

# Land Suitability Analysis of Biodiesel Crop Kemiri Sunan (*Reutealis trisperma* (Blanco) Airy Shaw) in The Province of West Java, Indonesia

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## Abstract

Increase in fossil energy demand should be balanced with the development of renewable energy, one of the source is from vegetable materials that could be processed into biodiesel. One of prospective biodiesel crop in Indonesia is Kemiri Sunan (*Reutealis trisperma* (Blanco) Airy Shaw). Kemiri sunan has certain growth condition for optimum reproduction. Land suitability analysis is needed to determine potential available land for planting kemiri sunan on West Java Province. To determine land suitability Multi Criteria Evaluation (MCE) is used, based on Geographic Information System (GIS). Determination of factors numerical weight was done using Analytical Hierarchy Process (AHP) method. The analytical parameter consist of climate criteria (altitude, rainfall, the number of dry month, humidity, and temperature) and land criteria (slope, soil texture, pH, solum thickness, and drainage). Result shows the area of suitable land for planting kemiri sunan is 981,067.20 Ha consist of 86,855.70 Ha of land in suitable criteria, 799,947.58 Ha land in moderately suitable category, dan 94,263.92 Ha of land in marginally suitable category. The suitable land area for planting kemiri sunan is spread in 23 districts on West Java Province. While available potential land for planting kemiri sunan after deduction by area allocated for another use is 141,955.56 Ha which consist of 19,582.74 Ha of land in suitable category, 103,974.62 Ha land in moderately suitable category, and 18,398.20 Ha of land in marginally suitable category. Area of available land is spread in 17 districts on West Java Province. Kemiri sunan is recommended for development at West Java Province as an effort for providing alternative energy and environment rehabilitation.

**Keywords:** Land suitability, Land availability, Kemiri sunan (*Reutealis trisperma* (Blanco) Airy Shaw), Biodiesel

## 1. Introduction

Nations in the world are aware of the increased use of fossil energy which is not balance with the availability of sustainable energy. Kusumaningrum and Munawar (2013) stated that beside used for domestic consumption, Indonesia fossil energy has been continually exported. Energy shortage will happen without proper management. The government of The Republic of Indonesia has taken steps connected to the depletion of fossil based energy through the establishment of The 2025 Sustainable Energy Vision. It is targeted for the next 15 years to come the minimal utilization of sustainable energy is 25% of total energy consumption. Indonesia possesses renewable energy in form of geothermal, biofuel, and other renewable energy in form of biomass, nuclear energy, hydropower, thermal energy and wind.

One of potential biofuel is biodiesel for its ability to substitute diesel fuel. Biodiesel industry has been developed in certain countries. According to Salim (2009), the increase in the Asia Pacific production capacity is an indicator of the growth in biodiesel industry and is potential to be the main source for export income as well as being part of the government strategy and policy to support environment sustainability. Furthermore Salim (2009) stated based on FAO projection in 2008, the world's biodiesel production up to year 2017 will be dominated by the European Union countries. For that reason, Indonesia biodiesel industry needs to be supported for well development. Domac *et al.*, (2005) stated that in developing countries, bioenergy and other renewable energy need to be promoted for its potential contribution to energy security and the benefit its provide for environment. Bioenergy development need to put into account factors affecting its implementation. According to Roos *et al.*, (1999), critical factors to consider in the bioenergy implementation are 1). integration to other economical activities, 2). *scale effect* of the bioenergy market, 3). competition in bioenergy market, 4). competition to other business, 5). national policy and its influence, 6) local wisdom and local view.

One of prospective biodiesel crop in Indonesia is kemiri sunan (*Reutealis trisperma* (Blanco) Airy Shaw). Biodiesel originated from kemiri sunan has advantages over the other crop. The advantages are a) oil content with approximate yield of 50% (Vossen & Umali, 2002), b) Biodiesel production is quite high, c) it will not compete with food due to its 50%  $\alpha$ -eleostearat acid content (Vossen & Umali, 2002), c) ability to reduce erosion and soil damage d) well carbon sequestration due to its dense canopy e) long production life. Feedstock availability and sustainability in the development of biodiesel are crucial factors. To guarantee the

availability of feedstock wide-scale crop development is needed. The main variable is the availability of suitable land that fit the growing requirements of the crop. Thus it is necessary to acquire information of potential land area for kemiri sunan planting taking into consideration the land use and spatial pattern planning.

## 2. Research Objective

The objectives of this research are :

- 1) To review land suitability class including area and spread for planting kemiri sunan at West Java Province.
- 2) To review area and spread of available land for planting kemiri sunan at West Java Province.

