LAND SUITABILITY FOR RICE PADDY IN THE LOWER CHI BASIN USING GIS

Rasamee SUWANWERAKAMTORN[a] and Benjaporn HIRUNKUL[b]

[a] *Asst.Professor , Geo-informatics Centre for Development of Northeast Thailand, Faculty of Science, Khon Kaen University, Khon Kaen Thailand 40002;*
Tel: +66 (0) -4320-2742; Fax. +66 (0) -4320-2743 *E-mail: rasamee@kku.ac.th*

[b] *Research Assistant, Geo-informatics Centre for Development of Northeast Thailand, Faculty of Science, Khon Kaen University, Khon Kaen Thailand 40002;*
Tel: +66 (0) -4320-2742; Fax. +66 (0) -4320-2743 E-mail:benjaporn@kku.ac.th

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ABSTRACT: Rice is an important economic crop grown extensively in Northeast, Thailand particularly in the Lower Chi Basin. To formulate the effective agriculture extension, land suitability for rice is needed. The purpose of this study was to explore the land suitability for rice cultivation based on integrated land qualities. The study area, the Lower Chi Basin, covers an area of approximately 242,361 ha on which soils are derived from alluvium and inherently low in fertility. Based on the FAO guidelines, the selected land qualities used for the evaluation included water availability index (W), oxygen availability (O), nutrient availability index (NAI), water retention (I), rooting conditions (R), excess of salts (Sa) and topography (T). The land qualities and their associated attributes were digitally encoded in GIS database. An overlay analysis with a multiplication model of the GIS layers was performed, providing the suitability of four classes: highly, moderately, and marginally and not suitable. The land suitability in the Lower Chi Basin, accounts for 33,010, 19,400, 133,650, 51,098 ha for highly, moderately, marginally and not suitable respectively. In addition, the study provides the spatial distribution of the suitability class and the land qualities with their associated characteristics for further analysis.

INTRODUCTION

Rice is an important economic crop of Thailand and a major exporter of the world, also the export of rice about 10 million tons which worth export approximately 183,422 million baths (OAE, 2009b). The Northeast, Thailand has an area more than other region approximately 5,514,946 ha or 48.18% of total areas (OAE, 2009a). However, rice yield in Northeast are low because of the Northeast region has a limit resource such as soil low fertility, uncertainty distribution of rainfall and the irrigation system is minimal etc.(Mongkolsawat et al., 2010). The region had a climate condition with three seasons, a rainy season from middle May to October, a cold season from November to February and dry season from March o May (Thanajaturon, 2006). The average annual rainfall between 1,300 to 1,500 mm. (Wijinhoud, J.D., 2003).

Many researches studies Geographic Information System (GIS) combination with a GIS model to assist in the allocation of land use in future and integration GIS modeling(Wang et al., 2004) and based on the land evaluation by FAO to selecte land qualities and economic. For example, Mongkolsawat et al. (2010) studies land evaluation for rubber tree in Northeast Thailand and Chuong,H.(2008) studies multicriteria land suitability evaluation for crops using GIS at community level in central Vietnam based on FAO guidelines has two evaluations to assessing physical land suitability(i.e. soil types, soil texture, soil depth and fertility of soil) and economic-environment.

Mashreki,M et al. (2011) assess land suitability for sorghum in Yemen using climate condition and soil factor, as well as Bydekerke et al.(1998) selected land qualities i.e. annual rainfall, climate , soil types etc. assessment for cherimoya in southern Ecuador.

In addition, analysis land suitability for crops used by GIS also bring Fuzzy system used combination with an important soil factors has an affect for crops (Ahamed et al., 2000). The purpose of this study was to explore the land suitability for rice cultivation based on integrated land quality using to be a database analyzed further.

