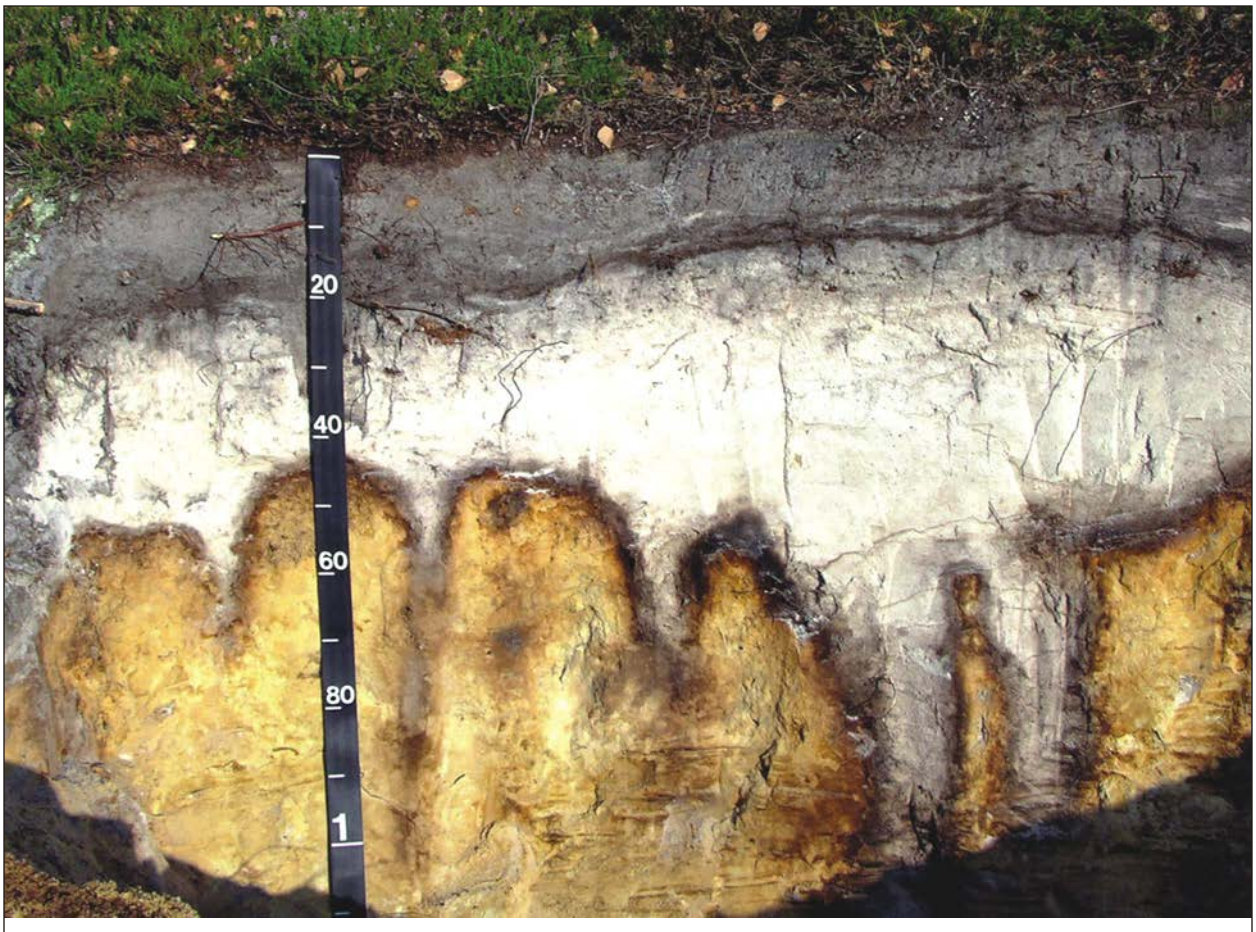

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Research Article
Land Suitability Evaluation For Nutmeg (*Myristica fragrans* Houtt) In Galela Region, North Halmahera Districts, North Maluku, Indonesia

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Abstract

Background and Objective: Galela area is a small part of the areas in the province of North Maluku. This area is gaining attention to developed plantation crops, one of the plantations commodities that is developed in this region is nutmeg. The selection of agricultural crops that will be developed should refers to the conditions of biophysic and crop growth requirements for the plant. This study aims to determine land suitability class for nutmeg plants in Galela area using two approaches methods and is associated with nutmeg productivity level. **Materials and Methods:** The research method is following on several stages i.e., land mapping unit (LMU), field survey, data collection, soil analysis, data compilation, interpretation and presentation of data. The determination of land suitability is determined by using the comparison method between the quality of the land on the condition of plant growth. The criteria was using two methods, namely simple limitation method (SLM) and sys criteria. **Results:** The result showed the actual land suitability for nutmeg using SLM system was obtained into two classes, S3 (marginally suitable) and N (unsuitable), whereas the potential land suitability was obtained into three classes i.e., S2 (moderately suitable), S3 and N. In contrast, there were two classes for the actual and potential land suitability according to sys criteria, S2 and S3. Limiting factors in the cultivation of nutmeg plants include rooting media (soil depth), nutrient retention, nutrient availability, erosion hazard, drainage, sodicity and water availability. Any type of improvement that can still be done consist of providing organic materials and fertilization. **Conclusion:** The land suitability using of sys criteria system was more appropriate in determining land suitability class for crop nutmeg in Galela region. This condition can be seen from the fact in the field at the time of the survey and collection of field data that the marginal land that evaluated using SLM system and their result are unsuitable, however, nutmeg can still grow well. The supply of volcanic ash material from Mt. Dokuno positively affect the growth of nutmeg.

