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Land Suitability for Potential Jatropha Plantation in Malaysia

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Abstract. Malaysia has embarked on several initiatives and policies towards renewable energy for improving quality. Jatropha Curcas is an oil seed-bearing plant, which potentially yields as a source of energy in the form of biodiesel. However, research on the determination of the potentially suitable area of Jatropha plant can be allocated still limited. This study aims to carry out a land suitability study on the Jatropha plantation using the geospatial technique such as Geographical Information System (GIS) and remote sensing. To achieve the aim, the objectives of this study are to i) determine significant weightage of parameters for Jatropha plantation and ii) identify the suitable location Jatropha plantation. The study area is carried out at peninsular Malaysia, and five (5) variables such as rainfall, temperature, land-use, soil and elevation data were used to achieve the analysis. The analytical hierarchy process (AHP), in the combination of Geographical Information System (GIS) methods, was applied to compute the weightage of the selected criteria, which is in geospatial data types. A map of the potential Jatropha location was generated using the criteria weightage. This study can help the cultivation of Jatropha in suitable areas and may reduce the burden on fossil fuels. It can assist smallholder-based initiatives to promote Jatropha cultivation on farmer-owned to enhance their living circumstances.

1. Introduction

Jatropha curcas grows in tropical and sub-tropical regions and lower altitudes of 0-500 meters above sea level [1]. The seed contains up to 37% of valuable oil [2], and it is a potential solution to the prevailing shortage of fossil fuel and environmental impacts [3]. Malaysia is a significant exporter of fossil fuel but currently faced with the severe energy crisis [4], which necessitates the search for a sustainable renewable form of energy as an alternative to fossil fuel in order to meet the sustainable development goal (SDG 7) that to ensure access to affordable, reliable, sustainable and modern energy for all by 2030, ensure universal access to affordable, reliable and modern energy services [5].

Malaysia has initiated this project in the year of 2008 when The Prime Minister of Malaysia, YAB Dato' Seri Hj. Abdullah Hj. Ahmad Badawi was briefed by BIONAS Chairman on Jatropha Plantation Agropolitan Project to eradicate poverty in rural areas. However, the project failed because of the high costs of land acquisition and labour [6]. Furthermore, a conventional method such as site investigation during its experimental cultivation scientists by observing its behaviour in different soils and climates was not an efficient method for Jatropha plantation [7]. Also, the failure of Jatropha plantation is due to the improper technique of site selection where the unsuitable area is proposed for the cultivation of Jatropha, no sustainable development plan for the different phases of the biodiesel production and no market for the oil Jatropha curcas [7]. Therefore, several studies [1], [8], and [9] have applied the Geographic Information System (GIS) method for identifying suitable locations to harvest Jatropha plant based on specific suitability criteria. A study by [1] used geospatial data such as rainfall, temperature, soil, land use, slope, elevation, watershed, road and village location for GIS mapping and validating the location of plant species [9]. In addition, rainfall, temperature, soil and elevation are commonly used in studies by [3], [8], [10] and [11]. This is proved that these parameters are most significant to identify a suitable area for Jatropha plantation. Therefore, to integrate and determine an appropriate location, study by [3] applied the Analytical Hierarchy Process (AHP) to identify suitable areas for jatropha production in Ethiopia by assigning a weight for each of them in a hierarchical order [12].

Although many studies have been implemented for Jatropha Curcas plantation, study-related in assessing location-based on spatial criteria in tropical countries is still limited. Therefore, this study used GIS and AHP to identify suitability location Jatropha production in Malaysia. The selected criteria in geospatial-based on the characteristics that make the land suitable for Jatropha plantation [1]. The result obtained can help to continue the national agenda that has been initiated in 2008 with efficient and modern technologies.

2. Study Area

Peninsular Malaysia, also known as Malaya or West Malaysia, is the part of Malaysia which lies on the Malay Peninsula and surrounding islands. A total of 59 accessions of Jatropha were collected from Selangor, Kelantan, and Terengganu states of Peninsular Malaysia (Figure 1). The study was conducted at Selangor, Kelantan and Terengganu. The Jatropha plantation area for the state of Selangor is situated at Serdang, Kuala Selangor, Hulu Langat and Kuala Langat while for the state of Kelantan are Pasir Puteh, Kota Bahru and Machang. In addition, for the state of Terengganu, the district with Jatropha plantations is Setiu and Kuala Terengganu [13]. According to [13], the weather and topography of the states are considered suitable to be a potential area for Jatropha plantation. The selected location is due to the availability and limited of spatial data provided by government agencies that significantly used for determination the area for the Jatropha plantation. Also, Malaysia, as a tropical country, could provide suitable conditions for this exotic species to grow [13].

