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Spatial Modeling Based Analysis of Land Suitability for Rubber Crop in Ranau District of Sabah, Malaysia

Muhammad Rendana, Sahibin Abdul Rahim, Tukimat Lihan, Wan Mohd Razi Idris and Zulfahmi Ali Rahman

School of Environmental and Natural Resources Sciences, Faculty of Science and Technology, Research Center for Tropical Climate Change System (IKLIM)
The National University of Malaysia, 43600 Bangi, Selangor Darul Ehsan

Abstract: Land suitability evaluation in agricultural activities is applied in order to reduce the exploitation of land that can be destructive potential and the characteristics of land. Land evaluation method that used for this study comes from "The Framework for Land Evaluation" which is developed by FAO (Food and Agriculture Organization). The study is conducted in Ranau district which to find suitable and available areas for development of rubber crop using Geographical Information System (GIS) technique. The process involves a spatial matching method between land characteristics/qualities and crop requirements. Subsequently, the overlay process is applied to set of layers of land qualities to produce land suitability map. The output revealed that 132,313 ha (36.5%) is very suitable (S1) for rubber crop cultivation, 118,643 ha (32.8%) is suitable (S2) and about 67,803 ha (18.7%) is moderately suitable (S3). While, 2,728 ha (0.7%) is temporarily not suitable (N1) and 40,693 ha (11.3%) is permanently not suitable (N2).

Key words: GIS · Land Characteristic · Crop Requirement · Ranau District · Rubber

INTRODUCTION

Malaysia is the main producer of natural rubber in the world in the past 1970 to 1980. The material used to economically for latex production, timber, vehicle components and other equipment. Over the many years have taken places in terms of land source allocation and productivity of rubber crop in Malaysia. Previous study by Rafain *et al* [1] found that rubber plantation in Malaysia has decreased from 1.43 million ha to 1.03 million ha or 28.1% during 2000 to 2010. Additionally, they assumed that the main source of the reduction may due to occurrence of high interest among of smallholders and estates to the oil palm sector which is considered giving the high market price. Currently, more than 90% of rubber production obtained from states of Malaysia Peninsular and the rest come from Sabah state of east Malaysia [2]. The condition showed that land resources in Sabah state has not been utilized properly especially, in each of local district of this state. The dominant vacant areas and favours land characteristics in Ranau district make it appropriate for area of study. In 2010, the land cover estimates for this region indicate that only 5,213 ha cultivated with rubber crop [2]. Thus, to meet the best production of rubber, the land resources in this region need to be utilized to the fullest extent. Land suitability analysis is a prerequisite for sustainable crop production [3, 4]. This analysis helps in determining the most suitable rubber crop growth areas.

The common problem in land suitability analysis is variability and complexity of different kind of data and information. The use of Geographical Information System (GIS) technique solves the problem. It offers high storage of data, flexible and more powerful tool than conventional data processing systems, as it provides large volumes of different kinds of data sets and manipulating the data sets into new data sets that can be displayed in the form of thematic maps [5]. Many recent studies of land suitability analysis have employed Geographical Information System (GIS) as a technique to evaluate for crop

Corresponding Author: Muhammad Rendana, School of Environmental and Natural Resources Sciences, Faculty of Science and Technology, Research Center for Tropical Climate Change System (IKLIM), Malaysia.
E-mail: mrendana02@gmail.com.

production. They have been successfully used it to generate land suitability map for wheat, rice, maize and other crops [3, 6, 7]. Therefore, the same technique from GIS approach will role playing in this study for producing land suitability map for rubber crop. The present study aims to delineate suitable areas for rubber crop in Ranau district using GIS technique for rubber crop development. This work was conducted to find the suitability of rubber crop to be cultivated in ultrabasic soil that it was characterized by low nutrient due to the high Ni and Cr content. The result will be used as a guide in the strategic land use decision making for local authorities.

