EVALUATING LAND SUITABILITY FOR INDUSTRIAL SUGARCANE WITH GIS MODELING.

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KEY WORDS: Land Suitability, Land Evaluation, Sugarcane, Geographic Information System

ABSTRACT: In Thailand sugarcane is considered as one of the most important crops. The importance of sugarcane is more than a subsistence crop. Thailand has developed a large and complex industrial system for processing and marketing of crop. To increase the productivity of sugarcane, the cultivation should be based on the suitability of land. The study was then aimed at identifying the land with suitability for sugarcane. The crop is cultivated mainly in the Northeastern part of Thailand where there are 15 sugar factories. The study area is then focused in this region. The evaluation is based on the method as described by FAO and used GIS capability for an integration of land qualities to create land unit. The crop requirement was studied from the previous experiments, literature reviews and ground investigation. Matching the land unit to the sugarcane requirement could be performed. The land qualities include water availability, soil, and topography. Each of the land qualities was digitally encoded in GIS database and subsequently performed the overlay process. The model criteria were organized and iterated to achieve a reliable results. The result obtained reveals that the area is approximately 10.94, 20.20, 12.43, 43.00, 11.68 and 1.74% of the total Northeast for highly suitable, moderately suitable, marginally suitable, unsuitable, unclassified area and water body respectively. This study provides an approach to identify parametric rating of the land qualities and overall insight into the integration of land qualities in relation to the suitability of land.

1. BACKGROUND

Thai sugarcane production represents 3.8 percent of world sugarcane production in 2000 and Thailand ranked fifth among world producers (Office of Agricultural Economic, 2007). The Northeastern region has the planted area of sugarcane, representing 34.5 percent of the national total or 323,925 ha in 2006. The average sugarcane yield in the North-East was estimated to be 47 ton/ha. All sugarcane produced in the North-East are supplied to sugar factories. There are 15 sugar factories in the North-East, distributing in 9 provinces. Sugarcane is usually planted either before or after the rainy season and can be harvested around 10 to 12 months after cultivation. A large number of farmers grow sugarcane on the basis of marketing price rather than the highly potential soils. Lands inherently unsuitable and depleted are used to plant sugarcane, resulting low productivity. As a consequence, the farmers suffered from increasing debt. The allocation of sugarcane to suitable land is needed to enhance the productivity. The land suitability, based on integration of land qualities is widely accepted. FAO guideline on the land evaluation (1983) is well known worldwide for land suitability evaluation method. In addition a number of reports provide methodologies on the application of GIS to the land evaluation (Mongkolsawat et al, 1999;

Charuppat, 2002; Thavone, 1999; Paiboonsak et al, 2004; Maleki et al, 2006) The land evaluation for sugar-cane was conducted with objective of identify spatial information of land suitability based on an integration of land qualities as related to sugar-cane requirement.

2. THE STUDY AREA

The study area, Northeastern Thailand, covers an area of 170,000 sq km with elevation differences between 120-1700 m, 1700 m on the North-western portion and 120 m on the low land of the South-eastern portion (Fig 1). Physiographically, the North-East is formed by the strong topography in the North-western portion and flat to gently undulating landscapes in the central portion. The land cover encompasses of dipterocarp and evergreen forests in the upland mountain zone, field crops on the well drained soil of the gently undulating areas and paddy rice on the flat and low lying areas. The soils on the undulating landscapes are mainly derived from alluvium of sandstone origin. The mean annual rainfall ranges from 1000-2500 mm and increases from the Southwest to the Northeast portions of the region.

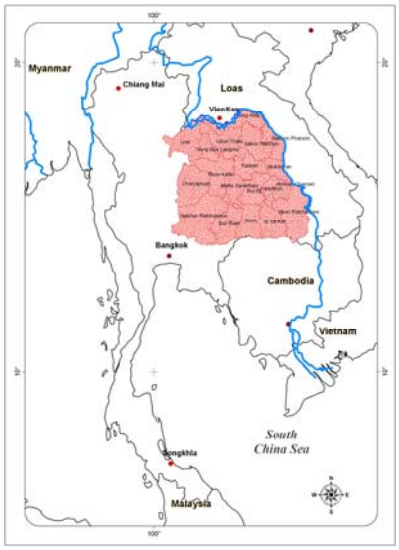

Figure 1 Study Area

3. METHODOLOGY

3.1 Analysis of Land Suitability

The process of evaluating the land in the Northeast is based on the FAO guidelines for land evaluation (FAO, 1983). This study implemented a synergistic approach, creating land unit as a result of land quality combination related to crop requirement. The land qualities or thematic layers were digitally encoded in GIS database and eventually performed the overlay of the thematic layers. With defined model for the sugarcane the output layer was classified into 4 classes: highly suitable(S1), moderately suitable(S2), marginally suitable(S3) and not suitable(N).