## 3. Research Methods

### 3.1 Research location and timeframe

The study area for this research is in West Java Province, Indonesia. The selection for the study area is based on the presence of kemiri sunan crop in West Java that grow well naturally or by planting. High consumption of diesel fuel in West Java is another fact that provide opportunities for the development of biodiesel as an alternative to meet the needs for diesel fuel West Java Province is one of the provinces in Indonesia that geographically located in latitude 5°50'-7°05' and longitude 104°48'-108°48'. West Java annual average rainfall in the 1998-2010 period is 2000mm/year. West Java soil type dominated by 3 kinds which are Latosol, Podzolik, and Alluvial with percentage area to total area of the West Java Province consecutively 35.5%, 21.8%, dan 18.4% (Utomo, 2013). This research was conducted for 2 months ( August - September 2014).

### 3.2 Materials and Equipments

Research material in form of digital map that include: 1) West Java topographical, 2) Semi-detailed Soil Map, 3) Climate Map 4) West Java Spatial Planning Map (RTRWP) 2010-2030, 5) Landuse Map, 6) West Java Administrative Map. Devices used in this research are computer with ArcGIS software 10.0 and Expert Choice 11.

### 3.3. Source and type of data

Source and type of data used is presented in Table 1.

Table 1. Type and source of data used in the research

Data type	Data source
Secondary <ul style="list-style-type: none"> <li>- West Java topographical map at scale of 1:250.000 (2001)</li> <li>- Semi-detailed Soil Map at scale of 1:250.000 (2004)</li> <li>- Climate Map at scale of 1:250.000 using database from The Meteorology and Geophysical Agency</li> <li>- West Java Spatial Planning Map (RTRWP) 2010-2030 at scale of 1: 250.000</li> <li>- Landuse Map at scale of 1: 50.000 (2012)</li> <li>- Criteria of kemiri sunan land suitability</li> </ul>	Geospatial Information Agency  Soil Research Institute The Meteorology and Geophysical Agency  Regional Planning Agency of West Java Province Ministry of Environment Ministry of Agriculture
Primary <ul style="list-style-type: none"> <li>- Quantitative numerical weight for criteria and factor for land suitability analysis</li> </ul>	Experts and data analysis

### 3.4 Parameter

This study used the parameter land suitability referring to land suitability criteria defined by The Ministry of Agriculture of The Republic of Indonesia in 2011 and also to literature review. The parameter is divided into:

- 1) Climate, includes altitude, rainfall, the number of dry month, humidity, and temperature.
- 2) Land, includes slope, soil texture, pH, solum thickness, and drainage.

### 3.5 Steps of analysis

#### 3.5.1 Classification of land and climate characteristic

Classification of land and climate characteristic was arranged based on land suitability criteria. Results of land and climate characteristic classification were used to prepare map from factors that include climate and land parameter.

#### 3.5.2 Land suitability analysis for kemiri sunan

The analytical method used for kemiri sunan land suitability analysis are Multi Criteria Evaluation (MCE), based on Geographic Information System (GIS). Analysis approach used in this research is Weighted Linear Combination (WLC) calculation approach. Mendas and Dellali (2012) stated that by integrating the multiple criteria analytical approach with GIS will provide strong spatial system support to produce land suitability map. Besides, according to Ismail *et al.*, (2012) GIS could ease the handling of many data in MCE. In MCE, weight of criteria and factor are determined through Analytical Hierarchy Process (AHP). Marimin and Maghfiroh (2011)

stated that AHP is able to simplify complex and unstructured elements into more organized elements. Land suitability parameter were organized into criteria, factors, and sub factors. The experts as resource persons from whom the criteria and factors were given score are the experts with expertise in bioenergy, cultivation, soil, and technology of kemiri sunan and possessed the field experience in the study of kemiri sunan. While the subfactor score is determined through the author scientific judgement referring to literature review results and kemiri sunan land suitability criteria. The criteria dan factor score was then analyzed using pairwise comparisons with AHP to determine the weight. Criteria assessment was done using 1-9 comparison scale presented by Saaty (1991). The weight for criteria and factor provide value of Consistency Ratio 0.00 can be found completely in Table 2.

Table 2. The Weight for criteria and factor in kemiri sunan land suitability analysis

Criteria	Weight	Factor	Weight	Sub-factor	Score
climate	0.691	altitude (MASL)	0.541	0-350	0.279
				350-700	0.649
				>700 -1000	0.072
		rainfall (mm/year)	0.170	1000-1500	0.279
				1500-2500	0.649
				2500-4000	0.072
		no. of dry month	0.158	3-4	0.279
				4-5	0.649
				5-6	0.072
		temperature (°C)	0.090	<24	0.102
				24-30	0.726
				>30	0.172
		humidity (%)	0.041	<71%	0.172
				71-88%	0.726
				>88%	0.102
land	0.309	slope (%)	0.082	<8	0.649
				8-25	0.279
				>25	0.072
		texture	0.130	loam sandy, silty loam	0.279
				loam, sandy loam	0.649
				sandy clay, silty clay, clay	0.072
		pH	0.153	acidic	0.102
				slightly acid-neutral	0.726
				basic	0.172
		solum thickness (m)	0.486	>1	0.875
				<1	0.125
		drainage	0.149	good	0.271
				very good	0.644
				middle	0.085

Criteria and overlay (weighted sum) factor with ArcGIS 10.0 software. Suitability range was calculated with filed calculator, and divided into 4 suitability ranges which are Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3) dan Not Suitable (N).