MATERIALS AND METHODS

Study Area: The study area is located about 108 km east of Kota Kinabalu and 227 km west of Sandakan (Fig.1). It lies between latitudes 5°30'N – 6°15'N and longitudes 116°32'E – 117°00'E with covering a total area of approximately 3,621.8 sq. km. The study area is bordered by Crocker Range from southwest to northwest with the tropical climate, dry and humid. Main geological formation and lithology of study area are originated from sedimentary rock and igneous rock intrusion from Mount Kinabalu.

Data Collection: The methodology of this study adopted with combination most aspects of data such as soil, climate, topographic characteristics and rubber crop requirement. The primary reference for soil data and crop requirement are the results of soil survey undertaken by Sahibin [8] and observation during fieldwork. The rainfall data obtained from several rainfall stations around study area. Furthermore, information on topography and slope features was derived from Digital Elevation Model (DEM).

Land Suitability Classification Method: According to the land suitability classification of FAO, there are two orders or groups of land suitability that is Suitable (S) and Not Suitable (N). Suitable Order is divided into Very Suitable class (S1), Suitable class (S2) and Moderately Suitable class (S3). Whereas, Not Suitable Order grouped into Temporarily Not Suitable class (N1) and Permanently Not Suitable class (N2) [9]. The degree of suitability reflects on intensity and number of limitations in each of class. Limitation or physical limiting factor can be defined as physical, economic or social factors which are able to restrict suitability of the land for different land use types [10]. There are some unique terminologies found in the guideline of FAO such as land characteristic, land quality

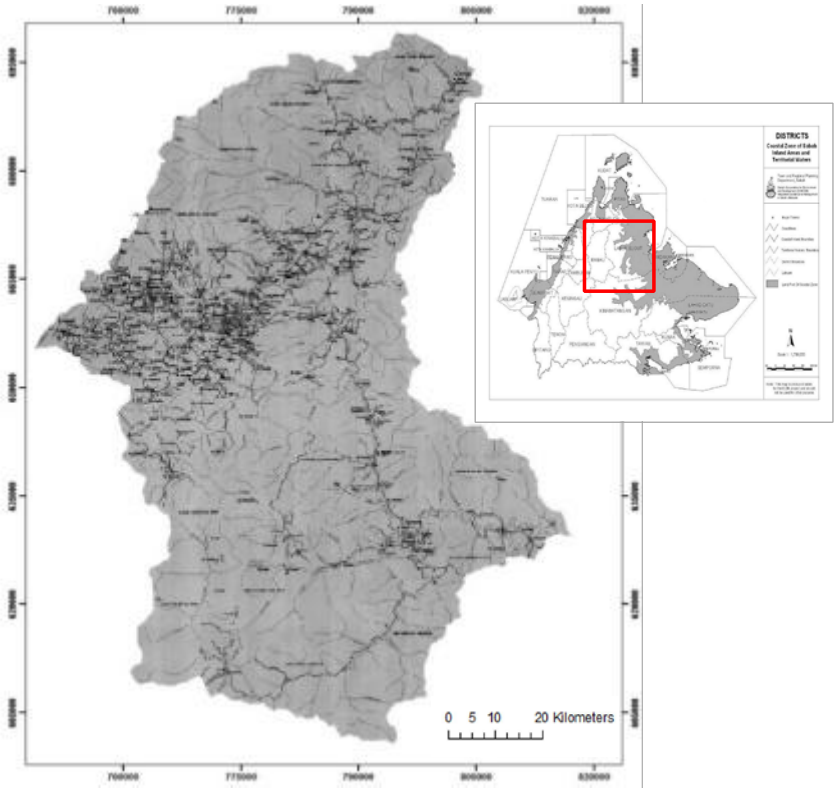

Fig. 1: The location of the study area.

