LAND SUITABILITY EVALUATION FOR SUGARCANE: GIS APPLICATION

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ABSTRACT

The objective of this study was to evaluate the suitability of land for sugarcane cultivation. The study area, Udon Thani province, is located in the upper Northeast Thailand and covers approximately 11,730 sq km. The evaluation of land in terms of the suitability is based on the method described in the FAO guideline. A land unit resulting from the overlay process of the identified theme layers has unique information of land qualities on which the suitability is based. The identified theme layers include climate, topography, chemical and physical properties of soil and soil toxicity. Those thematic land qualities with their associated attribute data were encoded in GIS database. Overlay operation was performed on those layers as the suitability model assigned. The model was a result of the crop requirement analysis. The matrix and multiplication models were applied to the overlay process and to formulate the suitability class. The result indicated that the highly, moderately and marginally suitable for sugarcane cover an area of about 0.85%, 17.97%, and 19.12% of the total provincial area respectively. In conclusion, the land suitability map for sugarcane established using GIS can enhance the planning alternatives within the area with meaningful strategy in terms of location.

1. INTRODUCTION

Sugarcane has long been regarded as a crop with agro-industrial importance of the country. Apart from sugar, its product could also be used for ethanol production which could be further used to produce "gasohol", the alternative source of energy of utmost importance at the time the world is confronted with energy crisis due to both fluctuation and continuous increase of fuel price. Enlargement of the sugarcane growing has taken place both in response to the energy crisis and to the price increase of sugarcane product without taking land potential and suitability into consideration. This misconduct has led to all sorts of problems including land misuse, environmental problems and debt increase. Land potential for sugarcane production is generally classified as spatial information directly derived from various sources of information which affect plant growth and yield. These include climatic, landform and soil information which vary both in terms of intensity and quantity with area. These information could be altogether processed to determine suitability classes for sugarcane growing of the land in a given area. Geo-informatic technology which at present, embodies Geographic Information System(GIS), Remote Sensing(RS) and Global Positioning System(GPS) has been further developed to provide greater efficiency. In particular, GIS has been used extensively for spatial analysis and land suitability as GIS functions could be employed for several forms of information including point, line and area. The system, therefore, possesses greater storage capacity for spatial information processed with identical standard. GIS also provides greater reliability with lesser time and cost compared with manual

operation (Bera et al, 2002). The integrated information perform is highly useful especially when it is used to support decision-making towards farming activities (Ghaffari et al, 2000; Rasheed et al, 2003). Charuppat (2002) adopted GIS to develop models for land suitability evaluation and found that the system is highly effective for the above-mentioned task.

This study aimed to use GIS to classify the suitability of land with integrated information for sugarcane growing. The spatial information resulted from this study could be used to assist proper land use based directly on its potential which not only help minimize environmental problems but also the increased income of individual farmers caused by improper land use.

2. STUDY AREA

Udon Thani province (Fig 1) selected as a target area of the study is situated between latitude 16° 48' - 18º 5' 24" N and longitude 102º 0' 36" - 103º 21' 21" E covering a total area of approximately 11,730,302 sq km.(Office of National Statistics, 2000). General topography is characterized by gentry undulating terrain with prominent mountain ranges. Mountainous area of the adjacent province lies in the western border. The province receives the average annual rainfall of 1,400-1,600 mm. Rainfall intensity in the southwest is lower than the area situated in the northeast region of the province. It was found that the soils occupying lowland and upland area were 29.16% and 58.57% of the study area respectively. Based on Landsat satellite data in 2002, it appeared that most of the area was used for paddy cultivation followed by upland crops with the growing areas of 15.37% and 19.02% of the study area.