### 2.5.3 Analysis of kemiri sunan land availability

The suitable land for kemiri sunan need to be integrated with land use map and spatial map to exclude the lands which are not permitted to be planted by kemiri sunan crop. Land attached with strategic function will be retained to its function. Based on land use map, The West Java Province is divided into several land use which are forest, mixed farms, mangrove, plantation, settlement, swamp, paddy field, shrub, pond, bared land, dry land agriculture, and water body. West Java Spatial consist of conservation area, forest utilization area, disaster hazard area, protected forest conservation, rural area, urban area, paddy field, and water body.

Steps for kemiri sunan land availability analysis as shown in Figure 1.

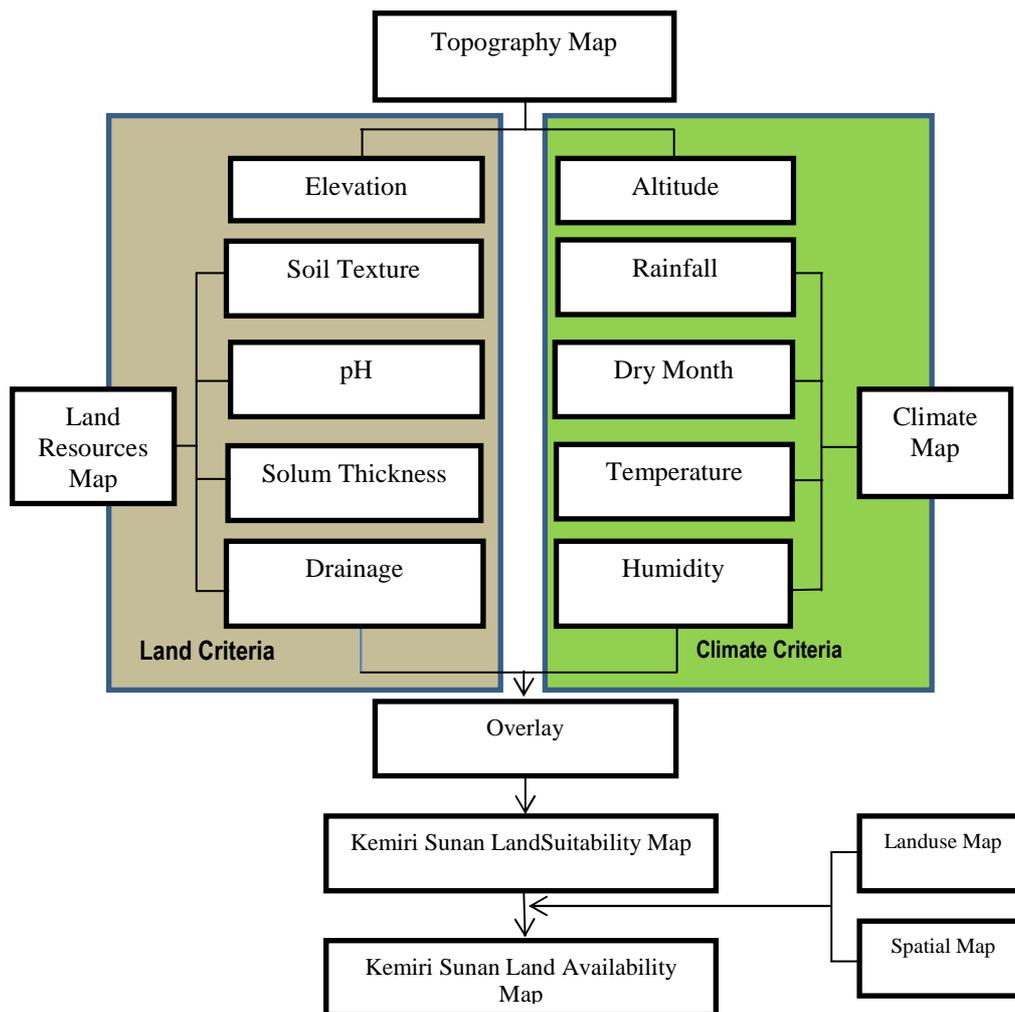


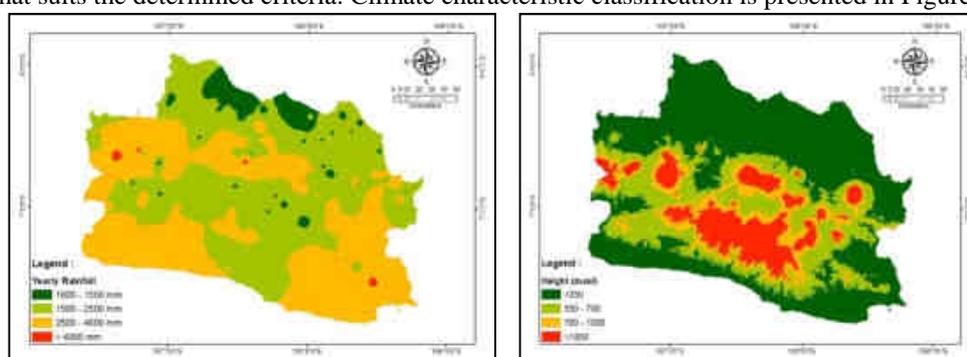
Figure 1. Steps for Kemiri Sunan Land Availability Analysis

## 4. Results and Discussion

### 4.1 Results

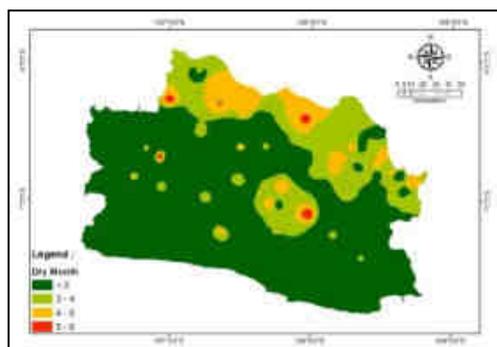