3.2 Crop Requirement

The sugar-cane requirements in terms of the land qualities to be used in the evaluation process were reviewed (Sys et al, 1993; FAO, 1983; Mongkolsawat et al, 1999; Charuppat, 2002; Thavone, 1999; Paiboonsak et al, 2004; Maleki et al, 2006). Furthermore a number of field experiments and regional experiences were also reviewed to support define the land qualities. In the North-East, the qualities used in this evaluation were selected with reference to the sugarcane land use and the nature of land unit. The land qualities used in this evaluation included water availability (W), nutrient availability index (NAI), particle size (PS), rooting conditions (R) and topography (TOPO). Each was considered as a thematic layer in the GIS database. Determinations of the diagnostic factors and the factor ratings are summarized in table 1.

3.3 GIS Layer Establishment

a) Water Availability (W)

Rainfall data of 30 years (1976-2005) recorded by the Metheorological Department was used for the establishment of the "W". Spatial interpolation of mean annual rainfall for the entire

North-East Thailand was undertaken with kriging method of the rainfall data to yield "W" spatial map. The spatial "W" layer was then divided into 4 classes.

Table 1 Land use requirement for sugarcane

Land use requirement			Factor Rating			
Land Quality	**Diagnostic Factor**	**Unit**	**S1(1.0)**	**S2(0.8)**	**S3(0.4)**	**N(0.1)**
Water Availability (W)	Annual Rainfall	mm.	>1600	1,100-1,600	800-1,100	<800
Nutrient Available Index (NAI)	*NAI = N x P x K x pH*		*≥0.32*	*0.05-0.32*	*0.0001-0.05*	*<0.0001*
	N	%	>0.2	0.1-0.2	<0.1	
	P	ppm	>25	6-25	<6	
	K	ppm	>60	30-60	<30	
	pH	-	6.1-7.3	7.4-7.8	7.9-8.4	>8.4
				5.1-6.0	4.0-5.0	<4.0
Particle Size (PS)	Particle size class	class	C,L,SCL,SiL, Si,CL,L	SiCL,SL	SiC,LS	C(%clay≥65), G,SC,AC,S
Rooting Conditions (R)	Soil Depth	cm.	>100	50-100	25-50	<25
Topography (TOPO)	Landform and Slope	Class & %	Table 1a			

Remark: Soil Texture(TXT); CL=Clay Loam, SiC=Silty Clay; SiCL=Silty Clay Loam; C=Clay, L=Loam, SiL=Silty Loam, LS=Loamy Sand, SCL=Sandy Clay Loam, SL=Sandy Loam, S=Sand, G=Gravel Soil

Table 1a Matrix of slope gradient and landform

Landform Slope (%)	Flood Plain	Low Terrace	Middle Terrace	High Terrace	Foot Slope & Erosion Surface	Mountain & Rock Outcrop
0-2	N	N	S1	S2	S1	N
2-5	N	S1	S2	S3	S2	N
5-12	N	S2	S3	S3	S3	N
>12	N	N	N	N	N	N

Remark: S1=1.0, S2=0.8, S3=0.4, N=0.1

b) Nutrient Availability Index (NAI)

The "NAI", is based on the method developed by Radcliffe et al (1982) and is given by NAI = NxPxKxpH. The soil map of Land Development Department (LDD) provides information of N, P, K and pH, those of which were used in the overlay process to create the spatial layer of NAI. The sub-layers (N, P, K, and pH) were assigned the values of rating factor as given in the table 1. The values of rating of the NAI are also given in the table 1.

c) Particle Size (PS)

The "PS" includes soil texture and coarse surface materials on which is important edaphic constraint for the sugar-cane. The PS is defined as class of the particle size. The values of rating factor of the particle size were given in the table 1.

d) Rooting condition (R)

The "R" land quality layer was determined using the soil depth. Available soil map was used to assign this factor rating for the evaluation.

e) Topography (TOPO)

The topography layer is a matrix of slope gradient and landform. The map of the slope and landform combination was digitally established and values assigned were given as in sub-table 1a.