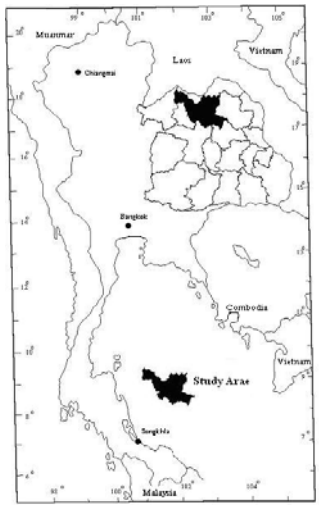

Figure 1. Study area

3. Methodology

The FAO guidelines for land evaluation were adopted to classify the land suitability for sugarcane (FAO, 1983). In order to develop a set of themes for a spatial integration, the crop requirement in relation to the land qualities were reviewed (Charuppat 2002, LDD 1992, Kuppatawuttinan, 1998, Sys et al 1993). In addition, ground survey and regional experiences were synthesized and selected to identify the land quality essential for the integration process. The land qualities selected include a number of land characteristics: Climate, physical properties of soil, chemical properties of soil, topography and agricultural constraints. Each of land characteristic is a thematic layer in GIS database and is finally used for the overlay process. Determination of the diagnostic factors and values assigned was shown in table 1.

The schematic chart of methodology used is presented in figure 2. The water availability was performed using the spatial analysis of annual rainfall and irrigated area. The chemical properties of soil were based on the method developed by Radcliffe et al (1992), and is defined as $N \times P \times K \times pH$. The information of these diagnostic factors was synthesized from the soil map of LDD. The physical properties of soil were identified using the multiplicative combination of texture, drainage and soil depth. The topography was performed by the matrix overlay of landform and slope. The analysis processes yield the resultant polygonal layers or land units are the integration of the thematic layers. The matrix overlay of soil salinity was then performed on the land unit obtained to identify the suitability map. The resultant layer yielded a suitability map with 4 classes: highly suitable, moderately suitable, marginally suitable and not suitable.

Table 1. Land quality and sugarcane requirement.

Land quality	Diagnostic factor	Unit	Factor rating*				Source
			S1=1.0	S2=0.8	S3=0.4	N=0.1	
Water availability	Rainfall and Irrigation	mm./ yr	1600-2500 Irrigated	1200-1600	900-1200	<900	Charuppat(2002) LDD(1992)
Physical properties of Soil	**DRN x DPT x TXT**		0.641-1.000	0.321-0.640	0.041-0.320	0.0-0.040	
	Drainage (DRN)	class	good, very good	moderate	somewhat poor	very poor, poor	Charuppat(2002) LDD(1992)
	Soil depth (DPT)	cm	>100	50-100	25-50	<25	LDD(1992), Charuppat(2002) Sys et al.(1993)
	Texture** (TXT)	-	C<65%,L,SCL, SiL, Si,CL	SiCL,LS	SiC,LS	C>(65%),G,S C,AC,S	Sys et al.(1993), Kuppatawuttinan(1998), Charuppat(2002
Chemical properties of Soil	**N x P x K x pH**		0.401-1.000	0.065-0.400	0.0-0.064	-	
	N	%	>0.2	0.1-0.2	<0.1	-	Kuppatawuttinan(1998), Charuppat(2002)
	P	ppm	>25	6-25	<6	-	Kuppatawuttinan(1998)
	K	ppm	>60	30-60	<30	-	Kuppatawuttinan(1998)
	pH	-	6.1-7.3	7.4-7.8 5.1-6.0	7.9-8.4 4.0-5.0	>8.4 <4	Kuppatawuttinan(1998), LDD(1992), Charuppat(2002)
Soil toxicity	Soil salinity	-	5,6,7	4,3	2,1	-	Charuppat(2002), LDD(1992)
Topography	Landform Slope	class %	see Table 2				-

Note : * Factor rating: S1 = High suitability (= 1.0), S2 = Moderate suitability (= 0.8),
S3 = Marginal suitability(= 0.4), N = Not suitability(= 0.1)
** Soil texture L=Loam, SiCL=Silty clay loam, SCL=Sandy clay loam, CL=Clay loam,
SL=Sandy loam, C=Clay(%clay<60), LS=Loamy sand, SC=Sandy clay,
C=Clay(%clay>60),S=Sand, G=Gravel soil, SC=Slope complex, AC=Alluvial complex
*** Salinity potential: 1 = Very Highly affected by salt, 2 = Highly affected by salt, 3 = Moderately affected by salt, 4 = Slightly affected by salt, 6 = Not affected by salt, 7 = Hill area

Table 2. Relationship between landform and slope for sugarcane growing

		Landform					
		Flood Plain	Low Terrace	Middle Terrace	High Terrace	Foot Slope & Erosion Surface	Mountain
Slope%	0-2	N	S2	S1	S2	S1	N
	2-5	N	S1	S2	S3	S2	N
	5-12	-	S3	S3	N	N	N
	12-20	-	N	N	N	N	N
	>20	-	N	N	N	N	N