#### 4.1.1 Classification of land and climate characteristic

Classification of land and climate characteristic is needed to analyze land suitability, is depicted in 9 maps which are location altitude map, annual rainfall map, dry month map, air temperature map, air humidity map, slope map, soil texture map, pH map, solum thickness map and drainage map. Every map describing area condition spread that suits the determined criteria. Climate characteristic classification is presented in Figure 2.

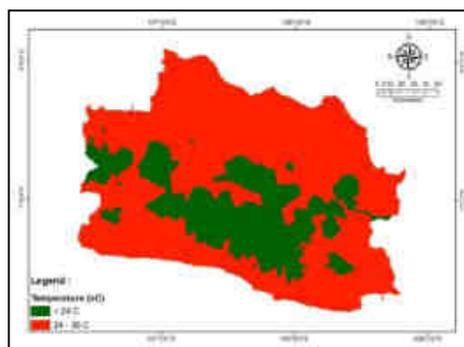


(a) Altitude (MASL)

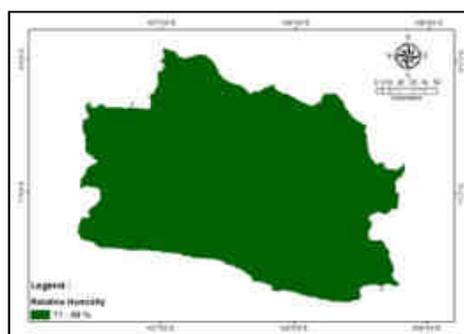
(b) Yearly Rainfall (mm)



(c) Number of dry month



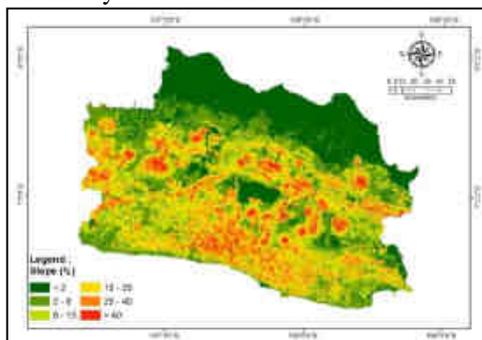
(d) Temperature ( $^{\circ}\text{C}$ )



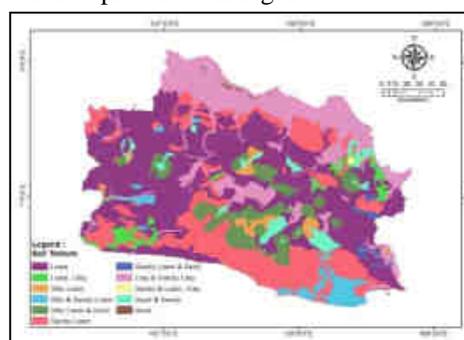
(e) Humidity (%)

Figure 2. Map Based on Climate Characteristic Classification

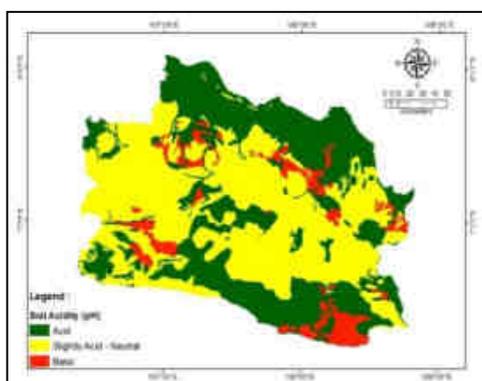
West Java Province is dominated by area with altitude  $< 350$  m asl, rainfall 1500-4000 mm and number of dry month  $< 3$ . The condition related to temperature in West Java Province which mostly at  $24-30^{\circ}\text{C}$  and air humidity 71-88%. Land characteristic classification is presented in Figure 3.