Key words: Simple limitation method (SLM), sys criteria, nutrient availability, erosion, volcanic ash

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The nutmeg (*Myristica fragrans* Houtt) is native plant from Indonesia and originated in Banda and Maluku[1-3] and has been known as a spice plant since the 18th century. The center of nutmeg production in Indonesia is located in Maluku Island, North Sulawesi and Aceh[2]. Up until now, Indonesia is the world's largest nutmeg producer (70-75%), besides other producer countries which are Grenade, India, Sri Lanka and Malaysia[4]. In 2014, Indonesia is the world's second largest of nutmeg exporter after Guatemala with export destination to Vietnam, Netherlands, The United States, Germany, India, Italy and Japan. Indonesia is able to meet the world nutmeg demands of 18.8% of total value of nutmeg world export[5].

North Halmahera Regency is one of the regencies in North Maluku province. This area is gaining attention to developed plantation crops with a development pattern focused on the people's core plantations[6]. Of a number of plantation commodities cultivated by farmers in North Halmahera district, nutmeg is one of the plantation commodities that is quite a lot of cultivated. In overall nutmeg plant occupies the third position after coconut and clove plants[7]. Galela is a small part of the region in North Halmahera district, this region also received attention for the development of nutmeg. As seen from the data of the total area and production of nutmeg in Galela districts, total area of North Galela district is 206 ha with production of 35.4 t (0.17 t ha^{-1}), West Galela district 2656 ha with production of 805.5 t (0.30 t ha^{-1}), Galela district 464 ha with production of 101.4 t (0.22 t ha^{-1}) and South Galela district 271.2 ha with production of 141 t (0.52 t ha^{-1})[8]. If those are compared with data on province level, Galela area is highly potent to develop and yield nutmeg at large scale. The data of North Maluku province has an area of 38509 ha for nutmeg with an average production of 6693 t (0.17 t ha^{-1})[9]. However, at provincial production level, it is higher than national production level which only reached 0.14 t ha^{-1} [10]. This condition describes that North Maluku remains superior in producing nutmeg.

The selection of agricultural crops that will be developed should refers to the conditions of biophysic and crop growth requirements for the plant. The determination of land suitability level for agricultural crops aims to make crops can be cultivated in certain areas that suitable with their environmental conditions, so that it can assist the farmers in selecting of commodities properly on each unit of land. Land evaluation is a process of predicting land performance over time according to the specific types of use both for agriculture and non-agriculture[11-15]. The principle purpose of agricultural land suitability evaluation is to predict the potential and limitation of the land for crop production[16,17]. Agricultural land suitability assessment is defined as the process of assessment of land performance when used for alternative kinds of agriculture[15,18-20]. The concept of sustainable agriculture can be defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs[21,22]. Continuous utilization of agricultural land in past decades, regardless of land suitability has caused much more destruction than provide the resources[23-25]. Hence, proper evaluation based on agricultural land use planning is essential to solve this problem.

Land evaluation is an approach or a way to assess the potential of land resources[26]. The land suitability evaluation for agriculture and forestry commonly used in various countries, basically refers to the classification of USDA land capability or land suitability classification developed by FAO[23]. In Indonesia and other developing countries, are generally more likely to use the system to FAO[23] because it is more detailed and complete[26]. In this FAO system, important terms related to land suitability evaluation, such as: land use type, land characteristics, actual land suitability, potential land suitability and so on. The FAO[23] framework by creating a land suitability table based on land characteristics or land quality. Land suitability assessment was carried at sub-class levels based on land suitability classification structure[17,25,26], namely: S1 (very suitable), S2 (moderately suitable), S3 (marginally suitable) and N (unsuitable).

Several land evaluation assessments have been developed using various approaches, including parameters multiplication system, addition and matching system or matching the quality and land characteristics to the land suitability criteria compiled based on the growing requirements of agricultural crops based land[27]. Land suitability criteria methods simple limitation methods (SLM)[28] and sys criteria[29], are two methods that are widely used for predicting local crop yields has been used to assess the land suitability for a variety of crops[30]. The SLM methods and sys criteria refer to FAO[23] framework.

The SLM[28] methods, the approach method is very simple after the matching between, by creating a land suitability table based on land characteristics or land quality, the final determinant of land suitability of this method is the worst value of the heaviest limiting factor of all land suitability classes although only one parameter. Examples of matching results obtained S1 = 1, S2 = 2 and S3 = 1, then the land suitability class is S3.

Sys criteria[29], the approach method is very simple after the matching between, by creating a land suitability table based on land characteristics or land quality

Table 1: Assessment of land suitability classification according to simple limitation method[28] and sys criteria[29]

Suitability class	Simple limitation method[28]	Sys criteria[29]
S1 (Very suitable)	A little barrier to their use	Land without limiting factor, or just have $\leq$ 4 S2
S2 (Moderately suitable)	Delimiter was to use	Land with more than 4 S2, or $\leq$ 3 S3
S3 (Marginally suitable)	Delimiter is rather heavy for its use	Land with more than 3 S3, or $\leq$ 3 N
N (Unsuitable)	Delimiter is very heavy for its use	Land with more than 3 N

but the determination of land suitability by calculating all the contributions of land characteristics, then scoring the class, the sum of the results of the score is expected to be obtained an objective evaluation of all the observable soil parameters in the field. Examples of matching results obtained S1 = 1, S2 = 2 and S3 = 1, based on the sys criteria scores (Table 1), then the land suitability class is included in the S1 class because it has $\leq$ 4 S2.

The SLM method and sys criteria, the approach method is very simple, easy to understand and has a graphical presentation, the system framework is also very complete and detailed so that it can be used for physical (qualitative) and economic (quantitative) land evaluation when necessary data are available[26]. However, these two methods also have difficulties, i.e data of land characteristics that can not be observed directly in the field, such as data about soil chemical properties, etc., so that indirect land suitability can be specified in the field. Elsheikh *et al.*[15] adds, another shortcoming of these methods in terms of not being able to explain the interaction between land characteristics.

