LAND SUITABILITY ASSESSMENT FOR RUBBER PLANTATION USING TOPSIS IN BURIRUM, THAILAND

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ABSTRACT: *Hevea brasiliensis*, simply called rubber tree, has become a major economic importance due to dramatically increasing price of its sap-like extract in the recent past. The new suitable areas for rubber growing in Thailand have been constantly required and sought for. Apart from the southern and the eastern coastal regions, long-term well known as rubber plantation areas, the northeastern plateau has been recently the region grading to be the new promising area for rubber plantation. Burirum, a province of the region, was taken as a case study area for spatial suitability assessment. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), which is a kind of ideal point methods in multi-attribute decision analysis, was used through sets of weights and ratings of a set of physical criteria prepared as GIS data layers. They include topographic, climatic, and soil characteristics of the area. Expertise in agriculture was applied to normalized categories rating and criteria weighting. The products of rates and weights performed under the local operation of raster-based analysis became weighted standardized indexes. The sum of the differences of indexes from the positive and negative ideal points of all criteria were estimated and used to assess and rank the land suitability for rubber plantation in the study area.

1. INTRODUCTION

The southern and eastern coastal regions of Thailand, where climate, soil, and elevation are more suitable, have long known as the most suitable areas for rubber plantation. However, due to dramatically increasing price of its sap-like extract (known as latex) in the recent past and the areas of those 2 regions become saturated, the rubber plantation area has been constantly required. The northeast region is considered to be the new promising area. Traditionally, agriculture in this region has been chiefly dominated by crop rotation such as cassava and sugarcane. The rate of economic return from these crops is very low compared to the return from the rubber. The main difference is that there is the return available for crops every year but after 5-7 years for the rubber. It is the time period required for the rubber trees to be mature for being productive. Once it is, it can last for few ten years. Plus, the promotion of rubber plantation in this region is one of the noticeable policies of the government.

Instead of using some other methods of Multi-Criteria Decision Analyses (MCDA) such as Simple Additive Weighting (SAW) or Analytical Hierarchy Processing (AHP) which have been often chosen for spatial suitability assessment (Hartman and Goltz, 2002; Al-Shalabi et.al., 2006; Suriporn Charungthanakij and Sunya Sarapirome, 2010), the TOPSIS was applied for this research. It was different from others in aspect that not only the indexes obtained from criteria weighting and rating were considered but it also took the best and the worst indexes available in the study area to compare to all indexes distributed in the whole area using the local operation of raster-based analysis.

The objective of the study was focused on using the TOPSIS analysis in ranking land suitability for rubber plantation in Burirum province. Only physical criteria were considered in this study. There were no socio-economic criteria involved. The result was compared to the existing rubber plantation area.

The study area

Burirum is situated in the lower part of the northeast region of Thailand and covers area about 10,310 km^2. The elevation of the area varies between 100 and 300 m above msl. Average annual rainfall varies between 1,000 and 1,400 mm while annual average temperature is between 23^o and 33^o C. High land and mountainous area cover about 25 % of the study area in the south while undulating terrain and flat area cover about 60 % and 15 % of the area.

2. MATERIALS AND METHODS

2.1 Concept of the TOPSIS

The TOPSIS analysis is an ideal point method. Its conceptual diagram is displayed in Figure 1. A set of suitable alternatives will be ranked on the basis of separation from the ideal points. An alternative which is closer to the ideal point will have higher rank of suitability. The relative closeness to the ideal point (c_{i+}) can be calculated using equation (1) (Malczewski, 1999).

$$c_{i+} = \frac{s_{i-}}{s_{i+} + s_{i-}} \qquad (1)$$

where s_{i+} and s_{i-} are the sums of separation of an i^{th} alternative from the positive and negative ideal points of criteria. Therefore, c_{i+} of each alternative is between 0 and 1. An alternative is closer to the ideal point as c_{i+} approaches 1.

First, normalized grid of each criterion is weighted. Positive and negative ideal points of each grid criterion are set up from the best and the worst score/rate attached in alternatives of its. The separations from both ideal points of all alternatives of each criterion are calculated. The sums of separation of the each alternative from the positive (s_{i+}) and negative (s_{i-}) ideal points of criteria are performed. Then, the relative closeness to the ideal point can be calculated using equation (1). All of these operations are the value approach performed under the local operation of raster-based analysis. Alternatives with higher c_{i+} show higher ranks of suitability.