Table 1: The relationship of land qualities and land characteristics

Land Quality	Land Characteristic-Related
Water Availability	Mean annual rainfall, soil depth, texture
Oxygen Availability	Drainage, flood event, texture, mean annual rainfall
Nutrient Availability	pH, P available, K available, Mg available
Work Capability	Stoniness, slope, drainage
Toxicity	Electrical conductivity (EC), toxic element

Table 2: The degree of rating land characteristics and land qualities for rubber crop

	Degree of Limitation (L) and Suitability Classification				
Land Characteristic/Land Quality	None	Slightly	Moderate	Extreme	Very Extreme
	S1	S2	S3	N1	N2
Water Availability					
Rainfall (mm/year)	>2000	2000-1500	1500-1200	-	<1200
Soil texture	SSiL, SiL	SCL, CL	LS	-	S
Drainage	Very good	good	Moderately good	Poor	Very Poor
Soil depth (cm)	>100	100-50	50-20	20-10	<10
Nutrient Availability (mg/kg)					
K^+ available	>312.8	156.4-312.8	78.2-156.3	<78.2	-
Mg^{2+} available	>54	36-54	18-35	<18	-
pH (H_2O)	5.6-7.0	7.1-8.0	4.5-5.5	<4.0, >8.0	-
P available	>25	15-25	6-14	<6	-
Oxygen Availability					
Soil texture	SSiL, SiL	SCL, CL	LS	-	S
Drainage	Very good	good	Moderately good	Poor	Very Poor
Work Capability					
Stoniness (%)	0-35	35-50	50-75	-	>75
Slope (°)	0-6	6-12	12-25	-	>25
Toxicity					
Toxic elements (mg/kg)					
Cd	0-1	1-3	3-8	-	>8
Cr	0-50	50-75	75-100	-	>100
Cu	0-30	30-60	60-125	-	>125
Ni	0-15	15-25	25-50	-	>50
Pb	0-50	50-100	100-250	-	>250
Zn	0-80	80-50	150-300	-	>300
EC (mS/cm)	0-4	4-8	8-15	-	>15

Sources: Modified from Sahibin (1995); Sahibin & Adams (1998)

and crop requirement. Land characteristic is related to the land quality, that land quality is the complex attributes of lands which consisted one or more land characteristics [11]. Meanwhile, crop requirement is the degree of land qualities/characteristics for the crop suitable to grow (Table 2). In other word, the crops will grow best in locations where the conditions meet their growth requirements. In this study, land evaluation conducted at various locations in study area, excepting at Mount Kinabalu area due to permanent limitations such as very extreme of soil depth and stoniness factor. Thus, this area has been classified into permanently not suitable class (N2) for any type of agriculture.

Geographical Information System (GIS) Technique: Since, land suitability analysis required the use of different kinds of data and information, the traditional method in land use planning normally will be time-consuming and unsuitable for this current work [12]. Thus, the recent development of technology, GIS technique presents as new technique to evaluate the suitability of multiple sites and conditions in rapid and systematic way [13, 14]. In this study, variability of soil and climate data was added to the GIS attribute table and grouped into several land characteristics which related to specific land qualities as shown in Table 1. Then, all land characteristics were projected into Malaysia coordinate system with namely "Timbalai RSO Borneo Meter". The next step, land characteristics that spatially spread over all of the study area were used to interpolate by Kriging interpolation method. Meanwhile, topography and slope features extracted from DEM that are available in a raster GIS format. Lastly, all land qualities/characteristics layers were overlaid through a spatial matching method with crop requirement to obtain the potential suitable areas of rubber crop in study area.

