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Suitability of Nutmeg Plant Habitats in Three Nutmeg Production Centers using the Geographic Information System and Aster DEM in West Java, Indonesia

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Abstract*: Nutmeg plant (Myristica sp.) produces seeds and mace as the main commodities of world spice trade. Nutmeg plant habitats in West Java are distributed mainly in Bogor, Sukabumi and Cianjur Regencies. This study aimed to determine the suitability of nutmeg habitats in three nutmeg production centers in West Java based on soil type and slope using the Geographic Information System (GIS) approach and Aster DEM (Digital Elevation Model) analysis. The study was conducted from August to December 2018, by collecting data of: a) The coordinates of the area planted with nutmeg using GPS (Global Positioning System), b) Field documentation in the form of descriptions around the data collection point, c) Soil analysis data, d) Land area data, e) Map of the earth scale of 1:50,000 scale from the Geospatial Information Agency, and f) Landsystem map of West Java scale of 1:250,000. Data were analyzed using Arc GIS 9.3. The results of land suitability analysis based on rainfall data for Bogor region was classified in the category of marginally suitable (S3), while the regions of Sukabumi and Cianjur were sufficiently suitable (S2). Temperature of Bogor region was categorized as the most suitable (S1), while Sukabumi and Cianjur regions were sufficiently suitable (S2) for nutmeg development. The distribution of nutmeg was in Latosol and Regosol soils, with soil pH of rather acidic (pH 4.78-5.98), clay texture, low to high C-organic content (1.5-4.5%) and moderate to high N-Total (0.2-0.5%). Cation exchange capacity ranged from 25-30 cmol(+)/kg with a base saturation level of around 55-60%. Based on slope, the distribution of nutmeg in the West Java region was in the range of slope with a flat (<8%) to sloping (8-15%) category, with altitudes between 400-900 m above sea level classified as suitable to very suitable for nutmeg development. The overall agroecological suitability of nutmeg plants in three nutmeg production centers in the West Java region was classified as suitable to be managed and developed.

***Keywords* : Aster DEM, Distribution, Geographic Information System, Land,Myristica sp.,**

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I. INTRODUCTION

Nutmeg (*Myristica fragrans* Houtt) is the main commodity in the world spice trade, as well as a superior export product of Indonesia compared to other spice commodities. Nutmeg plant is a plant belonging to the family Myristicaceae, one of the genera that is popular in Indonesia is *Myristica* or widely known as types of nutmeg. The distribution of nutmeg originates from the northern part of the Moluccas, especially Ambon and Banda so that Indonesia is named the center of origin and the center of genetic diversity of nutmeg [1 - 2]

The total area of Indonesia nutmeg plantations in 2017 reached 196,868 ha with a total production of 32,842 tons, around 99.69% cultivated by the public with production reaching 99.75% [3]. Nutmeg (*Myristica fragrans* Houtt) produces 2 main types of commercial herbs, i.e., nutmeg seed and mace. Nutmeg also produces bioactive compounds such as essential oils. Essential oil or nutmeg oil produced is widely used for health and as a flavor. Nutmeg oil is externally used in the health sector for rheumatism, analgesic and anti-inflammatory medicines [4]. Apart from being used for essential oils and flavors, nutmeg meat is also used as a raw material for the industry of sweets, syrups and jams. Therefore, Indonesia as the center of nutmeg origin needs to take a greater role in the management, development and utilization of nutmeg plants at the world level. West Java is one of the Indonesia national nutmeg production centers besides the Maluku Islands, Nangroe Aceh Darussalam, North Sulawesi, South Sulawesi and West Sumatra. Nutmeg plants spread to Java during the Marcopollo trip to China [5-6] . In 2017, the total area of nutmeg plants in West Java was recorded at 7,514 ha with production reaching 1,115 tons and average crop productivity of 148 kg/ha [3]. Even though nationally the area of nutmeg plantations in West Java is not the largest, West Java remains a national nutmeg center because the nutmeg processing industry is developing more rapidly than other regions [7]. This certainly in the development of nutmeg in West Java needs to be managed optimally to increase the production.

Bogor and Sukabumi Regencies are the main areas of nutmeg development in West Java Province. The total area of nutmeg plantations in Bogor Regency reaches 1,670 ha with production of 490 tons, while the total area of nutmeg plantations in Sukabumi Regency is 1,475 ha with production of 325 tons [3].