The research related to land evaluation and nutmeg has been done by previous researchers[1,3,16,22,31-36] but still less even specifically for the Galela region. This study aims to determine land suitability class for nutmeg plants in Galela area using two approaches methods and is associated with nutmeg productivity level.

MATERIALS AND METHODS

Study area: The research was conducted from February, 2015 through February, 2016 in Galela region, North Halmahera district and Laboratory department of land of Agriculture Faculty, Gadjah Mada University. Galela region, which administratively covers 4 sub districts i.e., Galela district, North Galela district, South Galela district and West Galela district (Fig. 1). Geographically, situated between N 01°14′20"-02°11'58" and E 127°43'24"-128°4'05", with total area of 63479 ha. The soil type sites were classified into six orders, namely Andisol, Mollisol, Inceptisol, Entisol, Alfisol and Ultisol[37] that developed under rainfall condition 2217.1 mm/year with an average air temperature of 26.1°C and agroclimate zone B (Q = 0.2065) reflecting wet condition with Udic soil moisture regime.

Topographic conditions in Galela region is vary starting from flat to very steep. The result of interpretation for earth surface map with scale of 1: 50000 in 2008, showed the widest slope in Galela is rather steep to very steep which is 33341.7 ha (51%). Geologically in Galela region is part of the Western arm of Halmahera island which is a series of volcanic mountains mixed with sedimentary rock. Based on the interpretation of geological map for Morotai Sheet of North Maluku with the scale of 1: 250000 in 1980 and field survey results at study site, it indicates that there are seven geological formations in the Galela region. The seven geological formations include Aluvium (Qa), Holocene volcano rock (Qha), Tufa (Qht), Coral limestone (Ql), Togawa Formation (Qpt), Vedic Formation (Tmpw) and Bacan Formation (Tomb).

Research methods: The research method is following on several stages.

Land mapping unit (LMU): LMU was obtained by overlapping geological map, land use map and slope map. The result of overlay then produce 17 LMU that cover the whole areas of study areas, respectively invloving 4 LMU's for North Galela district, 5 LMU's for West Galela district, 5 LMU's for Galela district and 3 LMU's for South Galela district.

Field survey and data collection: This stage was done through field survey on land units that have been represented in form spatial with scale of 1:50000. The main survey activities at the research site are by using transect system in all research areas determined based on LMU map and making volved, making minipit or boring for 104 points. The soil samples of boring results were then analyzed in the field by using a rapid analysis of soil characteristics[38]. After uniformity has been obtained, the process of delineation was conducted to determine 17 soil representative profiles. Selected soil samples were then analyzed for both physical and chemical properties in the laboratory. For climate data, data were collected from local climate stations for the last over 10 years involving rainfall (mm), air temperature (°C) and humidity (%).

Soil analysis: Soil samples were analyzed in the Laboratory of Soil Department of Faculty, Agriculture Gadjah Mada University involving physical and chemical soil properties. The

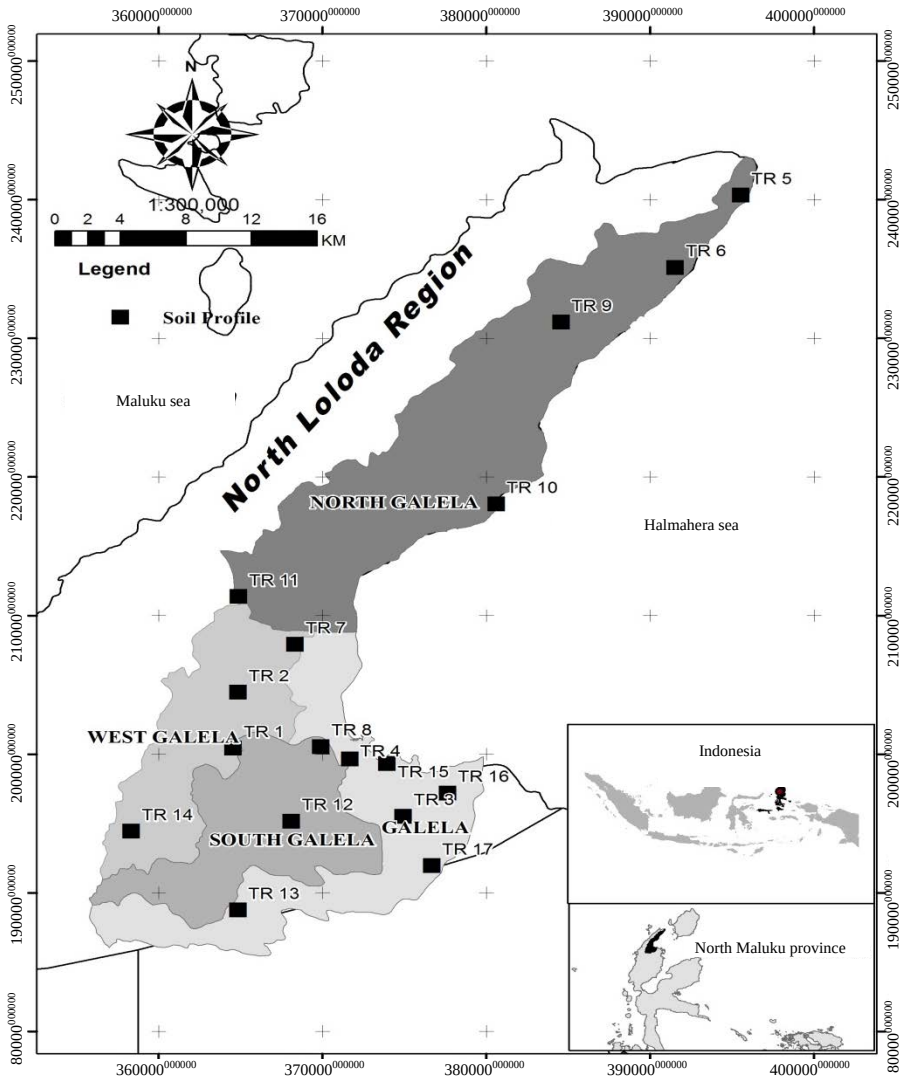

Fig. 1: Location map of the study area

physical properties that were analyzed include texture using pipet method, bulk density (BD) using ring method, particle density (PD) using Pycnometer Pyrex 50 mL[39,40] and porosity using formula of:

$$^{41}\text{Porosity (\%)} = \frac{1 - BD}{PD} \times 100$$

The chemical properties analyzed, including pH H_2O, pH KCl and pH NaF using pH meter (1:2.5)[40], electrical conductivity with EC meter (1:5)[40], C-Organic using Walkley and Black Methods[40], N-total using method Kjeldahl[40], P-available using Olsen Method[40] available through ammonium acetate extract 1 M pH 7[40], cation exchange capacity (CEC) through ammonium acetate extract 1 M pH 7[40], Exchangeable base cation (Ca^{2+}, Mg^{2+}, K^+, Na^+) through ammonium acetate extract 1 M pH 7, in which Ca^{2+} and Mg^{2+} were measured using AAS while for K^+ and Na^+ were measured using Flamefotometer FP 902[40], base saturation and sodium saturation percentage (ESP) using the formula:

$$^{41}\text{Base saturation (\%)} = \frac{\text{Total base cation}}{CEC} \times 100$$

$$^{42}\text{Na saturation (ESP) (\%)} = \frac{\text{Na cation}}{CEC} \times 100$$

Data compilation: The soil data result from laboratory analysis were then completed with subsequent climatic data and then processed using weighted average and arithmetic average[43,44]. The rating of average value as a result of soil chemical properties is based on the criteria of rating for soil chemical

properties according to criteria from Indonesia soil research institute (ISRI)[40], while the physical properties were evaluated based on the guidance of soil physical analysis by Kertonegoro *et al.*[39].

Interpretation and presentation of data: The determination of the actual suitability of each unit of the land in this study was determined using a matching method between the quality of the land on the condition of plant growth without any improvement on the limiting factor. Land suitability criteria use two methods, simple limitation method (SLM)[28] and sys criteria[29]. The different evaluation of these two systems are listed in Table 1.

Potential land suitability is determined by considering the inputs and management actions given to each unit of the land, after any efforts are made to overcome the limiting factors and then the evaluation is conducted referring to crop growth requirements.

RESULTS AND DISCUSSION

Land suitability for nutmeg according to simple limitation method (SLM) and sys criteria: The Food and Agricultural Organization (FAO) proposes an approach for land suitability evaluation in terms of suitability ratings from highly suitable to not suitable based on land characteristics[23,45]. Based on field observation that supported by laboratory analysis data, the matching process between land characteristics and crop growth requirements, land suitability evaluation using two methods indicate that there are variations of land suitability for nutmeg.

Table 2 showed that result of actual land suitability evaluation using SLM consists of 2 classes, namely N (unsuitable) and S3 (marginally suitable). According to sys criteria system, all of the land can be cultivated with nutmeg but with different classes, namely, class S3 and class S2 (moderately suitable). Based on the result of evaluation using these two methods, there are some limiting factors for nutmeg cultivation in Galela region, North Halmahera district, such as rooting media(soil depth) (rc), nutrient retention (nr), nutrient availability (na), erosion hazard (eh), drainage (oa), sodicity (xn) and water availability (wa). The results of Wakiah *et al.*[36], land suitability class for nutmeg plant in Bacan island of South Halmahera Regency is included in the appropriate class (S2) with relative humidity limiting factor. Akinci *et al.*[22], stated to assess the suitability of a given piece of land for agricultural production, many criteria need to be considered together.

Table 3 is of potential land suitability classes. Potential land suitability indicates conformity to land use determined from the unit of land in the circumstances to be achieved, after certain necessary improvement efforts are made to its limiting factors[46]. The type of improvement that will be done tailored to the level of management to be applied.

Table 2: Actual land suitabiliy classes for nutmeg in Galela district, North Halmahera, North Maluku

	Actual land suitability						
	Simple limitation method				Sys criteria		
		Large				Large	
LMU	Class	Ha	(%)	LMU	Class	Ha	(%)
TR5, TR2, TR15	Nrc	12046	19	TR5, TR2			
TR15	S3rc	12046	19				
TR11, TR16	Neh	20393	32	TR11,TR16	S3eh	20393	32
TR14, TR4, TR3	Nxn	3141	5	TR14,TR4, TR3	S3xn	3141	5
				TR7	S3oanaxn	4707	7
Sub Total		35580	56	Sub Total		47550	74
TR7	S3oanaxn	4707	7	TR1, TR8	S2naxn	4831	8
TR1, TR8	S3naxn	4831	8	TR9, TR10	S2 nrna	2363	4
TR9, TR10	S3nrna	2363	4	TR6, TR17, TR12, TR13	S2naeh	15998	25
TR6, TR17							
TR12, TR13	S3naeh	15998	25				
Sub Total		27899	44	Sub Total		23192	37
Total		63479	100	Total		63479	100

Note: LMU = Land mapping unit . The land suitability class written in numbers format is the sum of value, while the capital letters followed by the numbers and lower case indicate the level and limiting factors of the land suitability class. N = unsuitable, S3 = marginally suitable, S2 = moderately suitable, rc = the limiting factor of rooting media, eh = the limiting factor of erosion hazard, xn = the limiting factor of sodicity, oa = the limiting factor of oxygen availability, na = the limiting factor of nutrients available, nr = the limiting factor of nutrient retention

Table 3: Potential land suitability for nutmeg in Galela region, North Halmahera districts, North Maluku