3. Methodology

3.1. Data used

Several geospatial datasets such as rainfall, temperature, land-use and soil were used in this study. Rainfall and temperature data were collected from the Malaysia Meteorological Agency and Department of Irrigation and Drainage for two years (2017 and 2018). Rainfall and temperature data were selected during the northeast monsoon. About seven (7) points of telemetry stations and six (6) stations for temperature data were interpolated using the kriging method [14] of the states of Selangor, Kelantan, and Terengganu because kriging is an appropriate technique for spatial interpolation and provide unbiased linear estimation with error measurement [14]. The range of the total accumulation of the rainfall volume (mm) and temperature (°) was 280 – 3137 mm and 25° - 29° respectively. The digital elevation model (DEM) was used to represent the elevation, which obtained from the URL website; https://www.alospalsar.my with the spatial resolution is 12.5m, and the range of the elevation is -70 to 2150 m. The soil and land-use maps were acquired from the Ministry of Agriculture and PlanMalaysia, respectively. The soil map consists of soil types such as rudua-rusila, batu hitam, urban land, rengam, batang merbau, bungor-munchong and briah-organic clay and muck. The criteria are classified based on [10] and in three (3) classes in suitable (1), moderately-suitable (2) and not suitable (3) as stated in Table 1.

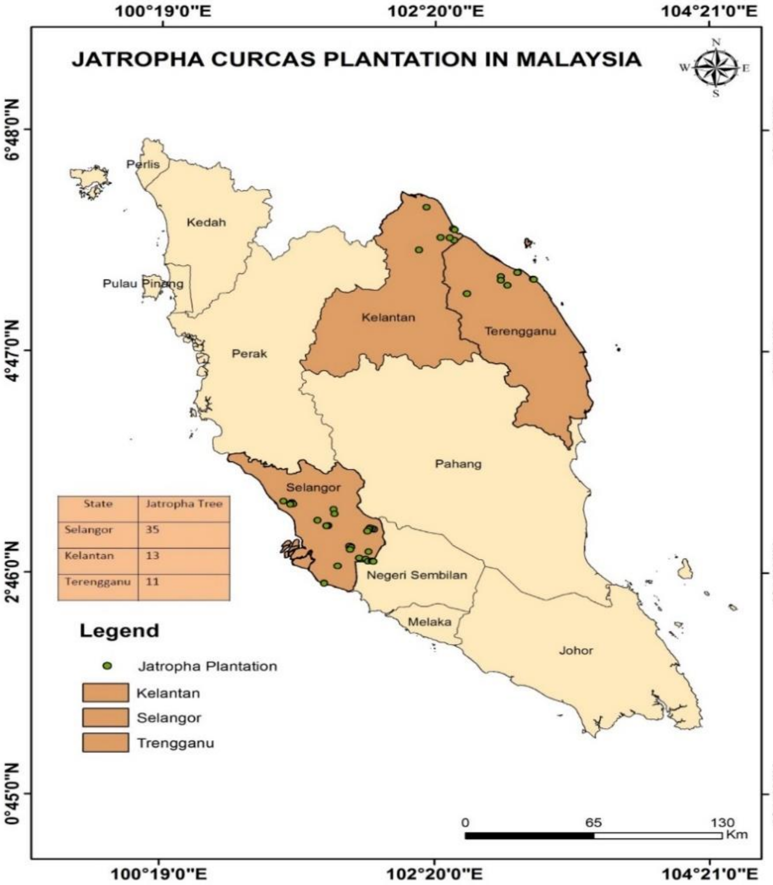

Figure 1. Selected Study Area, Peninsular Malaysia

3.2. Weighting of criteria

Weight and score for each factor chosen within the study were determined based on the AHP [12] method, which has been successfully used in many studies [9] and [13] for land suitability analysis. The comparison for each pair of criteria is stated in integer values from 1 to 9 based on Satty's scale (Table 2), where a higher number means the chosen factor is considered more important than the other. It has been mentioned by [8], where the weight of the criteria if significant when the consistency ratio (CR) less 0.1. The pairwise comparison matrix method was applied to classify the rank of selected criteria. The rank of each criterion is determined based on the author perspective [3], [11] while the value of consistency index (CI) and consistency ratio (CR) is computed in this study.