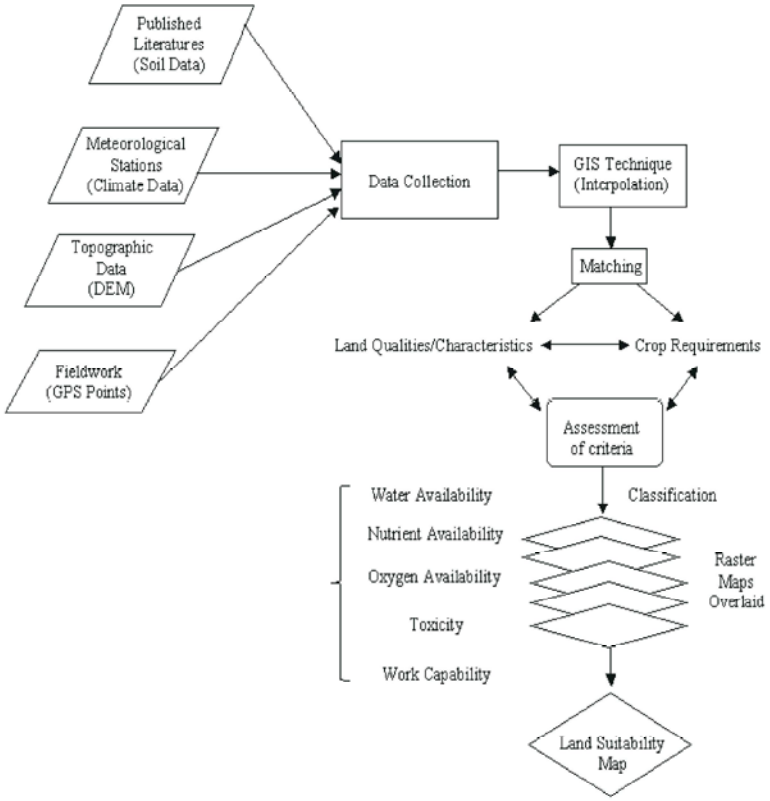

Fig. 2: The flowchart of methodology.

The process was applied to identify spatial suitability classes and degrees of limitations in each of soil mapping unit [15-17]. In GIS, land suitability classes were assigned ranging from 1 (refers to S1 class) to 5 (refers to N2 class) to make it easier to construction of models from which a new thematic map [18]. It is a one of advantages of GIS technique in order to develop a set of themes to produce a land suitability map. The flowchart of procedure used in this study is depicted in Figure 2.

RESULTS AND DISCUSSION

Spatial Analysis of Land Qualities for Rubber Crop: In this study, five types of land quality have been identified namely; water availability, nutrient availability, oxygen availability, work capability and toxicity. The result of water availability classification reveals that nearly 250,626 ha (69.2%) is very suitable (S1), 91,689 ha (25.3%) is suitable (S2) and 19,865 ha is permanently not suitable (N2) (5.5%) (Fig. 3a). Several limitations found in S2 sub-class such as, soil texture, drainage and rainfall. However, they are still categorized as minor limitations due to not contribute on major growth problem for rubber crop.

Nutrient availability is a type of land quality to assess major elements available in soil for rubber crop i.e. potassium (K), magnesium (Mg) and phosphorus (P). Those elements are important for leaf, branch and latex production. The nutrient availability classification indicates around 339,587 ha (93.8%) is very suitable (S1), 2,728 ha (0.7%) is temporarily not suitable (N1) and 19,865 ha (5.5%) is permanently not suitable (N2) (Fig. 3b). The decrease of nutrient suitability class is due to the presence of ultrabasic soil that gave a negative effect for availability of nutrient in soil of study area. Some areas nearly ex-Mamut copper mine and Lohan valley are recognized as low nutrient availability areas hence, they categorized into N1 class. It may due to occurrence of erosion, flooding, mudflow and mass movement down slope of ex-mine which flow directly into rivers and contaminate other nearby areas [19]. Moreover, oxygen availability classification indicates that 274,625 ha (75.8%) is classified into very suitable (S1) for rubber crop, 67,690 ha (18.7%) is classified into suitable (S2) and 19,865 ha (5.5%) is classified into permanently not suitable (N2) (Fig. 3c). Oxygen availability is important for root respiration and life of microbes in soil. Dominant of soil texture in study area