STUDY AREA

The study area is the Lower Chi basin is sub basin of the Chi basin in Northeast, Thailand (Figure1). It is located between 15°9' to 16° 0' N latitude and 103°42' to 104° 46' E longitude, covering four provinces consists of Roi-Et , Yasothon, Ubon Ratchathani and Sisaket that covers an area of approximately 242,361 ha on which soils are derived from alluvium and inherently low in fertility. Topography, the Lower Chi basin is flat to undulating slope landscapes almost of area and The land cover in basin consists of paddy field in the middle area, field crops in the upper and middle of area. The Chi basin is an important river and drained from upper to lower of the area (LDD, 2010).

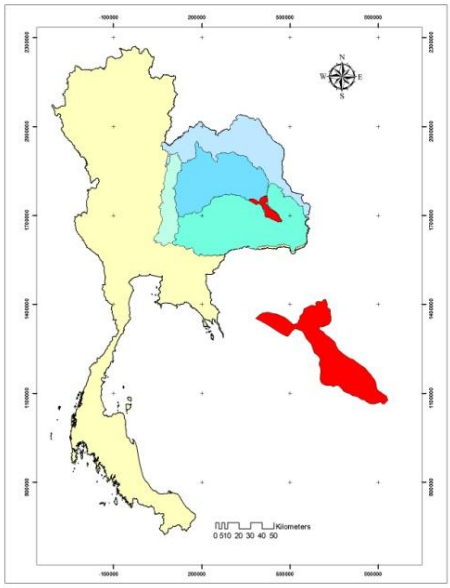

Figure 1. Study area: the Lower Chi basin

METHODOLOGY

In this study assess land suitability for rice ,based on FAO guideline (1983) as defined land qualities 25 types which the selected 7 land qualities used in this study for the evaluation included water availability index (W), oxygen availability (O), nutrient availability index (NAI), water retention (I), rooting conditions (R),excess of salts (Sa) and topography (T). After that, comparing between land use requirement with land qualities and determinate factor rating values ranging from 1.0, 0.8, 0.4 and 0.1 for highly suitable(S1), moderately suitable(S2),marginally suitable (S3) and not suitable(N).

Selected land qualities according rice requirement

- *Water Availability Index (W)*: water availability index is annual rainfall cumulative total of 30 years (1975-2005) and the sources from the Meteorological Department, which interpolate rainfall data in study area by Kriging analysis. The spatial 'W' layer was then divided to 4 suitability classes as defined by Mongkolsawat et al. (2009a).
- *Oxygen Availability (O)*: the O layer was creates from soil drainage data that define by USDA (1951) and then divided to 4 suitability classes as defined by Mongkolsawat et al. (2009a).
- *Nutrient Availability Index (NAI)* the NAI layer creates from overlay process spatial layer consist of nitrogen (N), phosphorus (P), potassium (K) and soil pH (pH) and that NAI layer is the method development from Radcliffe et al. (1982).
- *Rooting Conditions (R)*: the R layer was creates from soil depth is a diagnostic factor for the crops which Rooting Condition is an important land quality for land suitability evaluation (Sys et al., 1993). Then divided to 4 suitability classes as defined by Mongkolsawat et al. (2009a).

- *Water Retention (I):* the I layer was creates from soil texture data and then divided to 4 suitability classes as defined by Mongkolsawat et al. (2009a).
- *Excess of Salts (Sa):* an areas of the Northeast Thailand has the Mahasarakham geologic formation which soil salinity has effects to crops and defined suitability classes by Mongkolsawat and Paiboonsak, 2006**.**
- *Topography (T):* the T layer was creates from Matrix Convolution process which was used landform and slope to create this layer as defined by Mongkolsawat et al. (2009a) in Table 2.

The method of land suitability evaluation

In land evaluation which each land qualities for rice brought into overlay process in the GIS model. An overlay process as defined suitability classes for rice in the Lower Chi basin (in Table 1) and divided to 4 suitability classes such as highly, moderately, marginally and not suitable in Figure 2.