Source : Modified from Charuppat (2002) and Kuppatawuttinan (1998)

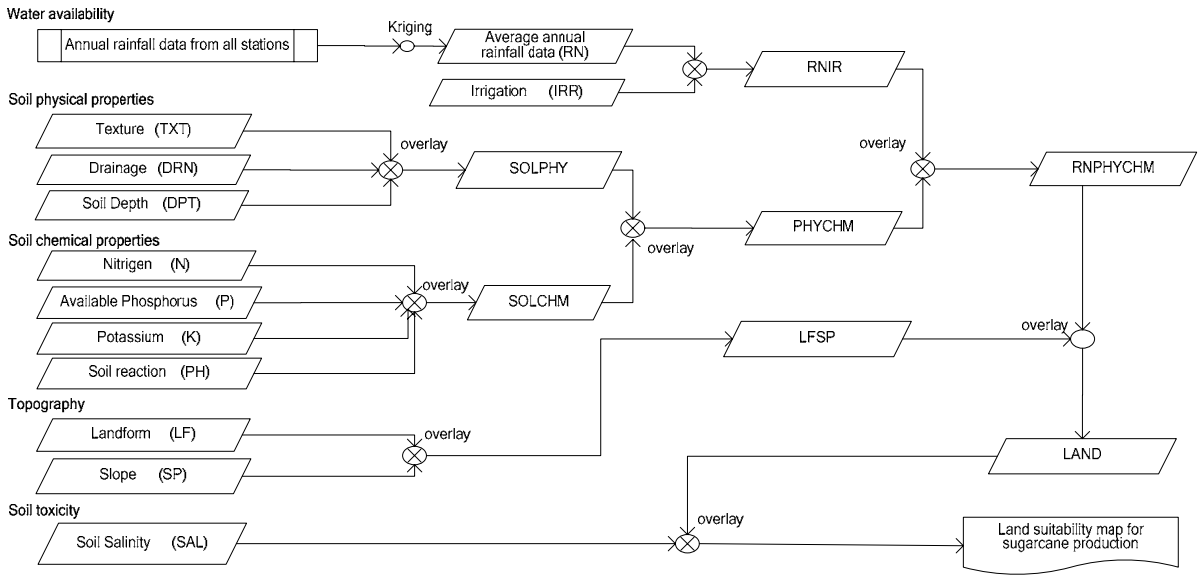

Figure 2. Schematic chart of the methodology

4. RESULT

Base on the overall physical characteristic of the area, suitability of the and in Udon Thani province for sugarcane production could be classified into several classes scattering throughout the study area as shown in Fig.4. Details of areas and suitability classes were give in Table 3 which were :

1) Area of high suitability (S1)

This referred the areas which processed the best physical quality for sugarcane production. However, the occupied the least of the area studies having total area of 99.763 km^2 or 0.85% of the provincial area. The land of this suitability class was found as long and narrow occupying upland area situation in the upper part of the province.

2). Area of moderate suitability (S2)

The land which was classified into this suitability class possessed moderate physical quality for sugarcane production. It covered total area of 1,537.926 km^2 or 13.11% of the provincial area being the second largest area compared with the area marginally suitable for sugarcane production. The land of this class scattered throughout the province the lower part of the study area.

3). Area of marginal suitability (S3)

Classified as low or marginally suitability for sugarcane production, this type of suitability class occupied the largest area of 1,666.858 km^2 or 14.2% of the lower part which is connected to Udon Thani province.

4). Area of non-suitability for sugarcane production

The area of this suitability class was regarded as unsuitable for sugarcane production. These are the areas which lies in floodplain which flooding may occur during the rainy season and those occupied with conservation area. In addition, this land class also included settlement and urban area as well as the area used by industrial sector and various communities. It occupied total area of 6,362.474 km^2 or 54.24% of province.

5). Mixed area

This referred the processing 2 different suitability class for sugarcane production which could not be clearly separated. This was resulted from data limitation particularly soil data (soil

Table 3. Land suitability for sugarcane production in Udon Thani province.