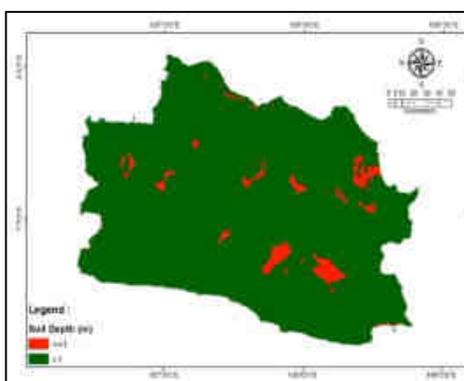
(a) Slope (%)



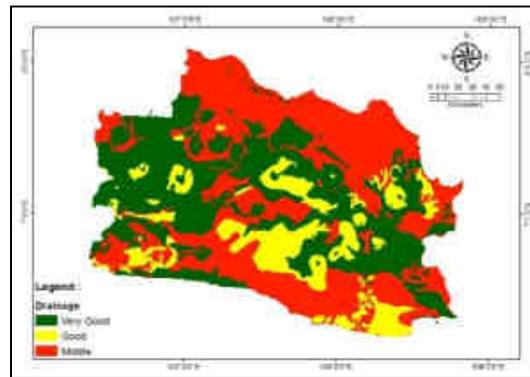
(b) Soil Texture



(c) pH



(d) Solum Thickness (m)



(e) Drainage

Figure 3. Map Based on Land Characteristic Classification

West Java Province is dominated by land with slope < 2%, pH slightly acid – neutral, and medium drainage. While solum thickness generally > 1 m with loam texture.

4.1.2 Land suitability class, area and spread of available land for planting kemiri sunan at West Java Province Based on overlay (weighted sum) and calculation by field calculator, resulted in the range of land suitability with 4 land suitability class as shown in Table 3.

Table 3. Kemiri sunan land suitability class

Suitability class	Range
Suitable (S1)	0.542-0.693
Moderately suitable (S2)	0.390-0.542
Marginally suitable (S3)	0.239-0.390
Not Suitable (N)	0-0.239

The map of land suitability for planting kemiri sunan is the result of overlay (weighted sum) of map of climate parameter and land parameter. Kemiri sunan land suitability map is shown in Figure 4.