	Potential land suitability		Large	
LMU	Simple limitation method	Sys criteria	Ha	(%)
TR5, TR2, TR15	Nrc	S3rc	12046	19
TR11, TR16	Neh	S3eh	20393	32
TR14, TR4, TR3	Nxn	S3xn	3141	5
Sub Total			35580	56
TR6, TR17	S3eh	S2eh	7019	11
TR7	S3oaxn	S2oaxn	4707	7
TR1, TR8, TR13	S3xn	S2xn	11423	18
TR9, TR10, TR12	S2warcnrnaeh	S2warcnrnaeh	4750	8
Sub Total			27899	44
Total			63479	100

Note: LMU = Land Mapping Unit . Land suitability classes according to number of limitation, while uppercase followed by number and lowercase defined intensity and type of limitations. N = unsuitable, S3 = marginally suitable, S2 = moderately suitable, rc = the limiting factor of rooting media, eh = the limiting factor of erosion hazard, xn = the limiting factor of sodicity, oa = the limiting factor of oxygen availability, wa = the limiting factor of water availability, nr = the limiting factor of nutrient retention

The soil solum indicates the depth of plant roots can reach and use the water as well as available nutrients[17,22]. The soil solum also provides an overview about weathering level of the advanced parent material of the soil. The soil that has a deep solum provides an advanced level of weathering of the parent material. Soil depth variation linked to soil formation processes such as chemical weathering of the parent rock, loss of material formed through weathering and transportation and deposition by soil by erosion[47]. Based on field observations, in the study site area, it has different depths. Soil depth could be considered as limiting factor for nutmeg growth associated with root penetration. The limiting factor of soil depth found in this areas is the existence of shallow rooting condition at the depth of $\geq$ 20 cm, in the form of a coral reef gravel layer, such as on LMU TR5. In addition to shallow solum, the soil also has sufficient attachment at top soil layers. In facts, in the field, there is no nutmeg plants surrounding this kind of soils. In LMU TR2, layer of pad was found but this layer can still be improved by dismantling during soil tillage process so that nutmeg plants can still grow. However, at the scale of the people's plantation, the recommendation of improvement by dismantling is very costly and it also spend high enough energy and farmers cannot do it because it is constrained by the cost. Similarly on SPT TR 15, as a stone quarry area, this area also has a layer containing rockhard. As a results, actual and potential land suitability evaluation using SLM or system determine the lands on TR5, TR2 and TR15 is classified into sub class N, while the evaluation using sys criteria system includes class S3.

Approximately 20393 ha (32%) of the study area has slope 50-70%, at TR11 and TR16 (Table 3). The land use in TR11 is used as a forest land with forest vegetation such as sugar palm and Tagalolo, whereas at TR16, although with a fairly sloping lands, local farmers still use the lands for mixed garden. The existence of a volcano that is Mt. Dokuno, it produces volcanic material that is quite fertile, so that although with a fairly sloping lands, nutmeg plants can still grow in this area. The high level of slope will also affect the depth of soil, where soils with high slope levels will have a low soil depth[22].

The high intensity of rainfall on the lands with fairly slope to steep slope can cause quite high erosion[17,48]. Erosion reduces the soil depth that is necessary for the development of plant roots and the amount of water that the plants need, decreases the content of nutritional elements and organic matter and consequently leads to the formation of soil that is unsuitable for cultivation[49]. Any efforts to reduce the rate of erosion can indeed be done by making the terrace system, planting contour parallel or planting cover crops but with a slope of more than 30%, management to overcome this limiting factor require a fairly high cost. The result of actual and potential land suitability evaluation using SLM system showed that the lands at TR11 and TR16 were classified into sub class N, while the assessment using sys criteria system includes class S3.

The growth of nutmeg requires soil conditions that is loose, fertile and very suitable in volcanic soils with well drainage[50]. Well drainage condition or poor drainage is limiting factor for nutmeg farming, so that an effort to improve drainage system is required with level of medium-high management. In the area of study, the drainage problems is found in TR7. The limiting factors found in TR7 involve nutrient availability (na), drainage (oxygen availability) (oa) and sodicity alkalinity (ESP) (xn). The existence of gley impact at a depth of $\pm$25 cm due to the inundation. The result of actual and potential land suitability evaluation using SLM system showed that the land on TR7 is classified into sub class S3, whereas based on sys criteria result in subclass S3 for actual land suitability but it is sub class S2 for potential land suitability.

The limiting factors of nutrient retention and nutrient availability, for long-term use can still be improved through organic matter application and fertilization. The management level is still low, it means that the management can still be carried out by farmers with relatively low cost. Several improvements to overcome nutrient retention (nr) and nutrient availability (na) include application of organic fertilizer and chemical fertilizer. The use of both types of fertilizers together to the sandy soil or eroded soil may inhibit leaching by rainwater and also the erosion. The result of evaluation for actual land suitability using SLM showed that the land with limiting factor of nutrient retention and nutrient availability is classified into subclass S3, whereas the assessment with sys criteria system includes S2 and S3. The results of the potential land suitability assessment evaluation with the SLM system are included in the S2 subclass, while the use of sys criteria system classified it into class S2 and S3. Map of the actual land suitability class and of the potential land suitability class for each method presented in Fig. 2-5.

Relationship between land suitability and nutmeg productivity: The calculation result of actual land suitability map for each sub-district is presented in Table 4, it showed that the using of SLM system for actual land suitability class S3, the highest percentage obtained at South Galela district (44%), followed by North Galela district (37%), Galela district (28%) and West Galela district (16%).

Whereas with sys criteria on the actual land suitability class S3, the highest percentage was found in South Galela district (94%), followed by West Galela district (92%), Galela district (83%) and North Galela district (74%) and for class S2, the highest percentage include North Galela district (26%), followed by Galela district (17%), West Galela district (8%) and South Galela district (6%).