Land suitability classes	Area	
	km^2	%
High suitability (S1)	99.763	0.85
Moderate suitability (S2)	1,537.926	13.11
Marginal suitability (S3)	1,666.858	14.21
Not suitability (N)	6,362.474	54.24
Mixed area	1,381.144	11.78
Moderate suitability / Marginal suitability (S2/S3)	(911.502)	(7.77)
Moderate suitability / Not suitability (S2/N)	(228.508)	(1.95)
Marginal suitability / Not suitability (S3/N)	(241.132)	(2.06)
Unclassified area	422.024	3.60
Surface water	260.114	2.22
Total	**11,730.302**	**100.00**

associate which appears in the soil map). The area in this category, in other words, possessed 2 classes of suitability which were the combination of S2/S3 (Moderate and marginal suitability) on other combinations. In Udon Thani, there were altogether 3 areas which fell into this cattery occupying total area of 1,381.144 km^2 or 11.78% of the province.

6). Unclassified area

This referred to the area without sufficient information required for land suitability classification. These included wetland or waterlogged sites in the province which occupied total area of 422.024 km^2 or 3.60%.

7). Surface water

This area was presented based on Landsat satellite imagery recorded between 1999-2000. It occupied total area of 260.114 km^2 or 2.22% of the province.

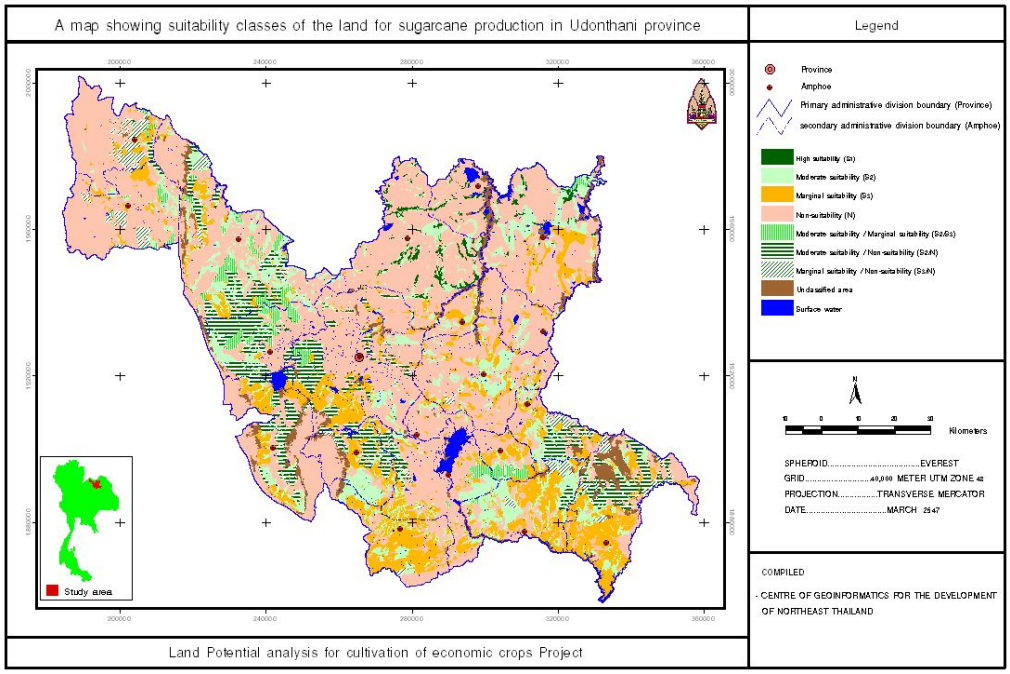

Figure 3. Land suitability for sugarcane.

5. CONCLUSION

Evaluation of land suitability for sugarcane production using spatial information model developed by GIS has been regarded as highly effective method which could be adopted to provide the required information compared with conventional operation. The method not only minimizes the factors introduced into the analysis but also provides the steps reliable outcome through clear cut step of operation which could be updated. The output obtained could be used to back up decision-making on sugarcane production at provincial level. Apart from this, this method could also be adopted to examine land suitability of certain target areas. For Udon Thani province, it was indicated from the result of this study that the area classified as high suitability, Moderate suitability and Marginal suitability occupied 0.85%, 17.87% and 19.12% of the provincial area respectively.

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