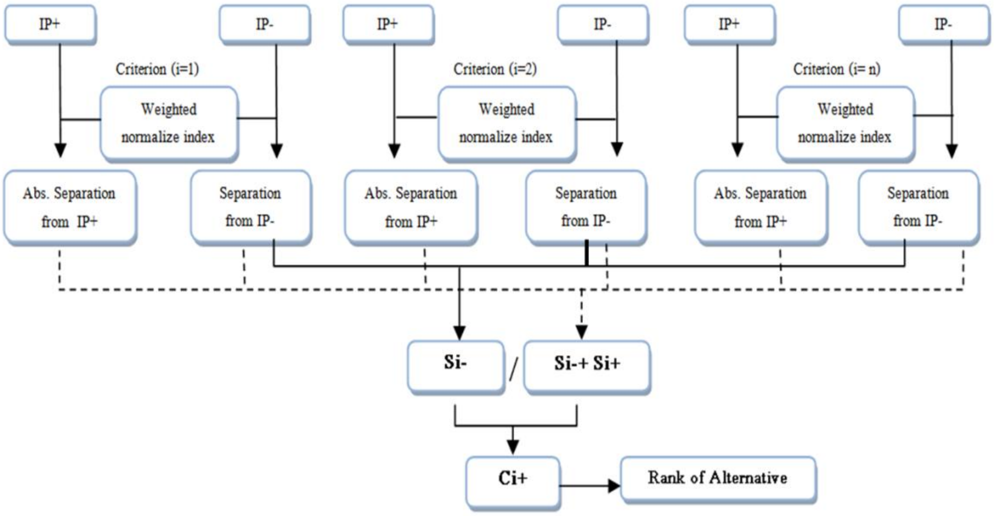


Figure 1 Conceptual diagram of the TOPSIS analysis (IP+ : positive ideal point, IP- : negative ideal point).

2.2 Criteria Selection and Preparation

According to Charat mongkolsawat and Wasana Phutklang (2010) and the Department of Agriculture (1988), the physical criteria influencing on suitability of land for rubber plantation include climatic criteria (rainfall and temperature), topographic criteria (slope and elevation), and soil criteria (texture, depth, drainage, and pH). The suitable average annual temperature is between 26 and 30^{o} C. Elevation change of every 100 m tends to cause 0.5 ^{o} C of average annual temperature change. The growth of rubber plants can be affected by this change. The suitable annual rainfall is at 1750 mm. The slope should be less than 20% while the elevation should be lower than 200 m. The depth of soil should be more than 100 cm whereas its pH should vary between 4.5 and 5.5. The most suitable soil textures include loam (L), silt loam (SiL), sandy clay loam (SCL), silty clay loam (SiCL), silt (Si), silty clay (SiC), and clay loam (CL). The ground water table should be deeper than 100 cm while good soil drainage without shallow solid rock beneath is preferred.

Relevant physical criteria of the study area were collected and prepared in form of 300x300 m^2 raster-based GIS layers. Annual rainfall and temperature data were interpolated from 10 meteorological stations distributed within the study area. The slope of the area was derived from Shuttle Radar Topographic Mission (SRTM) DEM data. Soil attributes in terms of depth, pH, texture, and drainage were extracted from the 1:100,000-scale soil map prepared by the Land Developing Department. All these criteria are displayed in Figure 2. They were further normalized to be able to commensurate.

