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Land Evaluation for Combining Economic Crops Using GIS and Remotely Sensed Data

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Abstract

In general, land evaluation for agricultural landuse is formulated by classifying lands with different capabilities. The suitability for various potential land uses is identified in relation to individual crop requirements. Within the planning area, an assessment of crop combinations is needed in order to lessen a price risk. This evaluation was then formulated with objective of classifying units of land as to their suitability for combining economic crops using GIS and remotely sensed data.

The study area, Song Kram Watershed, covers extensively in the Sakon Nakhon basin, Northeast Thailand with an area of about 13,080 km^2. The major economic crops in the area are rice cassava, sugar-cane and pasture crops. The suitability assessment for each crop was conducted using the method as described in FAO guidelines for land evaluation for rainfed agriculture. For each crop, land unit was created from overlay process of the defined theme layers or land qualities on which the suitability is based. As a result, suitability map layers with their associated class attributes for rice cassava, sugar-cane and pasture crops were obtained. Furthermore, the overlay process was then performed on these suitability map layers with selection criteria of only highly and moderately suitable classes. The resultant map obtained is a result of combination of the defined suitability class of combining crops. (rice, cassava, sugar-cane and pasture) within the area. Economically, the planning alternative that best matches landuse to land suitability should therefore be the most valuable and efficient.

Introduction

In Northeast Thailand, the agricultural land use cover an area of 71.09%, rice and field crops share about 44.78 and 25.41% respectively (Land Development Department LDD 1989). The major field crops in the watershed are sugar-cane and cassava which occupy the upland, well drained soils. Pasture is a minor consumer of water so the planners are interested in developing the livestock. The suitability of land for rice, sugar-cane, cassava and pasture is needed to maximize the production.

FAO guideline on the land evaluation system (1983) is widely adopted. The system was based on defined land qualities as related to individual crop. Establishment of land unit that best matches land use to its suitability is principal concept used. Sys et al (1991) applied the FAO concept and developed the crop requirements based on the experiment / experiences in tropical areas. Bo-heng (1990) established spatial model for land evaluation in China using remote sensing data and GIS. FAO (1983) also suggested the land evaluation for suitability of crop combination can support the alternatives for the proper decision. This suggestion is due to markets and prices that are liable to change from one crop to another. Consequently, development of land suitability map for combining crops is needed in order to reduce the price risk. There still needs to develop the modeling of land suitability for crop combination using computer based GIS and remote sensing data. The principal purpose of this study is to classify the land in relation to its suitability for crop combination using GIS and remotely sensed data.

Study Area

The study area, the Song Kram Watershed, is located in Northeast Thailand and covers an area of about 13,081 km^2. Mean annual rainfall ranges 1300-1800 m.m. Geologically, the Song Kram is formed by thick sequence of Mesozoic sediment, the Korat group ranging in age from upper Triassic to Tertiary. The extensive area is formed by flat to gently undulating alluvial plains which are drained easterly flowing drainage system. Apart from the gently undulating plains, , the other prominent topography of the area is the Phu-Phan range which lies in the southern part of the watershed. Paddy fields, field crops and the remnant of dipterocarp trees are common on the undulating plains. The dry dipterocarp forest is the main type found on the Phu-Phan mountain range. Soils are formed from alluvium and have inherently low in fertility.

Methodology

The suitability evaluation for each crop (rice, cassava, sugar-cane and pasture crop) was based mainly on the method as described by FAO(1983). For each crop, land units resulting from the overlay process of the selected land qualities were established. The selected land qualities include water availability (W), oxygen availability (O), nutrient availability index (NAI), water retention capacity (R) root conditions (D), salt hazards (S) and topography (T). The requirements of each crop were reviewed from a number of publications (FAO (1983), FAO (1991), LLD (1990) Sys et al (1993), Delante (1993)) in combination with experimental reports and regional experiences. Determinations of the various factor rating and values assigned for each land quality are summerized in the table 1, 2 , 3 and 4 for rice, cassava, sugar-cane and pasture respectively. Each land quality is a thematic layer in the GIS in which contains spatial data and its associated attributes.

The water availability was based on the amount of annual rainfall. The nutrient availability index based on the method developed by Radcliffe et al (1982) and is given by NAI = N x P x K x pH The spatial information for each diagnostic factor of NAI can be derived from LDD soil map. For pasture crop the pH is only a factor for NAI. The water retention capability is extracted from the diagnostic of soil texture and particle size. Moreover, soil map can provide information about root condition and salt hazards. The topography is a combination of slope gradient and landform which are derived using digital evaluation model and satellite data respectively. Each of land qualities with their associated attributes are digitally performed in a GIS to eventually produce the thematic layers. The factors rating defined in the table 1, 2 , 3 and 4 were attribute database as related to diagnostic factors.

Table 1. Land quality and factor rating for low land rice.