Table 1. Classification Criteria

Criteria	Layer Class	Ranking
Temperature	26.2 – 27.5	1
Rainfall	300 – 1500	1
	1500 – 2000	2
	2000 - 2437	3
Elevation	< 1500	1
	1500 - 2182	3
Land-use	Agriculture	1
	Bareland	1
	Urban Land	2
	Impervious Surface	3
	Water Sources	3
Soil	1) rudua-rusila	1
	2) batu hitam	1
	3) urban land	3
	4) rengam	3
	5) batang merbau	3
	6) bungor-munchong	3
	7) Briah-organic clay and muck	2

Table 2. AHP Scale of Importance

AHP Scale of Importance	Description
1	Equal Importance
2	Equality to Moderately
3	Moderate Importance
4	Moderately to Strong
5	Strong Importance
6	Strongly to Very Strong
7	Very Strong Importance
8	Very Strong to Extremely
9	Extreme Importance

The CR is calculated to determine the judgment error using equation (1-2) obtained from the study of [8]. This value indicates the probability that the ratings were randomly assigned. The CR is the ratio of the consistency index to the corresponding random index. The computed CI (equation 1) is divided by a random index (RI), which stated in Table 3, depending on the number of selected criteria (n). After assigning the value of importance on each criterion relation, the final value in those relations was used to construct the standard matrix as the final weight. The final weight obtained from the AHP process is applied to the overlay process using the parameters (Table 4). Table 3 shows three sets of criteria because to find the essential criteria needed for Jatropha plantation and also to minimise the characteristics of Jatropha plant.

$$\mathrm{CI} = \frac{\lambda - \mathrm{n}}{n-1} \tag{1}$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (2)$$

Table 3. Random Index (RI) for different numbers of factors

Number of factor (N)	1	2	3	4	5	6	7	8	9	10
Random consistency indices (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 4. Criteria of Jatropha Plantation

Set	Criteria	Number of Criteria
Set 1	Rainfall Temperature Elevation	3
Set 2	Rainfall Temperature Elevation	4
Set 3	Soil Rainfall Temperature Elevation Landuse	5

4. Result and Analysis

4.1 Selected criteria weight

Table 5 present the pairwise comparison matrix for three (3), four (4), and five (5) sets of the selected criteria for identification of the suitable place jatropha plantation. This criterion has been classified into three sets which are set one has three criteria (rainfall, temperature, and elevation), set two have four criteria (rainfall, temperature, elevation, and soil) and set three have five criteria (rainfall, temperature, elevation, soil, and land-use). The rank of each criterion is based on the author perspective [3], [11] to calculate the value of consistency index (CI) and the consistency ratio (CR). Tables 5 (a-c) indicate the value of the weight, ƛmax, CI, and CR were computed. The perspective for rainfall extremely significant compared to temperature and rainfall to elevation are very strong significant with the scale (7).

Table 5a. Pairwise comparison matrix for three (3) parameters

Parameters		**(A)**	**(B)**	**(C)**
Rainfall	**(A)**	1.00	9.00	7.00
Temperature	**(B)**	0.11	1.00	6.00
Elevation	**(C)**	0.14	0.17	1.00

Table 5b. Pairwise comparison matrix for four (4) parameters

Parameters		**(A)**	**(B)**	**(C)**	**(D)**
Rainfall	**(A)**	1.00	9.00	7.00	5.00
Temperature	**(B)**	0.11	1.00	6.00	7.00
Elevation	**(C)**	0.14	0.17	1.00	2.00
Soil	**(D)**	0.20	0.14	0.50	1.00

Table 5c: Pairwise comparison matrix for five (5) parameters

Parameters		**(A)**	**(B)**	**(C)**	**(D)**	**(E)**
Rainfall	**(A)**	1.00	9.00	7.00	9.00	9.00
Temperature	**(B)**	0.11	1.00	6.00	5.00	5.00
Elevation	**(C)**	0.14	0.17	1.00	2.00	2.00
Soil	**(D)**	0.11	0.20	0.50	1.00	4.00
Landuse	**(E)**	0.11	0.20	0.50	0.25	1.00

4.2. Site suitability analysis and mapping

Suitability maps generated from the combination of the criteria for rainfall, temperature, elevation, soil, and land-use, as shown in Figures 2-4. The maps were classified into three (3) such as suitable, moderately suitable, and not suitable [8]. A suitable area indicates that the area has favourable biophysical and climatic conditions for productive jatropha growth based on all considered criteria. A moderately suitable area indicates a second priority for jatropha production to be reserved for this reason only after all the requirements and decisions on the viability of this project over other opportunities have been studied. On the other side, unsuitable areas are locations that are not ideal for growing Jatropha. These are limited by water harvesting, inadequate rainfall, temperature scorching, and type of land-use.

