa Palm Suitability Map

The final Nipa palm suitability map in four classes ((high, moderate, marginal, and low suitable) was generated using the two derived thematic layers 1) suitability map in terms of environmental condition, and 2) suitability map in terms of physical condition. The two thematic layers were assigned weights using AHP giving the environmental condition more weights than physical condition (table 5).

Table 5. Pair-wise Comparison Matrix and RIW for Final Parameters

	Environmental Condition	Physical condition	RIW
Environmental Condition	1	3	0.75
Physical condition	1/3	1	0.25

RI = 0 *CI = 0* *CR = 0*

RESULTS, DISCUSSIONS, AND IMPLICATIONS

Suitable Area for Nipa palm

The final analysis for Nipa palm land suitability excluded the seashore, river, and a 20-m river buffer. As shown in table 6, 18.9 sq.km or 11,816.2 rai (or 41.9% of total area) are found to be highly suitable. This implies that if all area considered as highly suitable will be planted with Nipa palm, then sugar production which is the main Nipa palm products in the area will increase the estimated present production (15,000 kg/day) up to four times.

This table (Table 6) also suggests that there is a need of around 4000 Nipa palm farmers (which is roughly equal to 75% of the total population in the area) considering that at present there are approximately 1000 Nipa palm farmers in the area.

Table 6. Distribution of Areas According to Nipa Palm Suitability Analysis

Level of Suitability/ Landuse	Area (Has)	% of Total Area
High	1890.6	41.9
Moderate	693.2	15.4
Marginal	711.1	15.8
Low	903.1	20
Sea shore	197.4	4.4
River buffer	113.6	2.5

In addition, utilizing all Nipa palm sap for ethanol will yields around (3) three million liters per year which is six (6) times more than the present ethanol annual consumption of the Pak Phanang district.

Validation of Results

Existing Nipa palm extracted from the LU map (2009) covers around 400 hectares (2,420 rai) or 8.6% of the total area of amphoe Khanap Nak. According to land suitability map (figure 3 and table 7) produced from overlay analysis, almost 98% (3.78 hectares; 2362.19 rai) of the existing Nipa palm area fell under the highly suitable. This implies that the Nipa palm land suitability model derived in this study coincides with the criteria of the existing Nipa palm plantation. Therefore, Nipa palm plantation and production may be optimized using the suitability map derived in this study.

Table 7. Existing Nipa Palm vs. Nipa Palm Suitability

Pixel Value/ Code	**Area Has.**	**Rai**	**% of Existing Nipa palm Total Area**
21	378	2362.19	97.8
22	6	34.94	1.4
23	1	8.13	0.3
24	2	9.38	0.4

21 – Existing Nipa palm that fell in the 'highly' suitable area.

22 – Existing Nipa palm that fell in the 'moderately' suitable area.