Land use requirement			Factor or rating			
Land quality	Diagnostic factor	unit	1.0	0.8	0.5	0.2
Water availability (W)	Annual rainfall	mm.	>1,500	1,100-1,500	800-1,100	<800
Oxygen availability (O)	Soil drainage-	-	poor / very poor	poor	well	very well
Nutrient Availability Index (NAI)	NAI		≥0.60	0.40-0.60	0.10-0.40	<0.10
	N P K pH	% ppm ppm -	>0.2 >25 >60 5.6-7.3	0.1-0.2 10-25 30-60 7.4-7.8, 5.1-5.5	<0.1 <10 <30 7.9-8.4, 4.0-5.0	- - - >8.4, <4.0
Water retention capacity (R)	Soil texture	-	CL, Si, SCL, SiL, C, AC	L, SiCL, SiC, SL	LS	G, S, SC
Root Conditions (D)	Soil depth	cm.	>50	25-50	15-25	<15
Salt hazards (S)	Soil salinity potential	-	Low	Medium	High	non-saline
Topography (T)	Land form and slope	-	FL	LT	MT, HT, FS, M slope <5%	MT, HT, FS, M, slope >5%

Table 2. Land quality and factor rating for cassava.

Land use requirement			Factor or rating			
Land quality	Diagnostic factor	unit	1.0	0.8	0.5	0.2
Water availability (W)	Annual rainfall	mm.	1,100 -1,500	900-1,100 1,500-2,500	500-900 2,500-4,000	<500 >4,000
Oxygen availability (O)	Soil drainage-	-	well	moderate	poor	very poor
Nutrient Availability Index (NAI)	NAI		≥0.60	0.40-0.60	0.10-0.40	<0.10
	N P K pH	% ppm ppm -	>0.2 >25 >60 6.1-7.3	0.1-0.2 6-25 30-60 7.4-7.8, 5.1-6.0	<0.1 <6 <30 7.9-8.4, 4.0-5.0	- - - >8.4, <4.0
Water retention capacity (R)	Soil texture	-	L, Si, SiL, S CL, CL	SiCL, LS, SL	SiC, S	C, G, SC AC
Root Conditions (D)	Soil depth	cm.	>150	100-150	50-100	<50
Salt hazards (S)	Soil salinity potential	-	Low	Medium	High	non-saline
Topography (T)	Land form and slope	-	MT, HT, FS, M slope <5%	MT, HT, FS, M slope 5-12%	MT, HT, FS, M slope 12-20%	MT, HT, FS, M slope >20%, Fl, LT

Table 3. Land quality and factor rating for sugar-cane.

Land use requirement			Factor or rating			
Land quality	Diagnostic factor	unit	1.0	0.8	0.5	0.2
Water availability (W)	Annual rainfall	mm	1,600 -2,500	1,100-1,600 2,500-3,000	900-1,100 3,000-4,000	<900 >4,000
Oxygen availability (O)	Soil drainage-	-	well	moderate	poor	very poor
Nutrient Availability Index (NAI)	NAI		≥0.60	0.40-0.60	0.10-0.40	<0.10
	N	%	>0.2	0.1-0.2	<0.1	-
	P	ppm	>25	6-25	<6	-
	K	ppm	>60	30-60	<30	-
	pH	-	5.6-7.3	7.4-7.8, 4.5-5.5	7.9-8.4, 4.0-4.4	>8.4, <4.0
Water retention capacity (R)	Soil texture	-	L, Si, SiCL SiL, SCL, C L, SL	LS	SiC,	C, G, S SC, AC
Root conditions (D)	Soil depth	cm.	>100	50-100	25-50	<25
Salt hazards (S)	Soil salinity potential	-	Low	Medium	High	non-saline
Topography (T)	Land form and slope	-	MT, HT, FS, M slope <5%	MT, HT, FS, M slope 5-12%	MT, HT, FS, M slope 12-20%	MT, HT, FS, M slope >20%, FL, LT

Table 4. Land quality and factor rating for pasture.

Land use requirement			Factor or rating			
Land quality	Diagnostic factor	unit	1.0	0.8	0.5	0.2
Water availability (W)	Annual rainfall	mm.	1,500 -4,000	1,000-1,500 4,000-6,000	400-1,000	<400 >6,000
Oxygen availability (O)	Soil drainage-	-	well	moderate	poor	very poor
Nutrient Availability Index (NAI)	pH	-	5.1-6.5	6.6-7.3, 4.5-5.0	7.4-8.4, 4.0-4.4	>8.4, <4.0
Water retention capacity (R)	Soil texture	-	L, Si, SiL S, Cl SL, SiCL, C L	LS	C, AC, G SIC, S	SC
Root Conditions (D)	Soil depth	cm.	>50	25-50	15-25	<15
Salt hazards (S)	Soil salinity potential	-	Low	Medium	High	non-saline
Topography (T)	Land form and slope	-	MT, HT, FS, M slope <12%	MT, HT, FS, M slope 12-20%, LT	MT, HT, FS, M slope 20-35%, FL	MT, HT, FS, M slope, >35%