It can be seen that there is a correlation between land suitability class obtained from this research with the wide of area, production area and productivity. In reality, for North Galela district although actual land suitability criteria according to sys criteria system has the highest percentage for class S2 (26%) but it has low production compared to the

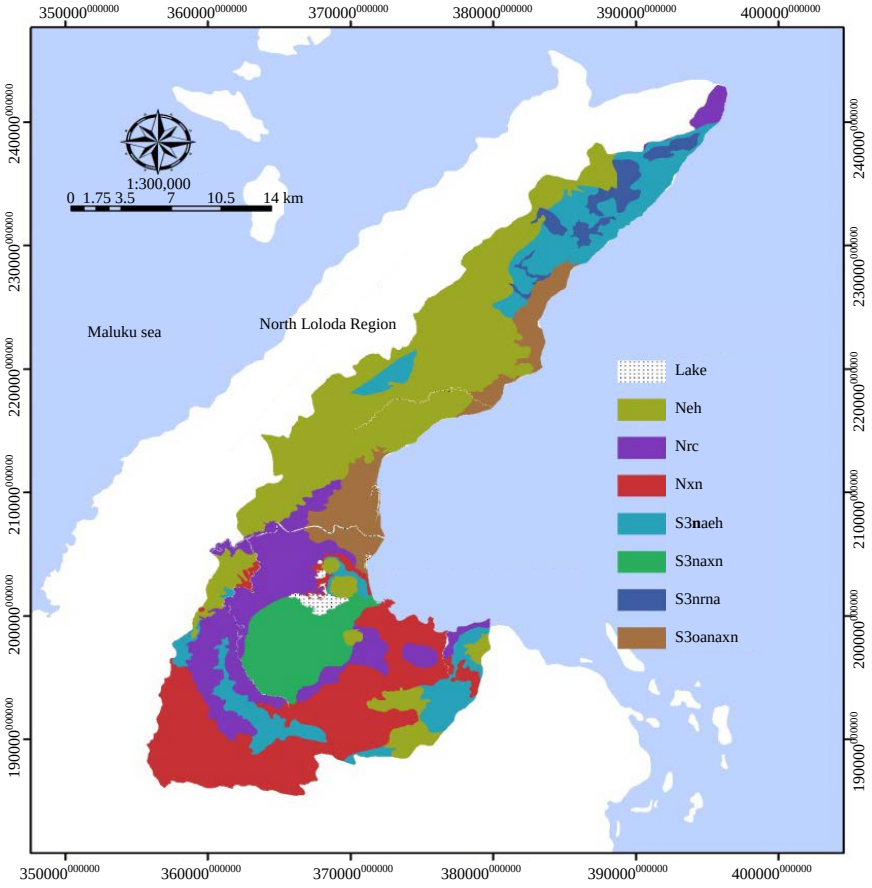

Fig. 2: Actual land suitability map for nutmeg according to simple limitation method in Galela region, North Halmahera districts, North Maluku

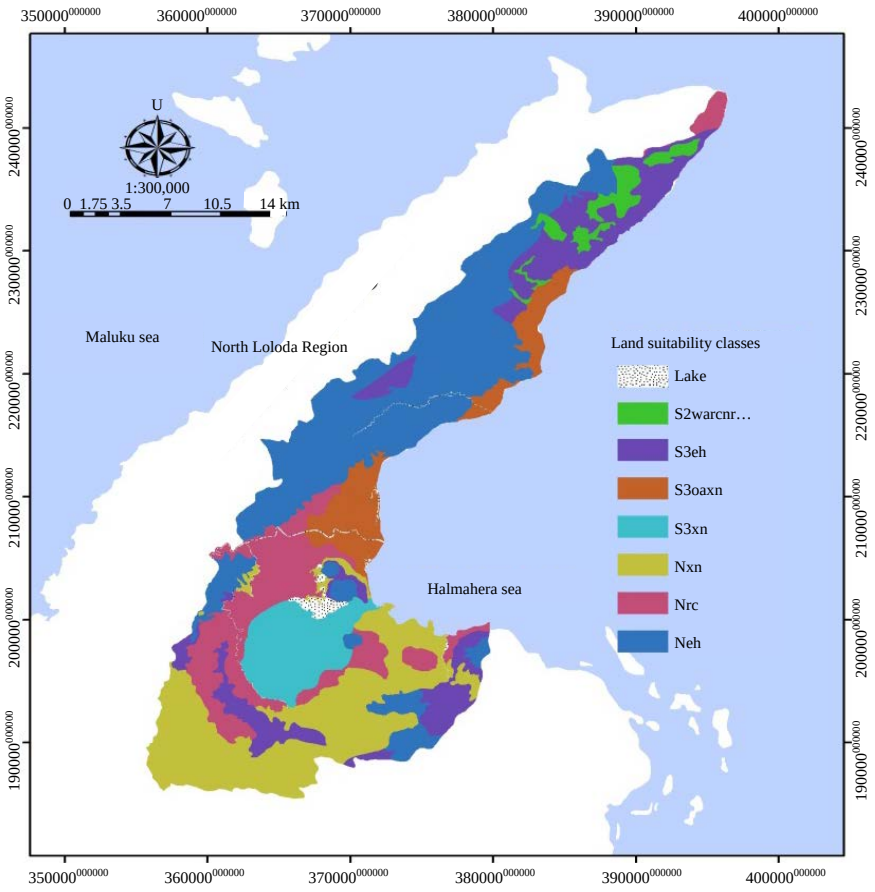

Fig. 3: Potential land suitability map for nutmeg according to simple limitation method in Galela region, North Halmahera districts, North Maluku