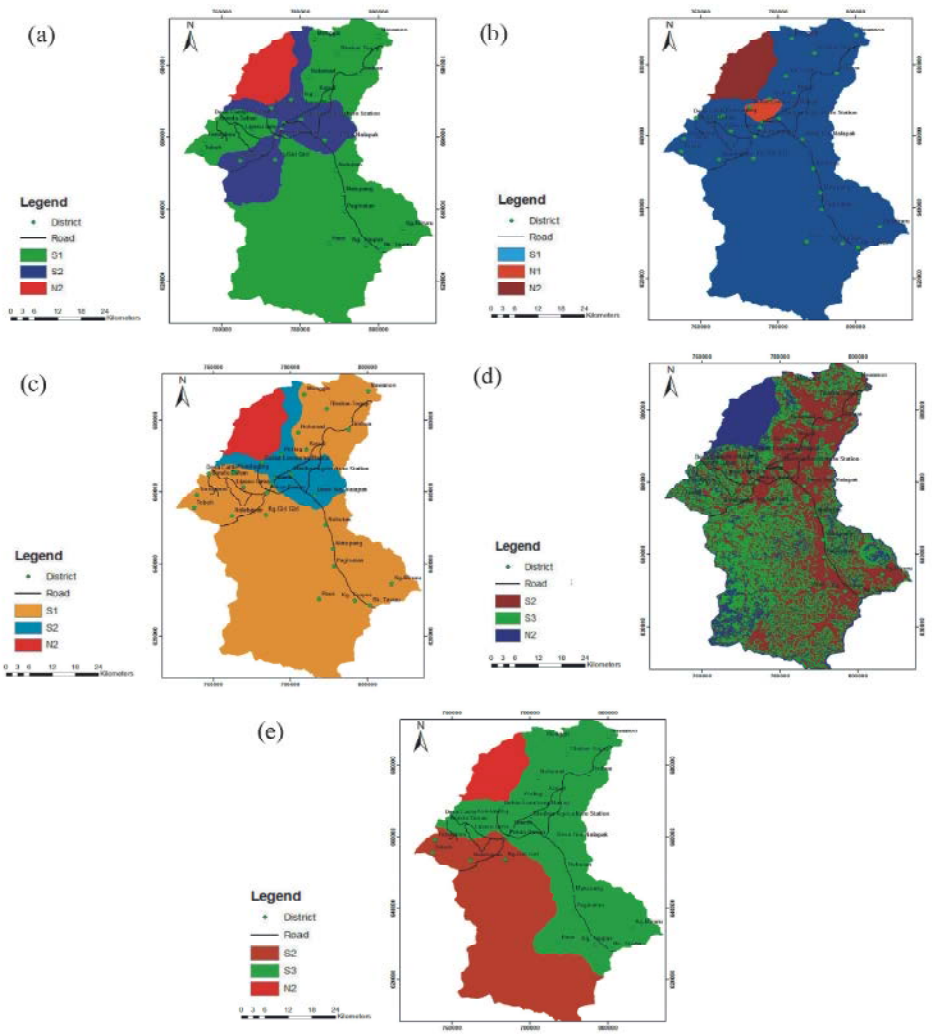

Fig. 3: Land quality criteria (a) water availability, (b) nutrient availability, (c) oxygen availability, (d) work capability and (e) toxicity used to evaluate land suitability for rubber crop in the study area.

that consisted of sandy silt loam, silt loam, sandy clay loam and clay loam were suitable types of soil texture for rubber growth.

Work capability involved some aspects such as topography, slope, erosion hazard and stoniness. Another previous study about soil erosion potential in Ranau district revealed that several areas with high level of erosion risk class found at highland areas such as Kundasang, Bundu Tuhan to Tudan, ex-Mamut copper mine and other extreme slope areas. It may be caused by extreme slope length, land preparation activities for agriculture use and bare land areas which are the main sources to accelerate erosion potential if the best management practice is not adopted [20]. The erosion hazard and stoniness are serious limitations that may decrease of suitability level into N2 class if both have been extreme condition. Spatial analysis of work capability classification found that rubber crop can be suitably (S2) grown in 147,123 ha (41.1%), moderately suitable (S3) in 174,364 ha (47.6%) and permanently not suitable (N2) in 40,693 ha (11.3%) (Fig. 3d). Furthermore, there are six elements that investigated for toxicity classification in study area i.e. Cd, Cu, Cr, Ni, Pb and Zn. Those elements can be derived from two sources which are originated from ultrabasic soil for the high Ni and Cr content and the ex-Mamut copper mine site which contributed to high Zn, Pb and Cu as suggested by Marcus and Murtedza [21]. However, the condition is still below tolerance limit of rubber crop. Spatial analysis obtained that 158,278 ha (43.7%) is suitable (S2) for rubber crop, 184,037 ha (50.8%) is moderately suitable (S3) and 19,865 ha (5.5%) is permanently not suitable (N2) (Fig. 3e).