Each of the defined land qualities with their associated attribute was digitally encoded in GIS database to create five thematic layers.

3.4 Land Suitability

The evaluation model for sugar-cane was given using the values of the factor rating as follows:

Suitability = W x NAI x PS x R x TOPO

These thematic layers were integrated by spatially overlaying each with the suitability model of the defined 5 layers. (Fig. 2) The output layer yields 4 classes: S1=highly suitable, S2=moderately suitable, S3=marginally suitable and N=unsuitable. The validation of the model was made, based on the field investigation of the crop yield.

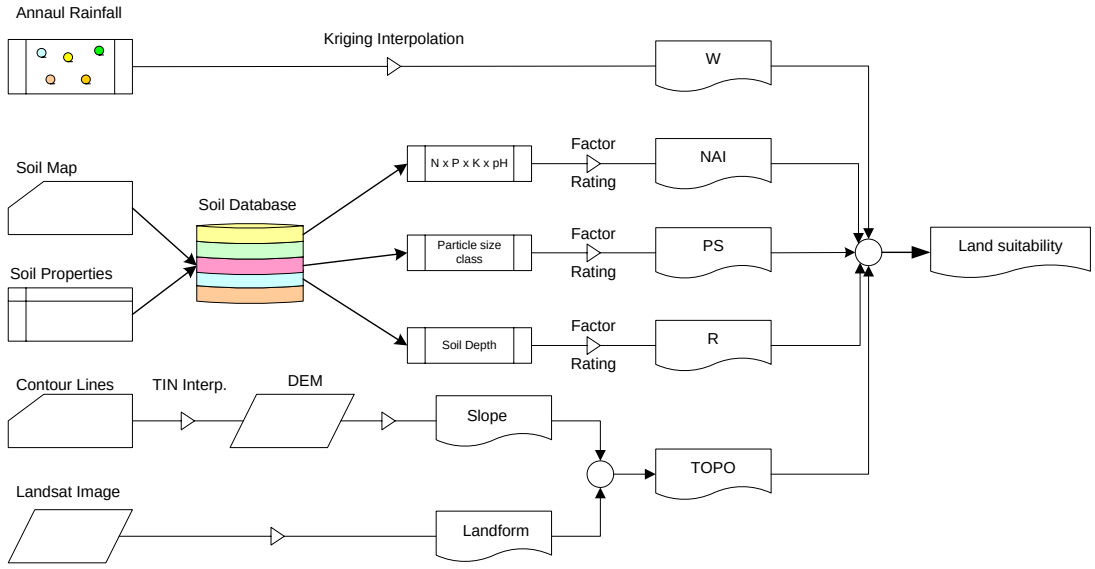

Figure 2. The process of studying land suitability for sugarcane.

4. RESULTS AND DISCUSSIONS

4.1 The Suitability Map

The suitability map resulting from the spatial overlay of land qualities for sugar-cane is shown in figure 3. The suitability area in addition to the map is shown in table 2. The suitability areas cover 10.94, 20.20, 12.43, 43.00, 11.68 and 1.74% for highly suitable, moderately suitable, marginally suitable, unsuitable, unclassified (conservation and built up) and water body respectively. The study provides an approach to identify parametric values in modeling the land suitability for sugar-cane. We provide the overall insight into the land qualities affecting the suitability of land spatially and quantitatively. The result indicated that the highly suitable lands are found on the soils inherently fertile, high availability of water with favorable physical landscape.

4.2 Model Validation

To validate the result reliability, sixty-seven plots with different suitabilities were superimposed on the map. The result was shown in table 3 with overall accuracy of 86.57% and kappa coefficient of 0.786.