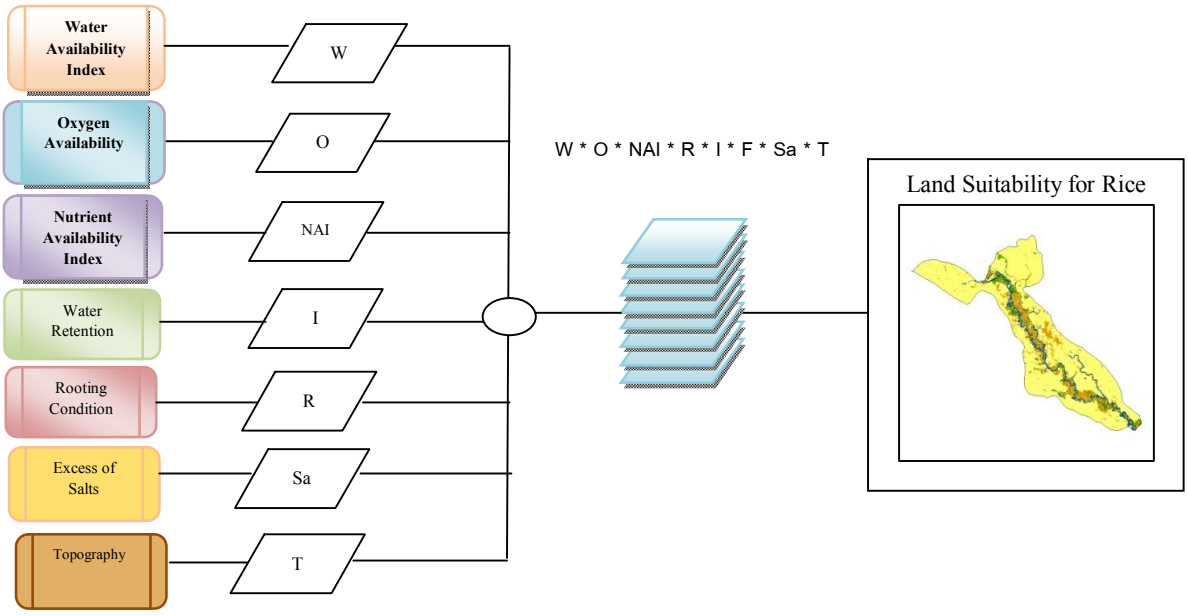

Figure 2. Schematic chart and method for rice

Table 1: Land requirement for rice.

Land use requirement			Factor rating			
Land quality	Diagnostic factor	Unit	S1(1.0)	S2(0.8)	S3(0.4)	N(0.1)
Water Availability Index (W)	Annual Rainfall	mm.	>1,500	1,100-1,500	800-1,100	<800
Oxygen Availability (O)	Soil Drainage	class	poor, very poor	Somewhat poor	mod.well	well, very well
Nutrient Availability Index (NAI)	NAI=N*P*K*pH	-	>0.160	0.026-0.160	0.003-0.026	<0.003
	N	%	>0.5	0.08-0.5	0.04-0.08	<0.04
	P	ppm	>50	25-50	10-25	<10
		ppm	>60	30-60	<30	-
	K	-	5.6-7.3	7.4-7.8 4.5-5.5	7.9-8.4 4.0-4.5	>8.4 <4.0
	pH					
Water Retention (I)	Soil Texture	-	CL,SiC,SiCL,C	L,SiL	LS,SCL,SL	S,G
Rooting Conditions (R)	Soil Depth	cm.	>50	25-50	15-25	<15
Excess of Salts (Sa)	Soil Salinity	class	non saline	low	medium	high

* Remark: 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.