Besides Bogor and Sukabumi Regencies, Cianjur Regency is also a region of nutmeg plant development in the province of West Java. Although the total area of nutmeg in Cianjur is limited of 321 ha, the production is quite high at 82 tons [3]. This may be due to environmental factors that are suitable for the development of nutmeg plant habitat in the region [8]. The suitability of nutmeg habitats with its environmental factors will affect the growth and production of nutmeg plants. These factors can be in the form of biological, physical, environmental, or human factors. According to Nutmeg plants produce good products, the characteristics of land for growing environment (agroecology) must be suitable with the needs of nutmeg plants [9]. Planting sites can also affect the physical and chemical quality of nutmeg essential oils produced [10]. To date, studies on the distribution and suitability map of nutmeg plant habitats with environmental factors are still very limited, including studies of land suitability that are suitable for nutmeg habitats in the West Java region. Land suitability analysis is a study of an area, in this case the carrying capacity of land for nutmeg crop commodities. Appropriate land selection requires methods of evaluating land suitability that are more actual and more reliable. One method that can be used to obtain information on environmental factors that are suitable for a plant species can be performed through modeling based on Geographic Information System (GIS) [11]. GIS has the ability to connect various data at a certain point on the earth, combine them, analyze and map the results. The data to be processed in a GIS is spatial data that is geographically oriented data and is a location that has a specific coordinate system, so that the GIS application can answer several questions such as: locations, conditions, trends, patterns and modeling. Remote sensing with GIS has the ability to provide information more quickly, a wider range of study areas and relatively lower cost requirements. Landform attributes, such as slope, slope aspect, slope profile curvature, and contour curvature can be calculated from digital elevation model (DEM) [12]. This attribute is one of the key inputs for land surveys based on geographic information systems (GIS). Therefore, this study examined the suitability of nutmeg plant habitats by utilizing GIS and Aster DEM analysis. This study aimed to determine the suitability of nutmeg plant habitats in three nutmeg production centers in the West Java region based on soil type and slope through the Geographic Information System (GIS) approach and Aster DEM (Digital Elavation Model) analysis.

II. MATERIALS AND METHODS

Time and Location

The study was conducted from August to December 2018. The location of the study was in the area of West Java Province in three regions of nutmeg development centers. These areas were Tamansari Subdistrict, Bogor Regency, located at 6°38'38.2" South Latitude and 106°44'49.0 East longitude with an altitude of 519 m above sea level; Parakan Salak Subdistrict, Sukabumi Regency, located at 6°48'27.0" South Latitude and 106°43'52.2 East longitude with an altitude of 522 m above sea level; and the Warungkondang Subdistrict, Cianjur Regency, located at 6°50'41.6" South Latitude and 107°5'07.5" East longitude with an altitude of 538 m above sea level.

Equipment and Materials

The object of research was the area of nutmeg plantation planted by the public in three nutmeg production centers in the West Java region. Equipment and materials used in this research were compass, tallysheet, meter, Global Positioning System (GPS) receiver, digital camera, Arc GIS version 9.3.

Data collection and Analysis

The data used in this study consisted of two types, i.e., primary data and secondary data. Primary data is the main data taken directly in the field at the time of the study, while secondary data is a variety of data sets that have been available or have been reviewed previously. Primary data used in this study were: a) Data on the coordinates of the area planted with nutmeg, whether monoculture or mix culture; b) Documentation in the field in the form of descriptions around the point of data collection; c) Soil analysis data. Secondary data used in this study were: a) Data on the area of nutmeg plantations in West Java; b) Earth map with a scale of 1:50,000 from the Indonesia Geospatial Information Agency; c) The land system map of the West Java region with a scale of 1:250,000. Collection of field data (Ground Check) was performed to obtain information on data in the field and the coordinates were taken by purposive sampling method. The information was used to check the validity of the visual classification results which results can be used as an example area (training area) in the classification of digital images. The coordinates were taken at three research locations using a GPS (Global Positioning System) device. The data collected was then analyzed using Arc GIS 9.3, based on soil type and Aster DEM (Digital Elevation Model).