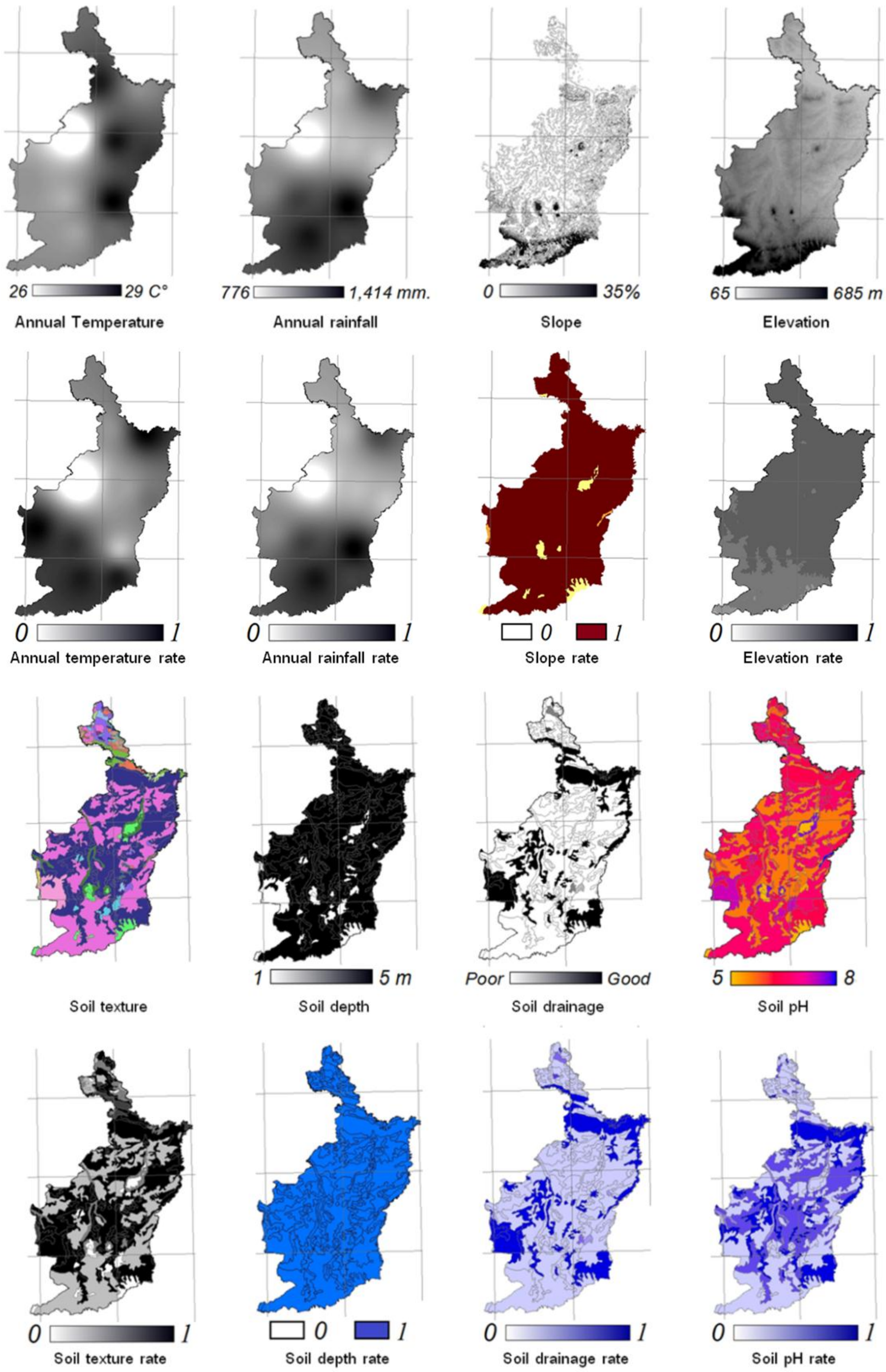


Figure 2 Physical criteria of the study area and their rates.

2.3 Criteria Rating and Weighting

Criterion rating

Different attribute characteristic of each criterion leads to different methods applied to rate normalization. The rates of any cell x_i of annual rainfall was normalized (x) using benefit score range procedure ($x = (x_i - x_{min})/(x_{max} - x_{min})$) (Malczewski, 1999). The annual rainfall of the area is normally lower than 1,750 mm. Depth of all soils in the area is thicker than 1m. Its rate become stable and therefore will not be incorporated in the analysis. Slope =<20 % was rated to be 1and 0 if >20 %. Elevation of the area is between 67 and 681 m above msl. They were normalized using cost score range procedure ($x = (x_{max} - x_i)/(x_{max} - x_{min})$). For annual temperature and soil pH of which suitable attributes are in range, the equation $x = 1-[| x_i-mv|/(0.5*R)]$ was applied, where x is normalized rate of any cell, x_i is an original rate of cell i, mv is presumable as the most suitable value (average of the suitable range), and R is the range of the most suitable values. Suitability of soil texture and soil drainage was rated to be 0 to 3 and 0 to 4 for not suitable to the most suitable. Therefore, average rate was applied for any soil having more than one kind of textures and drainage. Then, they were further normalized using benefit score range procedure. All rated criteria are displayed in Figure 2.

Criteria weighting

Weighting of criteria was operated based on assumption that agricultural practice and management will be best carried out for all species of rubber plants and variations of physical characteristics. The ratio estimation procedure (Malczewski, 1999) was applied to weighting all criteria within climatic, topographic, and soil criteria of which their sub-criteria were further weighted using the same method. The sets of weights were averaged from opinions of 3 experts on agriculture.

2.4 The TOPSIS Analysis

For all criteria, the products of their rates and weights performed under the local operation of raster-based analysis became weighted standardized indexes. All weighted standardized indexes of criteria within climatic, topographic, and soil criteria were summed up and normalized using benefit score range procedure. Climatic, topographic, and soil criteria were further weighted. The negative and positive ideal points of each of them were set up from their own minimum and maximum indexes. Then the TOPSIS analysis of these 3 criteria was performed following the concept described above.