Based on the normalized weightage (Table 6), final matrix weight, an overlay process is done to see the interaction between the parameter relationship. The CR of set 1 and set 2 was computed as 0.5 and 0.33, respectively, which is more than 0.1. It means that the CR values obtained were inconsistent ratio for determination of suitable place for Jatropha curcas [8]. While the five (5) parameters such as rainfall, temperature, elevation, soil, and land-use show an appropriate combination of the CR = 0.033 and its recommended for a suitable place of Jatropha Curcas plantation.

Using a group of criteria in Set 1, in 2017, two states such as Selangor and Negeri Sembilan are indicated as appropriate places, and the pattern of land suitability was extended to Perak region in 2018 for jatropha plantation. It is due to rainfall volume receiving in 2018 on the state of Perak, Selangor and Negeri Sembilan are included on Jatropha criteria which are around 1000 -1500 mm [10] and [15]. Temperature data on 2018 also included with the mean temperature around 26.2℃ until 27.4℃. However, the land suitability maps indicate that Kelantan and part of Terengganu states are maintained to unsuitable place for Jatropha plantation in the year 2017 and 2018 because rainfall volume is more than 1500 mm per year and the elevation data is more than 1500 metres above sea level. About 24 out of 59 existing Jatropha locations were planted at unsuitable places based on Set 1 and Set 2 where the soil types of the area are Rudua- Rusila and Batu Hitam with soil pH 6.2 and 6.5 respectively [16] (Figures 2 and 3).

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Table 6. Computed Value of Weight, λmax, CI, RI and CR

Set	Criteria	Weight	λmax	CI	RI	CR
1	Rainfall	0.73	2.65	0.45	0.58	0.5
	Temperature	0.21				
	Elevation	0.07				
2	Rainfall	0.59	4.878	0.293	0.9	0.33
	Temperature	0.26				
	Elevation	0.08				
	Soil	0.06				
3	Rainfall	0.59	5.150	0.037	1.12	0.033
	Temperature	0.22				
	Elevation	0.08				
	Soil	0.08				
	Landuse	0.04				