Table 2 Land suitability for sugarcane in the Northeast, Thailand

Land suitability classes	Area (%)
Highly suitable (S1)	10.94
Moderately suitable (S2)	20.20
Marginal suitable (S3)	12.43
Unsuitable (N)	43.00
Unclassified area	11.68
Water Body	1.74
Total area	**100.00**

Table 3 Confusion matrix

		Study Result				
		S1	**S2**	**S3**	**N**	**Total**
Ground Truth	**S1**	7	6	-	-	13
	S2	-	32	-	-	32
	S3	-	3	14	-	17
	N	-	-	-	5	5
	Total	7	41	14	5	**67**

Kappa = 0.786

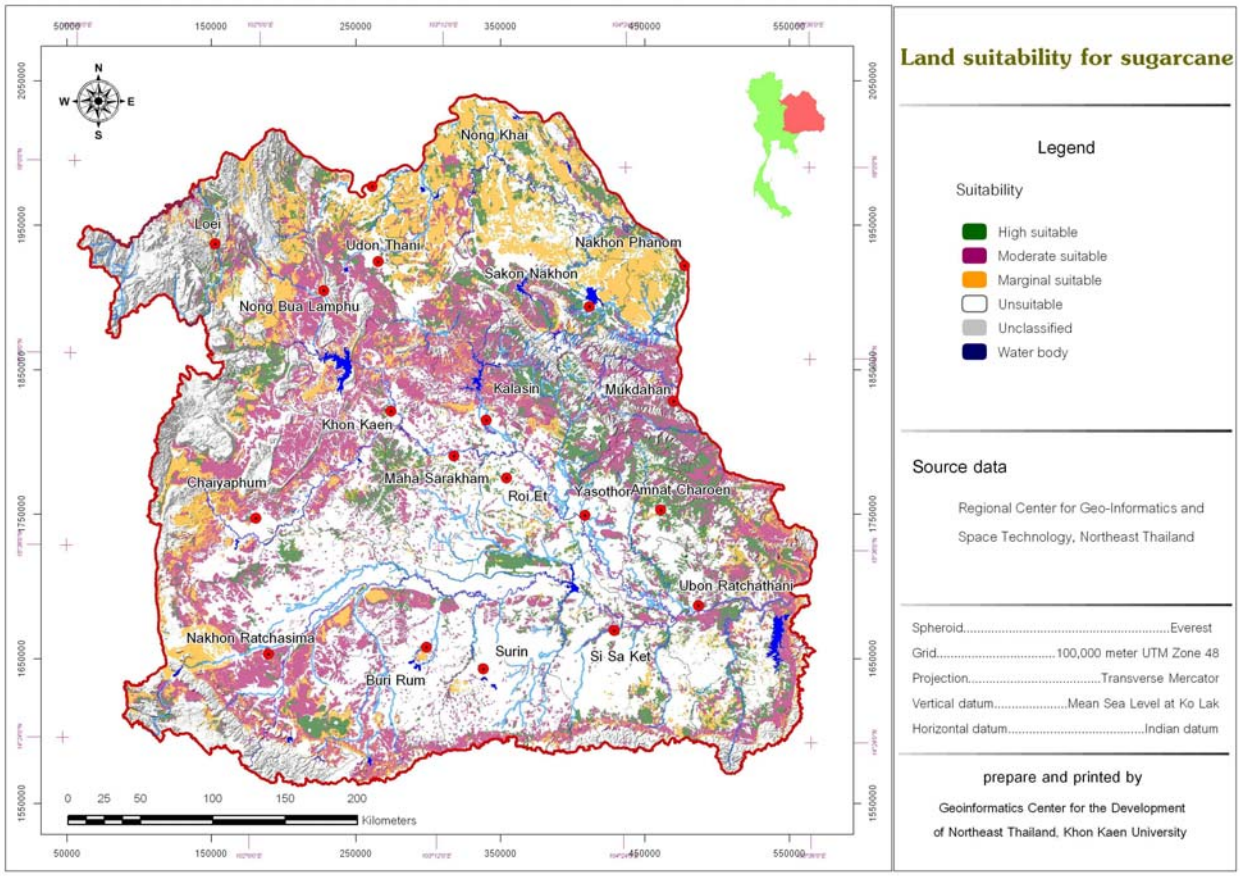

Figure 3. Land suitability for sugarcane.

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