23 – Existing Nipa palm that fell in the 'marginally' suitable area

24 – Existing Nipa palm that fell in the 'low' suitable area

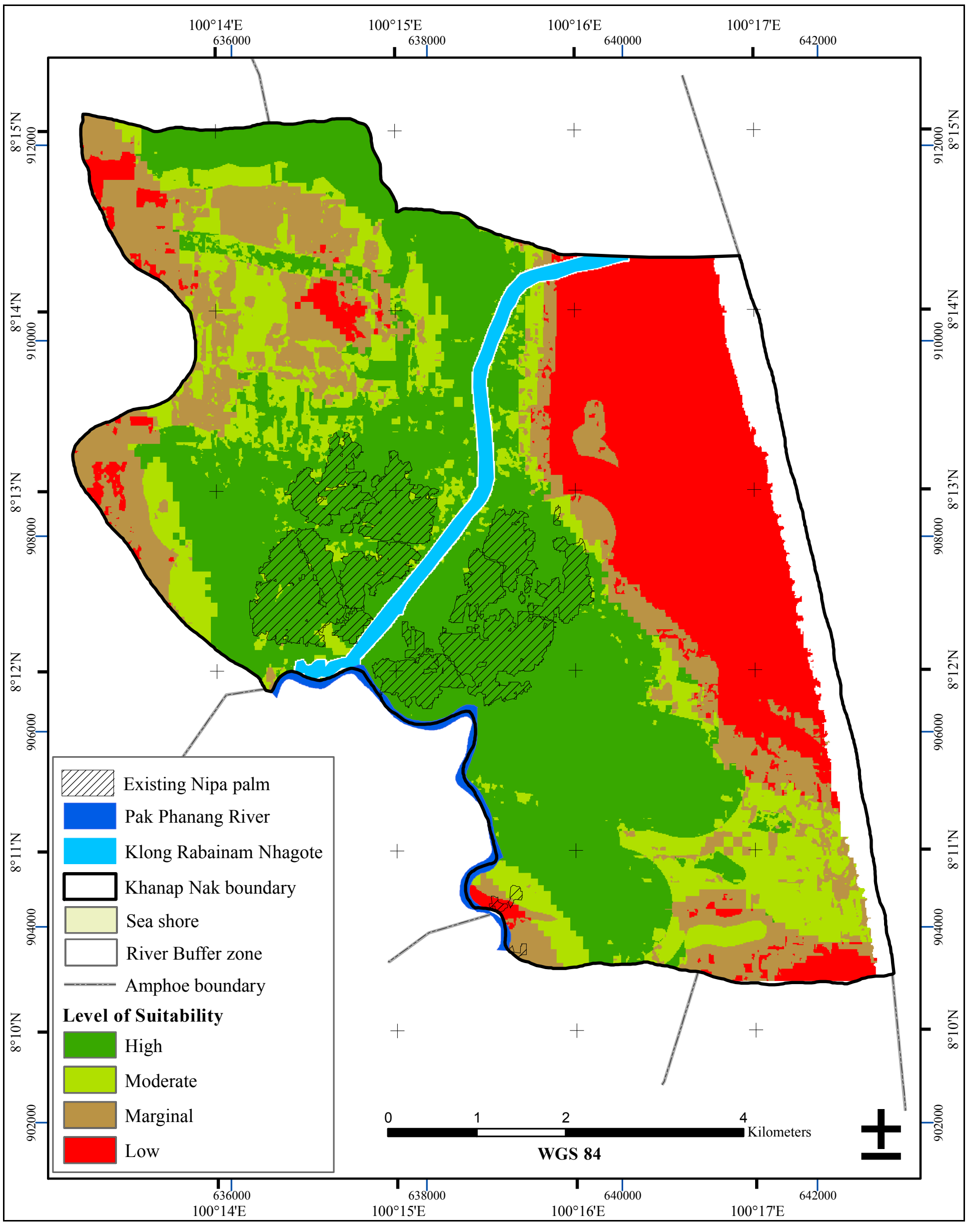

Figure 3. Existing Nipa Palm Overlay in derived Nipa Palm Suitability Map

CONCLUSIONS AND RECOMMENDATIONS

Governments around the world support biofuels production because of concerns about climate change and a possible reduction in the availability of imported crude oil. Thailand, with its geographic characteristics and location, is well positioned to effectively deploy biofuels in meeting energy needs. This land suitability analysis for Nipa palm gives an idea about best suitable lands for Nipa palm production so that its production would benefit the stakeholders.

This study did not include rainfall and temperature in defining suitability criteria since the study area is small (45 sq.km) and the rainfall and temperature in this area is within the range of the required rainfall (100-200mm/month) and temperature (20-35 degree Celsuis) in order for Nipa palm to grow (ICRAF, 2008). And it was also assumed that rainfall and temperature does not much vary locally. For a larger study area where rainfall and temperature varies much, it is recommended to include rainfall and temperature in the suitability analysis.

The study on the relationship between salinity level and sap-sugar production is also necessary to identify the optimum level of salinity that a nipa palm can produce sap, sugar, and ethanol at maximum production. A study also on factors why Nipa palm is not still used as a source of biofuel, in spite of its potential to produce ethanol.

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