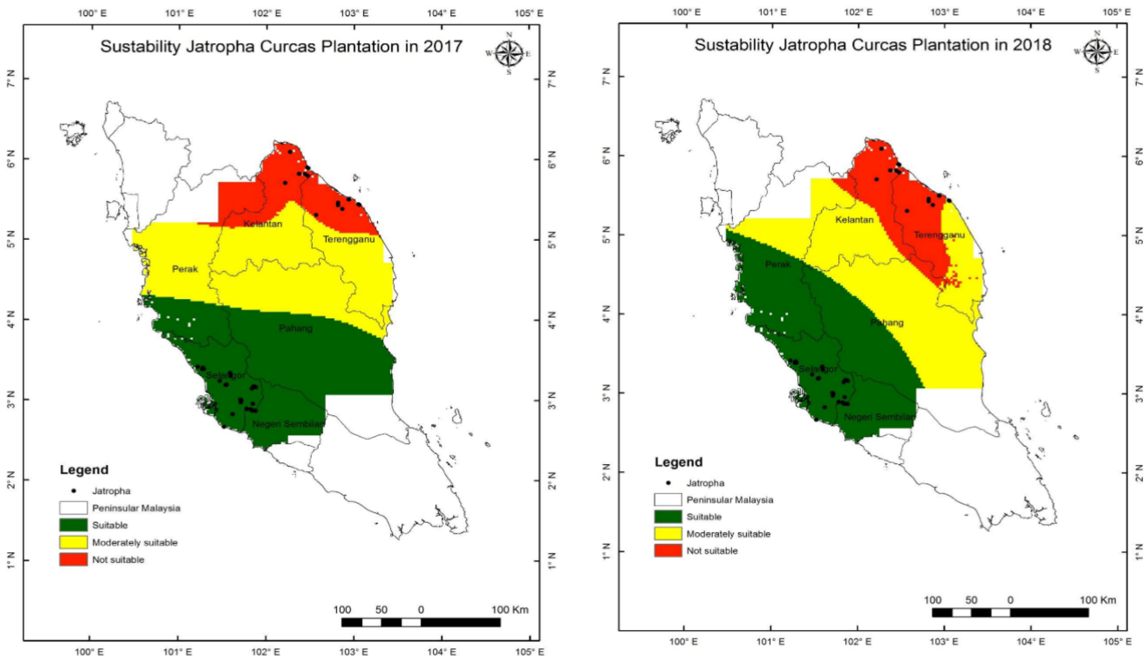

Figure 2. Land Suitability Maps of 2017 and 2018 using Combination of Three (3) Criteria

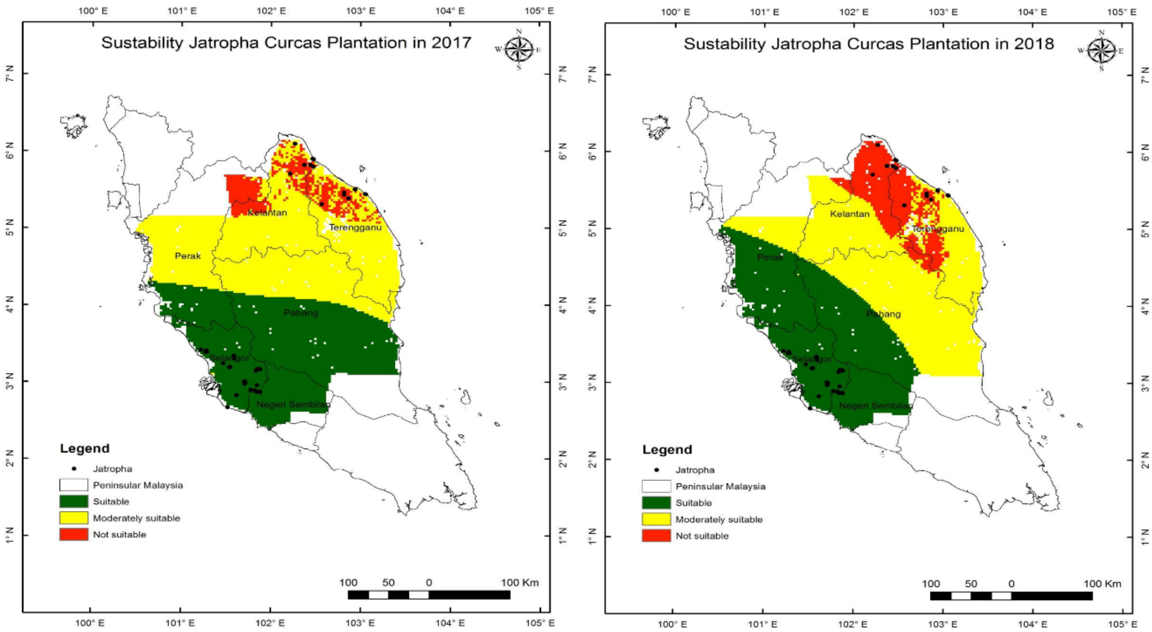

Figure 3. Land Suitability Maps of 2017 and 2018 using Combination of Four (4) Criteria