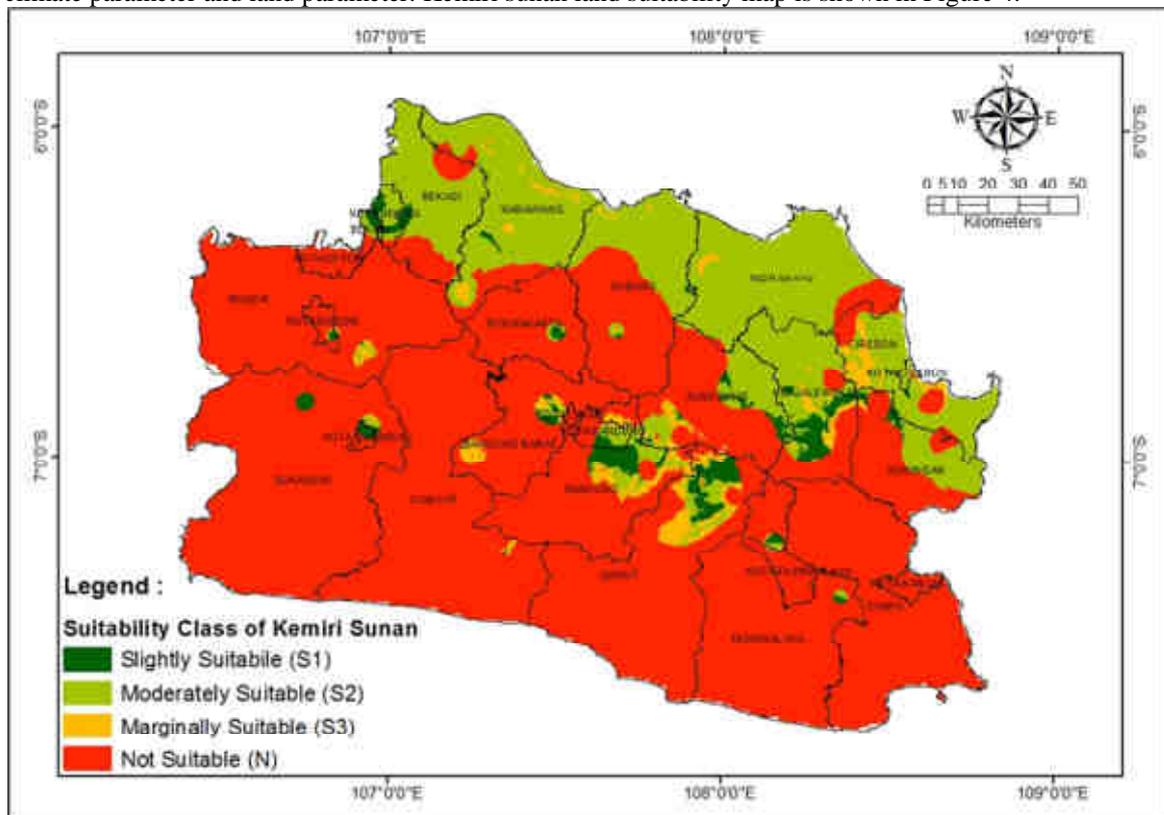


Figure 4. Kemiri Sunan Land Suitability Map in The Province of West Java

The suitable land for planting kemiri sunan is 981,067.20 Ha which consist of 86,855.70 Ha land of land suitability class in slightly suitable category, 799,947.58 Ha land of land suitability class in moderately suitable category, 94,263.92 Ha land in marginally suitable category. Spread of land area that are suitable for planting kemiri sunan in districts of West Java Province is shown in Table 4.

Table 4. Spread of available land for planting kemiri sunan at district on West Java Province

No	District	S1	S2	S3	Total area of suitable land
1	Bandung	13,912.12	14,090.26	15,481.49	43,483.87
2	Bandung Barat	2,779.34	2,571.05	8,267.02	13,617.41
3	Bekasi	4,009.13	95,103.82	-	99,112.95
4	Bogor	556.55	2,223.14	2,557.03	5,336.72
5	Cianjur	185.78	-	1,096.36	1,282.14
6	Cirebon	938.6	67,368.50	16,761.34	85,068.44
7	Garut	17,070.76	13,052.29	20,479.00	50,602.05
8	Indramayu	-	183,220.37	2,293.10	185,513.47
9	Karawang	1,386.11	155,223.78	7,683.52	164,293.41
10	Kota Bandung	2,676.02	4,915.27	1,220.89	8,812.18
11	Kota Bekasi	4,082.87	8,949.76	-	13,032.63
12	Kota Bogor	672.45	324.57	-	997.02
13	Kota Cimahi	-	137.9	9.3	147.20
14	Kota Cirebon	56.68	2,570.94	768.38	3,396.00
15	Kota Sukabumi	2,063.34	0.18	-	2,063.52
16	Kota Tasikmalaya	-	340.49	-	340.49
17	Kuningan	3,427.18	38,103.54	733.09	42,263.81
18	Majalengka	17,332.59	71,745.14	8,463.09	97,540.82
19	Purwakarta	1,640.93	1,838.41	-	3,479.34
20	Subang	743.88	91,306.81	1,460.98	93,511.67
21	Sukabumi	3,679.17	1,281.29	643.08	5,603.54
22	Sumedang	7,238.73	43,593.48	6,131.97	56,964.18
23	Tasikmalaya	2,403.47	1,986.59	214.28	4,604.34
	Total	86,855.70	799,947.58	94,263.92	981,067.20

#### 4.1.3 Area and spread of land available for planting kemiri sunan on West Java Province

Available land on West Java Province was attained by interpreting the integration result of map of available land for kemiri sunan with landuse map and west java spatial map. Map of available land for kemiri sunan is shown in Figure 5.