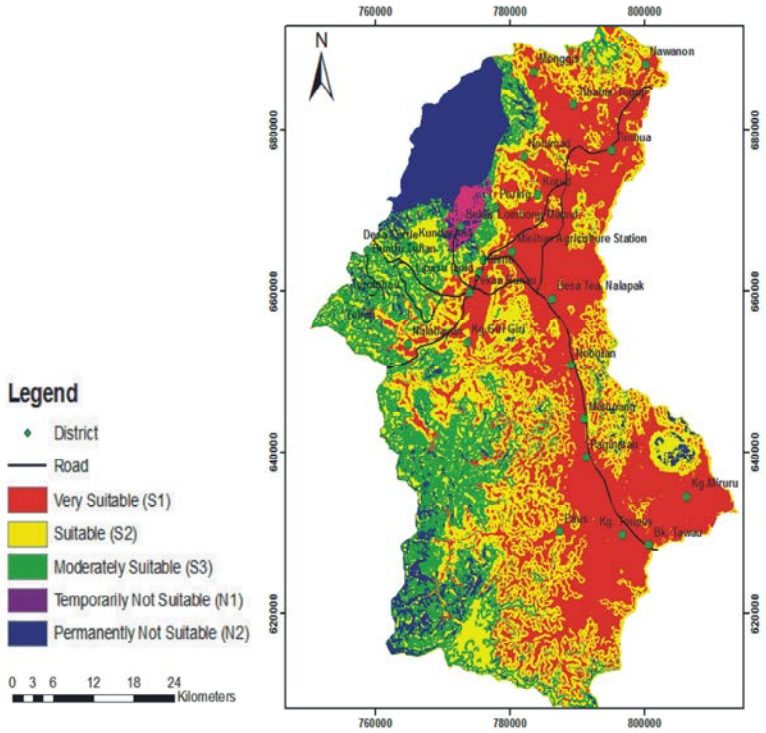

Fig. 4: Land suitability map for rubber crop cultivation in the study area.

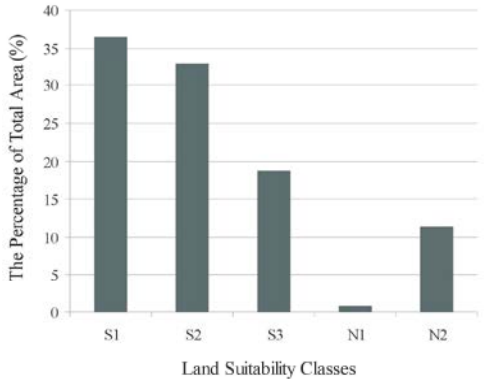

Fig. 5: The percentage of land suitability classes for rubber crop cultivation in the study area.

Land Suitability for Rubber Crop: The result from current land suitability analysis indicates that potential very suitable (S1) area where rubber crop can successfully cultivated is about 132,313 ha (36.5%), 118,643 ha (32.8%) is suitable (S2) and 67,803 ha (18.7%) is moderately suitable (S3) (Fig. 5). Suitable category (S) classes distributed from north part of study area such as, Monggis, Timbua, Nolumad, Kotud, Poring and spread towards south of study area such as, Matupang, Paginatan, Paus and Miruru Village (Fig. 4). Meanwhile, temporarily not suitable (N1) class covers with area of 2,728 ha (0.7%) which situated in areas with low nutrient availability. Additionally, permanently not suitable (N2) class covers with a total area of 40,693 ha (11.3%). Majority of N2 classes are consisted of areas with extreme slope (>25°), forest reserve and high level of stoniness.

CONCLUSION

The study has delineated that land suitability classification of FAO and GIS technique helps land suitability analysis to find potential suitable areas for rubber crop in the study area and expand the areas under this crop based on land suitability map. At the same time, it will develop permanently not suitable areas into forest reserve, state park, recreation and other purposes.

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