III. RESULTS AND DISCUSSIONS

Regional General Conditions

Geographically, Bogor Regency is one of the regencies in West Java Province. The area of Bogor Regency in the form of a land area is 2,663.81 km^2. Bogor Regency has various types of regional morphology, from a relatively low plain in the north to a plateau in the south with an altitude range of 15-2,500 m above sea level. Sukabumi Regency has a land area of 4,162 km^2 with an altitude of 0-2,960 m above sea level. Cianjur Regency has an area of 361,434.98 ha, located at an altitude of 7-2,962 m above sea level and has a slope of 0-40%.Based on data that the total area of nutmeg plants in West Java is the most widely distributed in Bogor and Sukabumi Regencies with an area of 1,696 ha and 1,476 ha, respectively (area range of 800-1696 ha) (3). Cianjur Regency region has an area of 320 ha of nutmeg plantation (area range of 247-321 ha). Map of the distribution of nutmeg in the three study locations is shown in Figure 1.

Fig. 1. Map of Nutmeg Plantation Area in West Java Province

Climate Characteristics of the Research Area

Based on data from the Meteorology, Climatology, and Geophysical Agency, Bogor Climatology Station (2019), the average amount of rainfall per year for the last 5 years (2014-2018) in Bogor, Sukabumi and Cianjur regencies ranged from 3,045-4,597 mm, 2380-4100 mm and 2764-4300 mm, respectively. During the research, the highest rainfall in Bogor region occurred in October 2018 with a total of 466 mm. In Sukabumi and Cianjur regions, the peak of rain occurred in November 2018 of 429 mm and 517 mm, respectively (Figure 2A).The highest number of rainy days for Bogor region began in October, while the other two regions occurred in November 2018 (Figure 2B). As rainfall increased, the humidity of an area is also increased. The highest humidity in the three regions of nutmeg development area also occurred in November 2018 (Figure 2C). Based on rainfall data, the land suitability class for Bogor region was classified as marginally suitable (S3), while Sukabumi and Cianjur regions were classified as sufficiently suitable (S2). High rainfall rates tend to increase weathering rates and clay formation and indirectly influences soil reactions (13). For plant growth, rainfall acts as a provider of plant water according to plant needs.

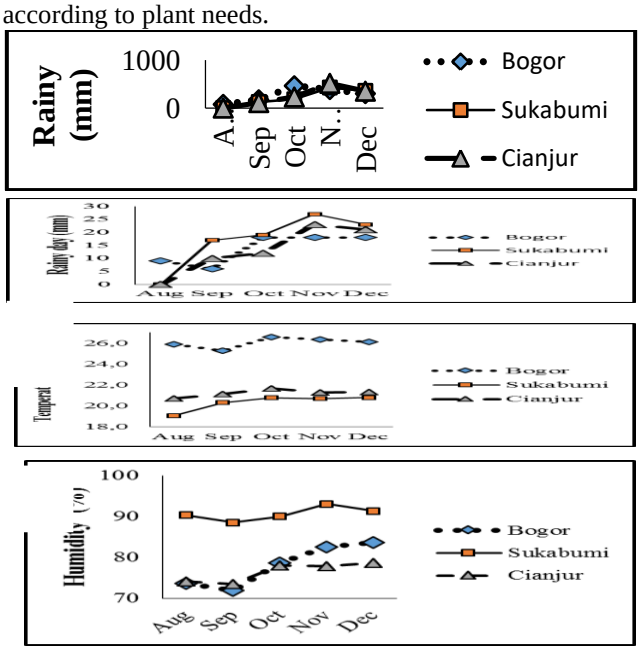

Fig. 2. Climatic conditions in three areas of nutmeg development centers: rainfall (A), rainy day (B), humidity (C) and air temperature (D).

Based on data on average monthly temperature for the three regions of nutmeg development centers, i.e., Bogor, Sukabumi and Cianjur, each ranged between 25-27°C, 19-21°C and 20-22°C, respectively. The highest temperature for Bogor, Sukabumi and Cianjur occurred in October 2018 were 26.6°C, 20.8°C and 21.7°C, respectively (Figure 2D). Based on land suitability class, the temperature in Bogor was categorized as the most suitable (S1), while Sukabumi and Cianjur regions were classified as sufficiently suitable (S2) for nutmeg development.

Temperature greatly influences the development of soil profile, and these factors determine the chemical and physical properties in the soil. High average temperatures tend to increase the rate of weathering and clay formation [13]. Surface temperature and vegetation have a very important role in analyzing the occurrence of drought. The relationship between surface temperature and drought cannot be separated from the evapotranspiration process which is an interaction between temperature, plants and soil [14]. The natural limiting factors of land suitability in an area are rainfall and temperature, in which areas with low rainfall and high temperature are the least suitable [15].