Remark

Soil : C = Clay, CL = Loam, L = Loam, Si = Silt, SiL = Silty Loam, Silty Clay, SL = Sandy Loam
LS = Loamy Sand, SCL = Sandy Clay Loam = SiCL = Silty Clay Loam, S = Sand, G = Gravel soil,
Ac = Alluvial Complex, SC = Slope Complex
Salt hazard : 1 very high, 2 = high, 3 = moderate, 4 = low, 5 = underlying salt rock, 6 = noneLand form
FL = Flood plain, LT = Low Terrace, MT = Middle Terrace, HT = high Terrace, FS = Foot Slope,
M = Mountain

The evalution model for each crop is Defined using the value of factor rating as follows : Suitability = W X O X NAI X R X D X S X T. The overlay process of these layers was performed to produce a resultant polygonal layer upon which the evaluation model was applied. The resultant layers yield suitability maps for rice, cassava, sugar-cane according to the resultant values as presented in the table 5. Furthemore, the overlay process was then performed on these suitability layers with selection criteria of only highy and moderately suitable classes. The land suitability map for combination of the selected crops can be produced accordingly.

Table 5. Suitability evaluation for each crop.

Value	Class
>0.2	Highly suitable
0.1-0.2	Moderately suitable
0.01-0.1	Marginally suitable
<0.01	Unsuitable

Results and discussion

The suitability map for economic crops is a combination of the selected crops with selection criteria of only highly and moderately suitable classes (Fig. 1). The suitability area of the crops is shown in table 6.

Table 6. The suitability area for rice, cassava, sugar-cane and pasture, Song Kram Watershed, NE Thailand

Class	%	Km2
highly suitable for rice	7.31	955.50
suitable for rice	0.09	11.20
highly suitable for sugar-cane / cassava	11.71	1571.83
suitable for sugar-cane / cassava	0.34	44.15
highly suitable for sugar-cane	1.44	188.71
highly suitable for pasture	31.37	4091.16
suitable for pasture	36.04	4701.82
non-suitable	5.92	761.51
village	2.62	341.97
water body	3.16	413.58
Total	100	13081.47

The study provides information about the suitability of land for not only a combination of selected crops but also individual crop. This is to offer the alternatives for agricultural land use to lessen the price risk. The areas have inherently low nutrient status so that the pasture crops are highly suitable and cover extensively in the study area. According to the land qualities in the area, the principal limiting factors are the soil depth and fertility. The result indicated that the highly suitable land for rice covers an area of about 7 percents and is restricted in the flood plain. Some 11.71 percent of the watershed is highly suitable for cassava and sugar-cane. It should be observed that the highly suitable area for pasture occupies the suitable area of the cassava and sugar-cane.

To evaluate the reliability of the method developed, the suitability classes were checked against the crop yields. The crop yields of highly suitable class were on average 4.17, 75 and 25 ton/ha for rice, sugar-cane and cassava respectively.

In conclusion suitability map of crop combination in the area can help support the alternatives to lessen the price risk. The alternatives for agricultural land use are dynamic and

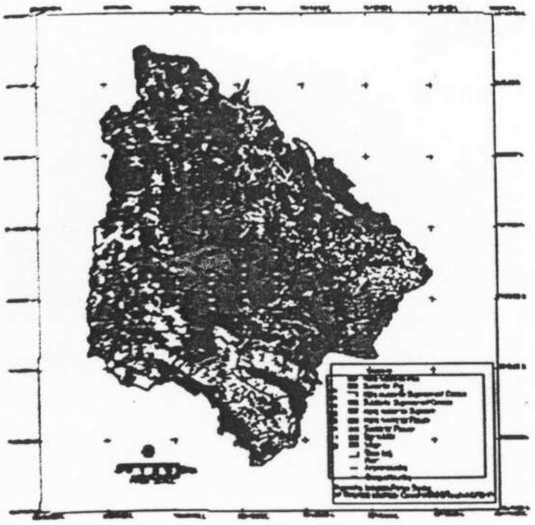

Fig. 1. Land suitability for economic crops, Song Kram Watershed, North-East Thailand.

varied according to the marketing price of the product. The process of developing alternatives for the watershed then requires a method of selection which has greatest value in terms of the cost effectiveness. The decision maker can make the proper decision given sufficient knowledge.

In addition. GIS layers established can enhance the planning alternatives within the watershed with reasonable information in terms of location. Perspectively, economic analysis to determine the cost of input and the values of output in the suitability map is needed to make these tasks meaningful to planning.

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