Table2: Landform and slope rating for rice**.**

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

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

Integrated land qualities for rice

Integration of land qualities to assess land suitability for rice , the selected land qualities used for the evaluation consist of water availability index (W), oxygen availability (O), nutrient availability index (NAI), water retention (I), rooting conditions (R), excess of salts (Sa) and topography (T). Which 7 land qualities overlay process to equation (1) and providing the suitability of 4 suitability classes: highly (S1), moderately (S2), and marginally (S3) and not suitable (N) considering from multiple of all land qualities (in Table 3).

$$\text{Overall Suitable} = W * O * NAI * R * I * Sa * T \quad \text{---------- (1)}$$

Table 3: Overall suitability for rice

Suitability Classes	Rating	W * O * NAI * R * I * Sa * T
S1	1.0	>0.6049
S2	0.8	0.1057-0.6049
S3	0.4	0.0008-0.1057
N	0.1	<0.0008

Data validation and field investigation

To checking data about land evaluation for rice as define survey point 30 sampling and collected data a location, yield per rai, terrain and soil properties etc. Then find relationship between the obtained maps and ground truth by Kappa coefficient (Cohen J, 1960).

RESULTS

Land suitability for rice

The results of this study land suitability for rice in the Lower chi basin is show in Figure 3 and which found has an area 33,010, 19,400, 133,650, 51,098 and 5,203 ha for highly, moderately, marginally , not suitable and water body respectively(Table 4).

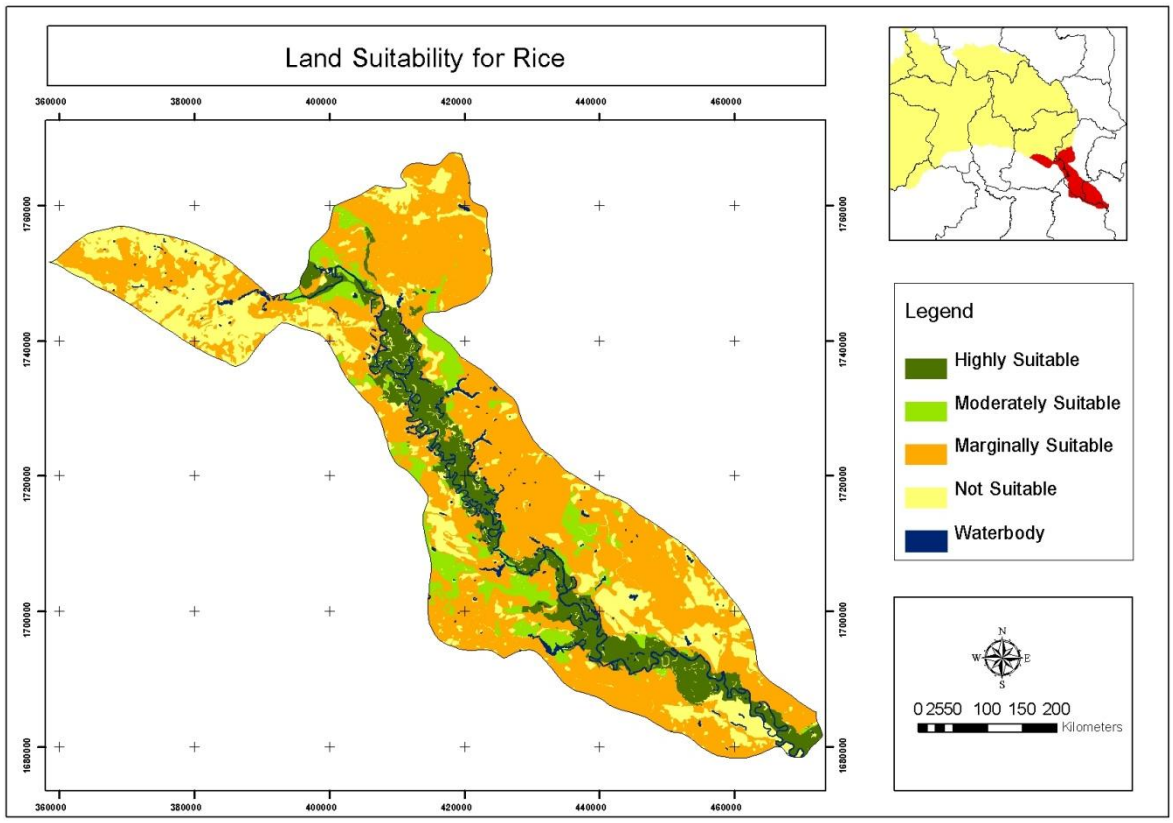

Figure 3. Land suitability for rice map.