Nutmeg Plant Distribution Map Based on Soil Type

Soil type is one of the parameters used in research to determine the suitability of nutmeg plant habitats and is a consideration in its development planning activities. Land is classified into several types, each of which has different properties and characteristics and can be mapped on a soil type map. A soil type map is needed to determine the distribution of soil types in each research location so that the future development of nutmeg can be adjusted to the soil conditions.

Based on the mapping results of soil types in the three study sites, it was found that nutmeg plants cultivated in Tamansari Subdistrict, Bogor Regency were found in the Latosol and Regosol soil types. Nutmeg in Parakan Salak Subdistrict, Sukabumi Regency and Warungkondang Subdistrict, Cianjur Regency were also widely cultivated in Latosol soil type, as shown in Figure 3 to Figure 5.

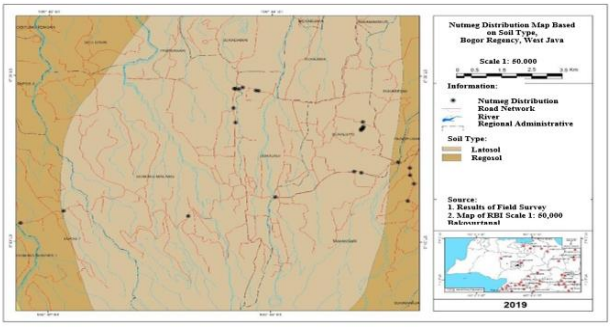

Fig. 3. Map of nutmeg distribution in Bogor Regency based on soil type

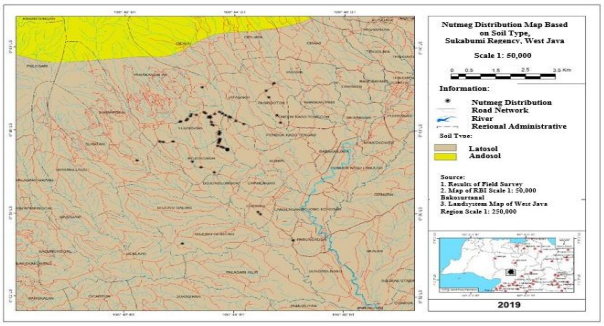

Fig. 4. Map of nutmeg distribution in Sukabumi Regency based on soil type

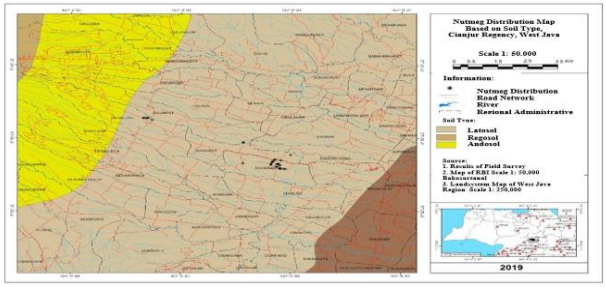

Fig.5. Map of nutmeg distribution in Cianjur Regency based on soil type

Latosol soil is included in the order of oxisol which is a soil that is rich in sesquioxide and has experienced further weathering, poor in chemical nutrients but has good chemical properties. Based on national land classifications, latosol soil is inceptisol soils. Other characteristics are type 1:1 clay minerals from the kaolinite and halloysite group, having low cation exchange capacity, low cation saturation (<35%) and low solute content due to weathering and leaching processes that have proceeded further and are quite sensitive to erosion. Latosol soil has a high clay content (> 60%), crumb to lumpy, loose and homogeneous color on the cross-section of the soil with a diffusion horizon limit, KB 50% or more (NH_4OAc), does not have a identifier horizon (except if buried> 50 cm of new material) besides the Mollic horizon A and the Cambic horizon B, show no symptoms of plintit in a depth of 125 cm from the surface, and do not have vertic properties.

Analysis of Soil Physical and Chemical Properties

Land is a three-dimensional system with properties and characteristics that reflect the influence of (1) climate, (2) vegetation, animals and humans, (3) topography, (4) soil parent material and (5) different time ranges. Land is a place where plants and animals grow. Laboratory analysis results of soil physical and chemical properties consisted of soil texture classes, electrical conductivity (EC), water content, pH H_2O, pH KCl, texture, available organic materials (C, N, P), Ca, K, Mg and Na exchange; Total Cation Exchange, Cation Exchange Capacity (CEC) and Base Saturation (BS) are presented in Table 1 and 2.