other three districts in production which is only 0.17 t ha^{-1}. The low production of nutmeg in this area is due to competition between plants, especially competition with coconut plants. The results of Patty and Kastanja[7] showed that most farmers in West Galela area (65.5%) cultivated nutmeg plants as intercrops among coconut plants that have been cultivated previously. This situation is similar to that occurring in North Galela district, the results of this study it appears that the nutmeg crop in the district of North Galela more planted on the S3 class, whereas in class S2 which has the largest area, it planted mostly with coconut plants. In addition, the North Galela district areas is mainly dominated by coral reef and away from volcanoes, so that no nutrient-rich volcanic material required for nutmeg, it is the results in low nutmeg production. In contrast, for the other three sub-districts, the production is still quite high, the highest production achieved in South Galela district 0.52 t ha^{-1}, followed by West Galela district 0.30 t ha^{-1} and Galela district 0.21 t ha^{-1} (Table 5). The high production of nutmeg in these three regions because the soil is quite fertile. The existence of material in the form of volcanic ash came from Mt. Dokuno volcano is able to fertilize the surrounding soil, even though the class S2 is lower than the North Galela district area, mostly nutmeg was planted in this class S2 so the production is quite high. Volcanic ash is a material of falling volcanic material that is ejected into the air at the time of the eruption. According to Wahyuni *et al.*[51], volcanic ash contains various major elements (Al, Si, Ca and Fe) and minor (Na, K, Mg, Mn, P, S and Ti). These minerals have the potential to increase the mineral reserves of the soil, enrich the chemical structure and improve the physical properties of the soil. The results of Lubis[52] showed that the addition of planting media material in volcanic ash with higher doses can increase plant height, top dry weight and root length in corn plants.

The SLM system the final determinant of land suitability is the worst value of the heaviest limiting factor of all land suitability classes although only one parameter, whereas according to sys criteria, it can be obtained by calculating all the contributions of land characteristics, then scoring the class, the sum of the results of the score is expected to be obtained an objective evaluation of all the observable soil

Table 4: Total areas of actual land suitability for each district in Galela

	Districts							
	North Galela		West Galela		Galela		South Galela	
Class SLM	Large (Ha)	(%)	Large (Ha)	(%)	Large (Ha)	(%)	Large (Ha)	(%)
Nrc	779	03	5486	51	1290	9	1562	14
Neh	16325	60	2188	20	1622	11	432	4
Nxn	-		1414	13	7415	52	4330	38
Sub Total N	17104	63	9088	84	10327	72	6324	56
S3naeh	5254	19	851	8	2423	17	704	6
S3nrna	1867	7	-		-		-	
S3oanaxn	2973	11	407	4	1327	9	-	
S3naxn	-		380	4	175	1	4275	38
Sub Total S3	10094	37	1638	16	3925	28	4979	44
Total	27198		10726		14252		11303	100
Class C. Sys								
S3rc	779	3	5486	51	1290	9	1562	14
S3eh	16325	60	2188	20	1622	11	432	4
S3oanaxn	2973	11	407	4	1327	9	-	
S3naxn	-		380	4	175	1	4275	38
S3xn	-		1414	13	7415	52	4330	38
Sub Total S3	20077	74	9875	92	11829	83	10599	94
S2naeh	5254	19	851	8	2423	17	704	6
S2nrna	1867	7	-		-		-	
Sub Total S2	7121	26	851	8	2423	17	704	6
Total	27198		10726		14252		11303	100

Note: SLM = Simple limitation method. Land suitability classes according to number of limitation, while uppercase followed by number and lowercase defined intensity and type of limitations. N = unsuitable, S3 = marginally suitable, S2 = moderately suitable, rc = the limiting factor of rooting media, eh = the limiting factor of erosion hazard, xn = the limiting factor of sodicity, oa = the limiting factor of oxygen availability, nr = the limiting factor of nutrient retention

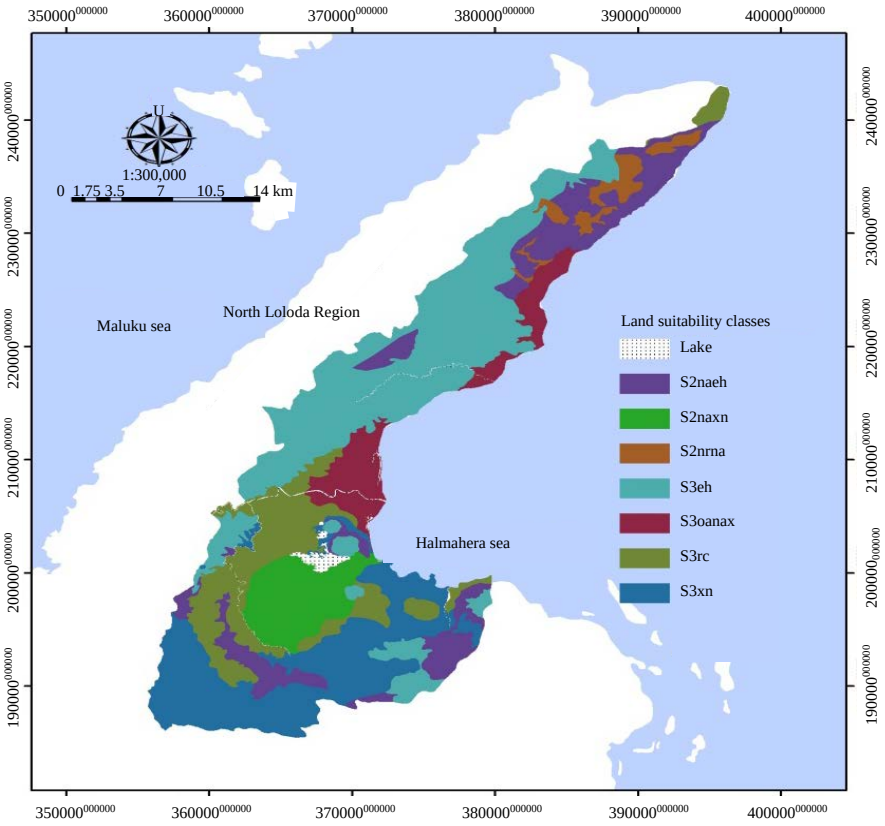

Fig. 4: Actual land suitability map for nutmeg according to sys criteria in Galela region, North Halmahera districts, North Maluku