a) Highly suitable: this referred the areas which processed the best physical quality for rice however, has an area approximately 33,010 ha or 13.62 % of study area found was an irrigation area.

b) Moderately suitable: this referred the areas which processed the moderate physical quality for rice has an area approximately 19,400 ha or 8.00% of study area which found as distribution in upper area and middle area of the Lower Chi basin.

c) Marginally suitable: this area classified as low or marginally physical quality for rice has an area approximately 133,650 ha or 55.15% of study area was found as distribution in upper area to lower area of the Lower Chi basin.

d) Not suitable: this area classified as not suitable for rice because of these areas which lies in floodplain or conservation area and community has an area approximately 51,098 ha or 21.08%.

Table 4: The suitability area for rice**,** The Lower Chi basin, Northeast of Thailand**.**

Land Suitability for Rice	Area(Hectare)	Percent (%)
Highly Suitable	33,010	13.62
Moderately Suitable	19,400	8.00
Marginally Suitable	133,650	55.15
Not Suitable	51,098	21.08
Water body	5,203	2.15
Total	**242,361**	**100**

Reliability of the suitability maps

To assess of the result map were checked between the result maps with ground truth. In the field survey has define survey point 30 sampling (in Figure 4.) found had a relationship 20 point the confusion between the obtained maps and ground truth is show in Table5**.**

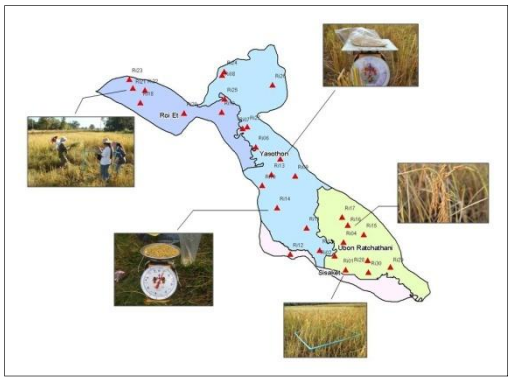

Figure 4. Sample point in field survey

Table 5: The confusion between the obtained maps and ground truth**.**

Survey	The obtained map				
	S1	**S2**	**S3**	**N**	**Total**
S1	6	1	-	-	7
S2	3	3	3	-	9
S3	1	1	10	1	13
N	-	-	-	1	1
Total	10	5	13	2	30

DISCUSSION

To assess land suitability for rice has considered crop requirement and the selected multi land qualities used for the land evaluation. In the result and data validation depending on the variant factor such as rainfall data, flood area and soil fertility etc.

CONCLUSIONS AND RECOMMENDATION

In conclusion, the land suitability for paddy rice in the Lower Chi basin using Geographic Information System (GIS) based on integrated land qualities for rice consist of water availability index (W), oxygen availability (O), nutrient availability index (NAI), water retention (I), rooting conditions (R), excess of salts (Sa) and topography (T). The land qualities and their associated attributes were digitally encoded in GIS database. An overlay analysis with a multiplication model of the GIS layers was performed, providing the suitability of 4 classes: highly, moderately, marginally, not suitable. The land suitability in the Lower Chi Basin, accounts for 33,010, 19,400, 133,650 and 51,098 ha for highly, moderately, marginally and not suitable respectively. Integrate GIS with land use planning decision support for agriculture plan and used a resource sustainable in the future**.**

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