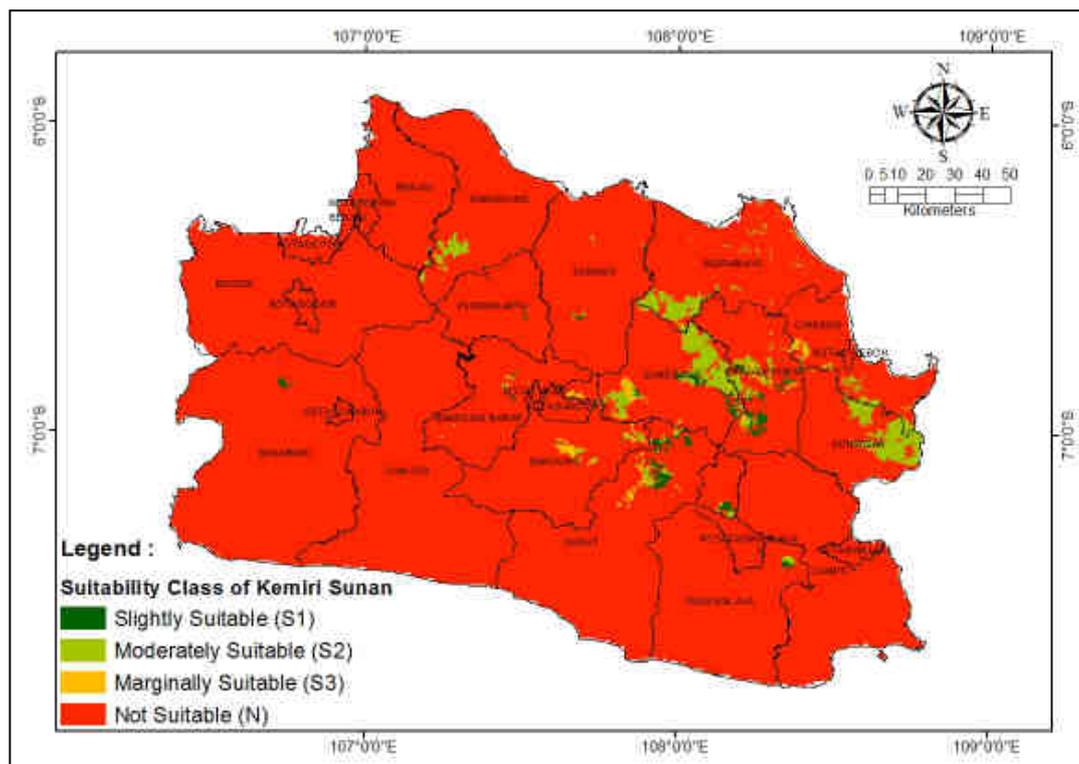


Figure 5. Kemiri Sunan Land Availability Map in The Province of West Java

Available land for planting kemiri sunan is 141,955.56 Ha which consist of 19,582.74 Ha of land with suitability class in suitable category, 103,974.62 Ha land in moderately suitable category, 18,398.20 Ha land in marginally suitable category. Spread of available land for planting kemiri sunan at districts on West Java Province is shown in Table 5.

Table 5. Spread of available land for planting kemiri sunan at districts on West Java Province

No	District	S1	S2	S3	Total area of available land
1	Bandung	128.3	2,354.51	5,234.35	7,717.16
2	Bandung Barat	471.37	113.98	841.63	1,426.98
3	Bekasi	0.01	431.82	-	431.83
4	Bogor	7.75	3.55	25.78	37.08
5	Cirebon	11.89	6,338.01	2,395.69	8,745.59
6	Garut	6,137.52	3,267.40	3,658.15	13,063.07
7	Indramayu	-	17,395.51	0.48	17,395.99
8	Karawang	3.56	6,757.66	1.63	6,762.85
9	Kota Bandung	0.17	11.72	216.39	228.28
10	Kota Tasikmalaya	-	45.58	-	45.58
11	Kuningan	232.17	24,954.23	-	25,186.40
12	Majalengka	5,352.03	10,182.77	2,379.10	17,913.90
13	Purwakarta	251.81	69.86	-	321.67
14	Subang	298.79	829.42	9.64	1,137.85
15	Sukabumi	908.55	3.23	21.94	933.72
16	Sumedang	3,771.48	29,668.69	3,399.14	36,839.31
17	Tasikmalaya	2,007.34	1,546.68	214.28	3,768.30
	Total	19,582.74	103,974.62	18,398.20	141,955.56

#### 4.2 Discussion

Based on priority/numerical weighing result, kemiri sunan land suitability is affected more by climatic condition than the land condition. Climatic condition is more naturally takes place and cannot be manipulated with human intervention. Climate factor numerical weight is given the highest value. This relevant to the characteristic of kemiri sunan that require sunlight intensity to form fats in its seeds. Rainfall is another factor affecting the

growth of kemiri sunan. Kemiri sunan grows well on rainfall 1500-2500 mm. Another climatic factors affecting based on numerical weight are in consecutive numbers of dry month, temperature, and humidity. While on land criteria, solum thickness has the greatest numerical weight. According to Supriadi *et al.*, (2009) kemiri sunan grows well in soil with thick solum to rather thick. Solum thickness or the effective depth of the soil affecting plant growth and rooting. Winarso (2005) stated that soil depth will affect plant growth in terms of media volume to fulfill the water needs, nutrients and rooting process. Akinci *et al.*, (2013) stated that soil depth is important factor that effecting soil hidrology character and behavior to resist erosion. In addition to solum thickness, soil pH is another influencing factor. Winarso (2005) defined pH as matter's relative acidity or basicity. Soil pH is a defining factor for microorganism activity and domination. Other influencing land factor based on numerical weight are in consecutive drainage, soil texture, and slope. Ismail *et al.*, (2012) using soil drainage factor to determine land suitability in various type of land use at Western Dessert, Egypt. One of the result is that soil drainage is the limiting factor for land use type of surface irrigation land. According to Curcio *et al.*, (2013) soil texture has its role in soil degradation process and water transportation also in control of soil quality and productivity.