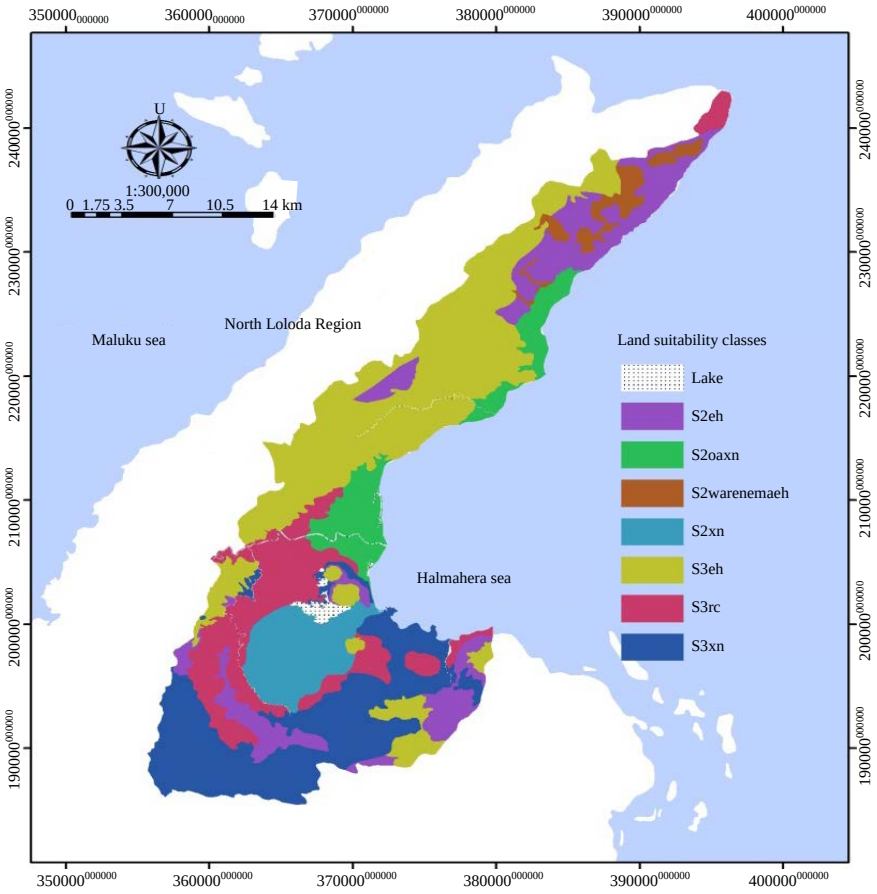

Fig. 5: Potential land suitability map for nutmeg according to sys criteria in Galela region, North Halmahera districts, North Maluku

Table 5: Total areas and production of nutmeg in Galela region, North Halmahera districts

Districts	Large (ha)	Yield (t)	Production (t ha^{-1})
North Galela	206	35.40	0.17
West Galela	2656	805.5	0.30
Galela	464	101.4	0.22
South Galela	271.2	141.0	0.52

Source: Department of Agriculture of North Halmahera[8]

parameters in the field. From the potential land suitability evaluation, the assessment based on SLM system was obtained into three classes, namely S2 (moderately suitable) with total area of 4750 ha (7%), S3 (marginally suitable) with an area 23149 ha (36%) and N (not suitable) with an area 35580 ha (56%). This means that based on SLM system around 27899 ha (44%) can be recommended for nutmeg, while 35580 ha (56%) is not recommended. Assessment of potential land suitability class using sys criteria system result in two classes i.e., S2 (moderately suitable) with a total area of 27899 ha (44%) and S3 (marginally suitable) with a total area of 35580 ha (56%). According to sys criteria system, all lands can be recommended for nutmeg although with different suitability levels.

Based on this data, it can be described that the results of land suitability evaluation using of sys criteria system was more appropriate in determining land suitability class for nutmeg in Galela areas. This condition is also supported by the fact in the field at the time of survey and field data collection, that the marginal land which was evaluated using SLM system and result in not suitable, however, nutmeg can still grow well. The highest nutmeg production was achieved in South Galela, followed by West Galela and Galela. The existence of material in the form of volcanic ash came from Mt. Dokuno is able to fertilize the surrounding soil in these three areas.

CONCLUSION

Results of research indicate that the land suitability using of sys criteria system was more appropriate in determining land suitability class for crop nutmeg (*Myristica fragrans* Houtt) in Galela region. This condition can be seen from the

fact in the field at the time of the survey and collection of field data, that the marginal land that evaluated using SLM system and their result are unsuitable, however, nutmeg can still grow well. The existence of material in the form of volcanic ash came from Mt. Dokuno, is able to fertilize on the land that owns the limiting factors nutrient availability and slope in Galela region, North Halmahera district. It was thought that the role of volcanic ash is potential as adders the mineral reserves of the soil, enrich the chemical structure and improve the physical properties, so in visible that of nutmeg that grow in the area around Mt. Dokuno appears in plant thrive and production is quite high.

SIGNIFICANCE STATEMENTS

This study found a possible right approach in determining land suitability classes for crops of nutmeg (*Myristica fragrans* Houtt) in Galela region, North Halmahera, North Maluku, which can be useful for nutmeg farmers that cultivated plants and really are in accordance with the environmental conditions. This study will help researchers to predict the potential and limiting factors for crop production of nutmeg that has not been done by other researchers. Thus, a new theory about the use of appropriate methods of evaluation approach, can reach the local government, especially the nutmeg farmers in the Galela region and the nutmeg farmers in other regions in general.

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