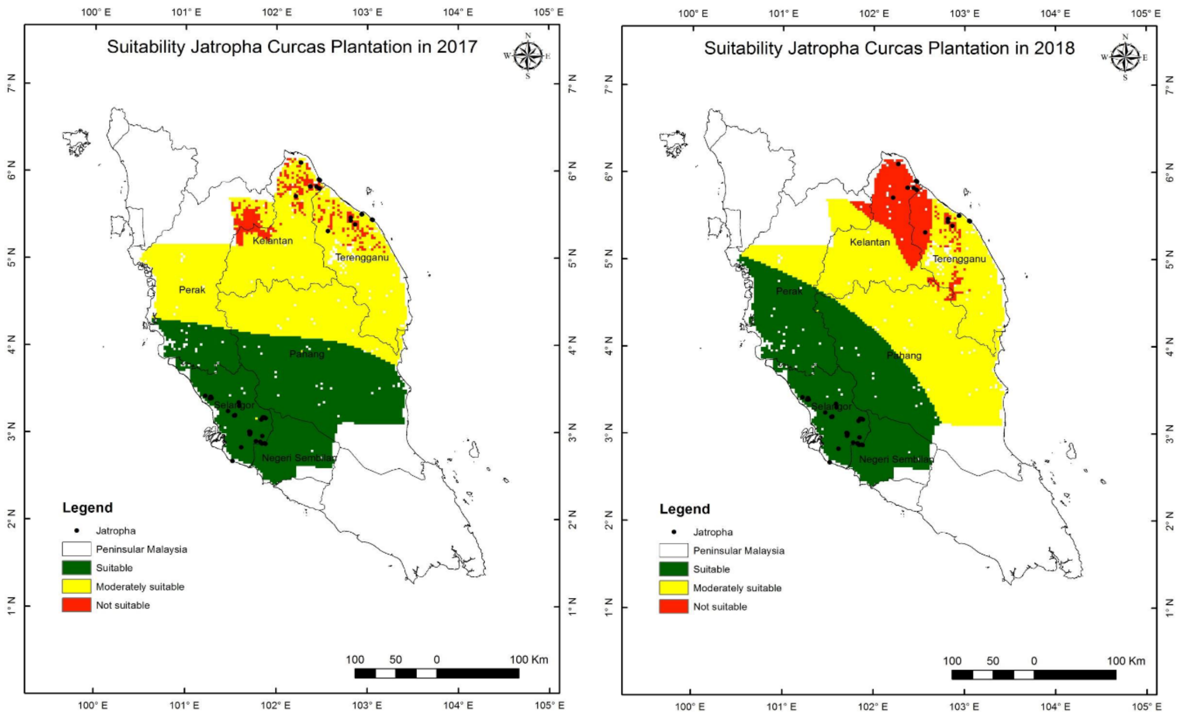

Figure 4. Land Suitability Maps of 2017 and 2018 using Combination of Five (5) Criteria

Figure 4 presents quite a similar pattern of suitable area for Jatropha plantation using five (5) criteria as compared to the map generated from the three (3) criteria. This has happened because rainfall volume retrieved in the year 2017 is around 360mm to 1500mm at the area of Selangor, Negeri Sembilan, Perak and Pahang. In conclusion, the most suitable years for Jatropha plantation is in the year 2018 because the criteria of climate such as rainfall and temperature meet to the needs of Jatropha plantation as compared to 2017. The computed area of the land suitability maps using different sets of criteria are indicated unsimilar area in hectares unit (Table 7).

Table 7. Percentage of the land in 2016

Parameters	Categories Value	Area in Hectares	Percentage (%)
	Suitable	1480	14
3 parameters	Moderately suitable	5875	57
	Not suitable	2889	29
	Sum	**10 244**	**100**
	Suitable	1375	14
4 parameters	Moderately suitable	4304	45
	Not suitable	3906	41
	Sum	**9585**	**100**
	Suitable	391	4
5 parameters	Moderately suitable	8862	93
	Not suitable	283	3
	Sum	**9541**	**100**

5. Conclusion

Several criteria such as rainfall, temperature, elevation, soil and land-use data were selected to estimate the suitable area for Jatropha plantation. The AHP method was used with the complimentary of pairwise comparisons which calculate all the possible relations between criteria. The suitable area was classified into three (3) classes such as suitable, moderately suitable and not suitable. The results indicate that the five criteria are significant enough to locate suitable places of Jatropha plantation with CR = 0.033. Temperature, rainfall, elevation, soil and land-use were identified as the significant environmental factors governing the performance of Jatropha. From the results, the state most suitable for jatropha plantation is states of Selangor, Perak, Negeri Sembilan and Pahang.

Therefore, the study showed that the country has ample opportunity to invest in Jatropha plantation. Nonetheless, proper technologies for developing, managing and processing jatropha products should be given considerable attention in order to get the best profit from the field. The establishment of jatropha plantations should focus on the geographical locations established to avoid conflicting interests in the use of a plantation. However, with some limitations that may require frameworks for socio-economic and environmental management to make use of them for investment in this field, more land is potentially reasonably suitable. This study is significant to bring high income to farmers and also to achieve a sustainable environment with the potential plant of renewal energy. Furthermore, this study can solve the drawback mentioned where using the traditional method will cause of planting Jatropha at the unsuitable location. Careful selection of Jatropha plantation can be executed in proper technique such as GIS and remote sensing as recommended in this study, which can expedite the process of estimating location suitable with suitable weather and topography.

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