Table 1. Physical and chemical properties of the soil in the study locations

Location	pH 1:5		Texture (Pipette Method)			Soil texture class	EC*	Gravimetry
	H_2O	KCl	Sand	Dust	Clay			Water content
			(%)				µs/cm^2	(%)
TS-B	5.33	4.78	27.34	28.73	43.93	Clayey loam	48.00	9.78
PS-S	5.82	5.24	14.13	18.71	67.16	Clayey loam	78.00	9.34
WK-C	5.98	5.45	12.35	24.49	63.16	Clayey loam	82.00	8.86

Table 2. Chemical properties of the soil in the study locations

Location	C-org	N-Total	P	Ca	Mg	K	Na	Al	H
	(%)	(%)	(ppm)	(cmol$^{(+)}$/kg)				(cmol$^{(+)}$/kg)	
TS-B	4.55	0.35	2.63	11.33	2.24	0.62	0.08	0,11	0,1
PS-S	4.22	0.52	2.44	11.51	3.32	1.63	0.08	tr	0,11
WK-C	1.66	0.22	64.28	12.82	3.56	1.17	0.14	tr	0,11

The analysis of soil physical and chemical properties (Table 1) shows that the three locations of nutmeg development centers have a slightly acidic soil pH (pH 4.78 - 5.98). Obtained soil texture ratios of sand: dust: clay for each location were as follows: Tamansari Subdistrict, Bogor Regency (27.34: 28.73: 43.93), Parakan Salak Subdistrict, Sukabumi Regency (14.13: 18.71: 67.16) and Warungkondang Subdistrict, Cianjur Regency (12.35: 24.49: 63.16). Based on the growing environmental requirements, the location with a slightly acidic pH level and texture conditions of clay and sandy clay are still in the suitable category for the development of nutmeg plants [16].The results of the analysis of soil chemical properties (Table 2) show that the measured C-organic materials for Tamansari Subdistrict in Bogor Regency and Parakan Salak were in the range of 4.22-4.55%, while for Warungkondang Subdistrict it was 1.66%. The value of soil C-organic in the range of 4.22-4.55% is included in the high category, while the soil C-organic content of 1.66% is included in the low category (PPT 1983). The measured N-Total in the three study locations was in the range of 0.2-0.5%, meaning that it is in the moderate to high category. Cation exchange capacity in the three study sites ranged from 25-30 cmol (+)/kg with a base saturation level of around 55-60%, and this condition shows the CEC is in the high category (PPT 1983). The high CEC value is supported by the high availability of organic materials.Efforts to increase land suitability to a higher level on both sites can be done by rehabilitation of physical and chemical fertility, but relatively expensive costs are required. Fertility rehabilitation is carried out by applying soil and water conservation techniques (both mechanically and vegetatively), while chemically it is done by liming to reduce soil acidity, adding organic matter to increase nitrogen content or adding NPK fertilizer (17).

Nutmeg Plant Distribution Map Based on Slope

Slope is a rising or falling of a land and greatly affects the growth and productivity of vegetation. Slope is the ratio between the vertical distance and horizontal distance of a land. Slope or slope tilt map is a map showing the condition of slope level in a land. The flatter the slope of the land, the more fertile it will be. This can occur because the rate of washing soil nutrients on flat land is slower than other slope classes. The slowness of nutrient leaching allows the preservation of nutrient deposits in more quantities than locations with high steepness [18].

The slope classification is divided into 5 categories: flat (<8%), sloping (8-15%), rather steep (16-25%), steep (26-40%), and very steep (>40%). The class division refers to the division of classes by the Director General of Watershed and Social Forestry Management, No. P.4/v-set/2013 regarding Technical Guidelines for Critical Land Spatial Data Preparation.