3. RESULT AND DISCUSSION

3.1 Weights of Criteria

The weights of annual rainfall and temperature were 0.557 and 0.443 while weights of slope and elevation were 0.509 and 0.491. Weights of soil attributes in terms of depth, pH, texture, and drainage were 0.256, 0.224, 0,264, and 0.256, respectively. Weights of climatic, topographic, and sol criteria were 0.37, 0.315, and 0.315, respectively.

In general, weight assignment is considered more or less subjective. It depends on experts chosen to express their opinions in questionnaires, communication between researchers and experts, and method of weight assignment used. In this case, 3 local experts on agriculture were requested to provide information after well communication was carried out. The ratio estimation procedure was chosen for weighting because the content of questionnaires was considered scientific without socioeconomic criteria involvement. A score of 100 was assigned to the most important criterion and smaller weights were then given to criteria lower in order. This method allows more flexible and convenient in weighting. Nevertheless, if the set of experts is changed, the sets of weights will be changed as well. But dealing with more scientific matter, the result should not be changed intensely. One thing should be mentioned is the rates of criteria were assigned taking as much detail as influencing factors can be provided.

3.2 Result of the TOPSIS Operation and Ranking

The result of TOPSIS analysis was a grid in form of raster-based relative closeness to the ideal point (c_{i+}). The cell with higher c_{i+} indicates area with more suitable for rubber plantation because the less s_{i-}, the sum of separation of the i^{th} alternative or cell from the negative ideal point of criteria, indicates the area containing influencing indexes closer to positive ideal point of rubber plantation. The indexes were divided using natural breaks into 4 classes, namely, the 1st most suitable, the 2nd most suitable, the 3rd most suitable, and the 4th - not suitable as shown in Figure 3. The area extent in rai (Thai area unit – 625 rais is equal to 1 km^2) and percentage of each class is displayed in Table 1.

The 1st and the 2nd most suitable classes covered more than half of the area while the total existing rubber plantation area was only 9 %. Its largest covering area is about 5 % of the 1st most suitable class.

3.3 Comparison of the TOPSIS Land Suitability and the Existence of Rubber Plantation Area

Area extent of each suitability class compared with existing area of rubber plantation is tabulated in Table 1. The comparison in aspect of districts and the 1st most suitable is displayed in Figure 4. It indicates that there still has been the most suitable area much available in all districts for rubber plantation. This information is helpful for policy makers and decision makers to promote rubber plantation in the area.

Table 1 The area extent in rai (625 rais is equal to 1 km^2) and percentage of each suitability class.

Suitability/existing growing area	Area extent of suitability area				Sum
	1st	2nd	3rd	4th(not)	
Suitability area(rai)	1,923,133	2,783,525	1,231,637	340,954	**6,279,249**
Suitability area (% of total area)	30.6	44.3	19.6	5.4	**100**
Existing growing area (rai)	101,242	45,280	6,824	4,306	**157,652**
Existing growing area (% of suitability class)	5.26	1.63	0.55	1.26	**9**