Area of suitable land for planting kemiri sunan at West Java Province is 981,067.20 Ha or 25.7% of total West Java Province area. The suitable land are spread in 23 districts on West Java Province. Land utilization for planting kemiri sunan should pay attention to the West Java Province landuse and spatial planning. Land use planning is an important factor. Jie *et al.*, (2010) stated that land use planning has important role in resources distribution and land use organization.

Land use for forest is not led towards development of kemiri sunan due to its strategic function for West Java Province. Forest in West Java is included to conservation area to maintain the sustainability of environmental function, environment carrying capacity and to support sustainable development. Meanwhile plantation and paddy field are cultivation area to support economic growth and food needs. Plantation in West Java plays a big role in developing agricultural sector, both for government-owned large estate as well as private and people's estate. In year 2013 lahan paddy fields in West Java produced 60.78 kuintal/Ha rice and cultivated land produce 41.44 kuintal/Ha of rice. (BPS, 2014). Conservation area, conservation area for protected forest, urban, paddy field, and water body are spatial pattern that should remain for its important function to West Java Province particularly for agricultural sector and environmental sustainability, thus they were excluded from kemiri sunan land availability calculation. Land use that are potential for kemiri sunan planting are mixed farm, shrub, bared land, and dry land agriculture. For that consideration, the area that could be planted with Kemiri Sunan with regards to other land use and landuse planning is 141,955.56 Ha, in details suitable area is 19,582.74 Ha, moderately suitable 103,974.62 Ha, and marginally suitable 18,398.20 Ha. The area of available land is spread in 17 districts on West Java Province. Districts with significant area of available land consecutively are district of Sumedang, Kuningan, Majalengka, Indramayu, and Garut. Herman *et al.*, (2013) stated that Majalengka and Garut possessed yield block of kemiri sunan plant height. Kemiri sunan from Banyuresmi population at Garut and kemiri sunan from Jumat population at Majalengka has been established as prominent variety of kemiri sunan.

Land availability is determining factor in developing kemiri sunan for biodiesel. Research by Liu *et al.* (2011) stated that land availability is the strength factor in bioenergy production on marginal land. In comparison to West Java total area, 141,955.56 Ha is only 7.12% yet meaningful in regards to potensial biodiesel production from kemiri sunan which is approximately 487,2 millions of liters. Kemiri sunan development as biodiesel crop goes along to West Java Province characteristic which own numbers of land that are suitable for planting kemiri sunan and the high demand of biodiesel as solar (diesel) substitution alternative. Dusmanescu *et al.*, (2014) stated that renewable energy has certain characteristic, in which the implementation process is suited to the area character. The land availability calculation is presented in Table 6.

Table 6. Kemiri sunan land availability calculation

No	Class of land suitability	Area of suitable land		Area of land allocated for other landuse and landuse planning		The area of available land for kemiri sunan plantation	
				Area for other landuse *1)	Area of landuse planning *2)		
		Ha	%	Ha	Ha	Ha	%
1	Suitable (S1)	86,855.70	2.36	52,889.34	14,383.62	19,582.74	0.53
2	Moderately suitable (S2)	799,947.58	21.78	649,279.91	46,693.05	103,974.62	2.83
3	Marginally suitable (S3)	94,263.92	2.57	55,094.74	20,770.98	18,398.20	0.50
Total S		981,067.20	25.71	757,263.99	81,847.65	141,955.56	7.12
4	Not suitable (N)	2,691,512.75	73.29	757,263.99	81,847.65	1,852,401.11	92.88
Total S + N		3,672,579.95	100.00	1,514,527.98	163,695.30	1,994,356.67	100.00

\*1) Based on landuse map of West Java Province 2012

\*2) Based on RTRWP 2010-2030 map of West Java Province

#### 4. Conclusions and Recommendations

The area of suitable land for planting kemiri sunan is 981,067.20 Ha which consist of 86,855.70 Ha of land in slightly suitable category, 799,947.58 Ha of land in moderately suitable category, 94,263.92 Ha of land in marginally suitable category. The suitable land area is spread in 23 districts on West Java Province. While available potential land for planting kemiri sunan after deduction by area allocated for another use is 141,955.56 Ha which consist of 19,582.74 Ha of land in suitable category, 103,974.62 Ha land in moderately suitable category, and 18,398.20 Ha of land in marginally suitable category. Area of available land is spread in 17 districts on West Java Province. Kemiri sunan is recommended for development at West Java Province as an effort for providing alternative energy and environment rehabilitation.

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