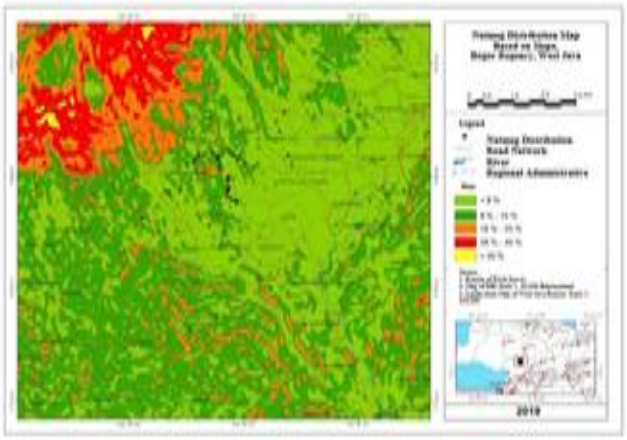

Fig. 6. Map of nutmeg distribution in Bogor Regency based on slope

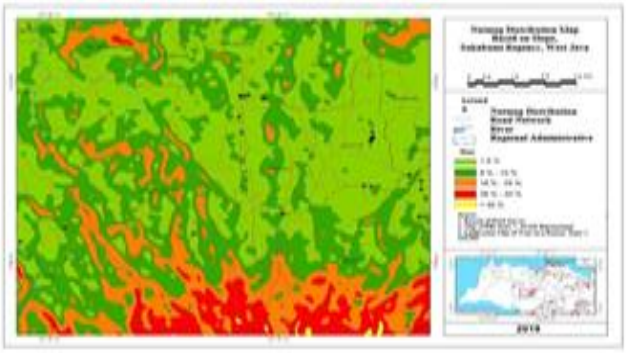

Fig. 7. Map of nutmeg distribution in Sukabumi Regency based on slope

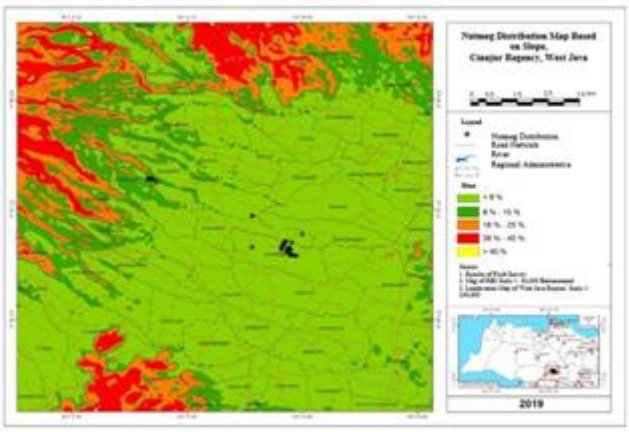

Fig. 8. Map of nutmeg distribution in Cianjur Regency based on slope

The results of the nutmeg habitat distribution analysis based on the slope are shown in Figure 5 to Figure 7. The results show that the distribution of nutmeg plants in three research locations, i.e., in Bogor, Sukabumi and Cianjur Regencies was in the range of slope with a flat (<8%) to sloping (8-15%) category. This shows suitable habitat for nutmeg plant distribution, which is on a flat to gentle slope level. The presence of a large number of nutmeg plants in flat and sloping land may also be influenced by the level of soil fertility. The flatter the slope of the land, the more fertile it will be. This can happen because the rate of washing soil nutrients on flat land is slower than other slope classes. The slow leaching of nutrients allows the preservation of nutrient deposits in greater quantities than locations with high steepness. Slope of land affects root cohesion on soil types and young vegetation of a plant (8).The results of determining the coordinate points conducted at three research locations using GPS (Global Positioning System) with a purposive sampling method showed that the distribution of nutmegs was in the altitude range between 400-900 m above sea level (asl). The site altitude variables for the distribution of nutmeg are divided into three categories of altitude classes, i.e., 0-700 m asl (very suitable location), 700-900 m asl (suitable location) and > 900 m asl (almost suitable location) (16). This condition indicates that the presence of nutmeg plants in the West Java region based on the location altitude variables was in the category of very suitable to suitable.

IV. CONCLUSION

The results of the land suitability analysis based on rainfall data for Bogor region was classified in the marginally suitable category (S3), while the Sukabumi and Cianjur regions were sufficiently suitable (S2). Temperature of Bogor region was categorized as the most suitable (S1), while Sukabumi and Cianjur regions were sufficiently suitable (S2) for nutmeg development. The distribution of nutmeg was in the Latosol and Regosol soils, with a rather acidic soil pH (pH 4.78-5.98), clay texture, low to high C-organic content (1.5-4.5%) and moderate to high N-Total (0.2-0.5%). Cation exchange capacity ranged from 25-30 cmol (+)/kg with a base saturation level of around 55-60%. Based on the slope, the distribution of nutmeg plants in the West Java region was in the range of slope with a flat (<8%) to sloping (8-15%) category, with location altitudes between 400-900 m asl classified as suitable to very suitable for nutmeg development. The overall agroecological suitability of nutmeg plants in three nutmeg production centers in the West Java region was classified as suitable to be managed and developed.

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