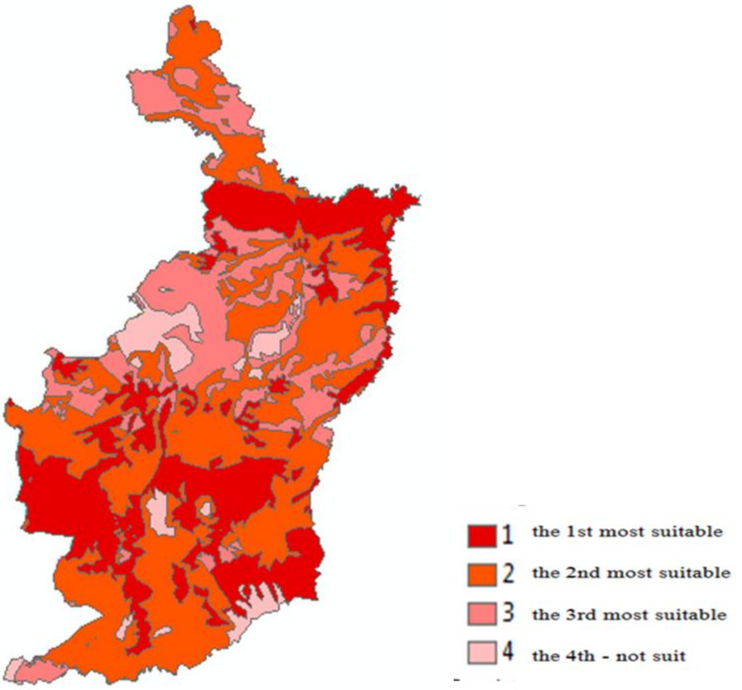
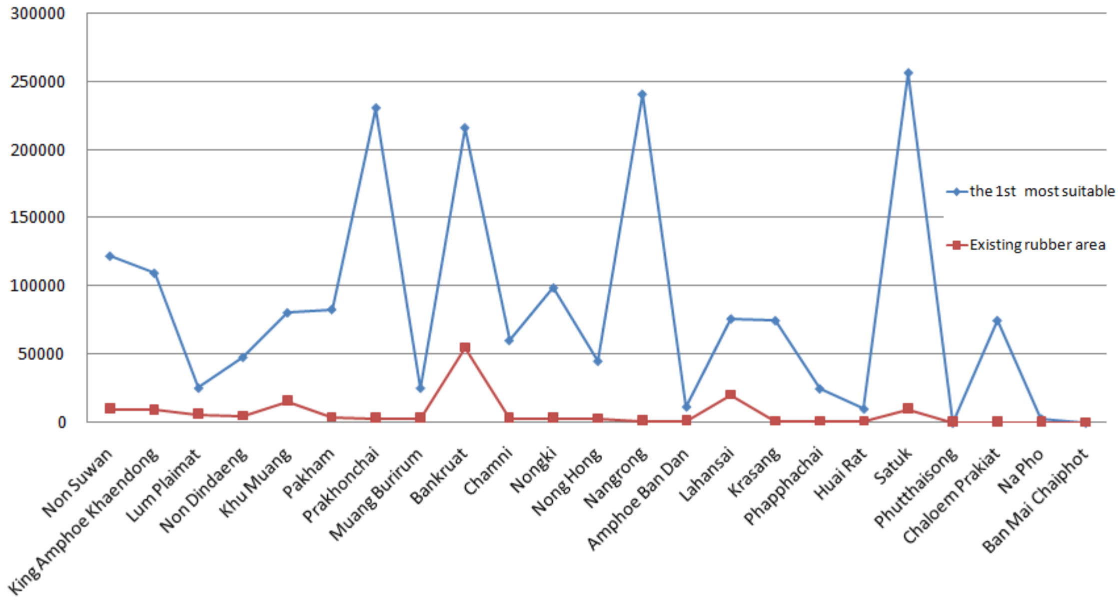


Figure 3 The TOPSIS land suitability of rubber plantation in the study area



Source: the Office of the Rubber Planting Aid Fund (2551)

Figure 4 Graphic comparison of existing rubber plantation area and the 1st most suitable area in each district.

4. CONCLUSION AND RECOMMENDATION

The TOPSIS analysis was used to successfully rank the land suitability for rubber plantation. Benefit of using the TOPSIS analysis is that the negative and positive ideal points set up explicitly reflect the own characteristics of criteria in the study area. Even though the set of weights can be applied to other areas, the ideal points will be different unless they have the same criteria characteristics. Additionally, the sets of rates of physical criteria were assigned in this study based on specific land characteristics fit for rubber plantation and the capability of the study area. The result is expected to be appropriate for policy makers and planners in set up spatial promotion program of rubber plantation in the area.

The foresee barrier for rubber plantation promotion in the area can be the resistance of change from the traditional agricultural style. Therefore, social and economic criteria should be involved in the analysis for further study in order to convince to the change.

References

Al-Shalabi, M. A. Mansor, S. B., Ahmed N. B., and Shiriff, R., 2006. GIS based multicriteria approaches to housing site suitability assessment. Shaping the Change, XXIII FIG Congress, Munich, Germany, October 8-13, 2006, 17 p.

Charat mongkolsawat and Wasana Phutklang , 2010. Spatial modeling of land suitability evaluation for rubber plantation in northeast Thailand. National Conference on Space Technology and Geoinformatics, 15-17 December 2010, Bangkok, Thailand, A2-3#1-24.

Department of Agriculture, 1988. Suitable area for rubber plantation in the northeast region, Thailand. Academic guideline no. 13, 45 (in Thai).

Hartman, D.H. and Goltz, M.N., 2002. Application of the analytic hierarchy process to select characterization and risk-based decision making and management methods for hazardous waste sites. Environ Eng Policy 3: 1-7 p.

Malczewski, J., 1999. GIS and Multicriteria Decision Analysis, John Wiley & Sons, Inc., New York, pp.103-260.

Suriporn Charungthanakij and Sunya Sarapirome, 2010. Land suitability assessment for industrial location development using MCDA. The 31st Asian Conference on Remote Sensing, 1-5 November 2010, Hanoi, Vietnam, TS 07.5, 6 p.