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Suitable and available land for cashew (*Anacardium occidentale* L.) in the island of Lombok, Indonesia

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Abstract

Cashews have a potential economic value for local people, and as a conservation plant that is appropriate for small islands, which usually have limited resource capacities. The research for this paper was conducted on Lombok Island, Indonesia with the objective to delineate the potential areas for cashew, based on land availability and land suitability. Land availability was analyzed by taking into account the land use and land cover maps interpreted from SPOT-6 imagery, a Forest Areas Status map and a map from the Official Spatial Land Use Plan. The evaluation of the land's suitability for cashews was conducted at a land mapping unit resulting from a soil survey, carried out at a scale of 1:25,000. The suitability analysis was done using a maximum limitation method, where the suitability level was defined by the lowest soil characteristics which determined the plant's requirements. The land evaluation criteria were established in previous research, which included this island as an area of criteria establishment. The research results show that the land on this island has suitability status for cashews ranging from S2 (moderately suitable) to N (not suitable). The limiting factors include water availability, nutrient retention, available nutrients and rooting media, some of which can be improved. According to the available and suitable land, an area of 4,075.6 ha can be assigned as first priority, 18,167.3 ha as second priority and 43,582.8 ha as third priority for cashew expansion areas.

Key words: Geographic information system, horticultural crop, land evaluation, land use planning

Introduction

Cashew (*Anacardium occidentale* L.) is an important export-oriented horticultural crop (Rejani and Yadukumar, 2010; Rupa *et al*., 2013) and its cultivation has increased in Indonesia during recent years. Previously in Indonesia, this plant was used as a greening plant; however, as its economic potential has increased, the plant has been cultivated for commercial purposes. In Indonesia, small land holders conduct 95% of its cultivation, while the state or private estates operate only on 5% (Statistics Indonesia, 2013a). The data of the Indonesian Directorate General of Plantation (2014) show that the cashew area in Indonesia in 2008 was 573,721 ha and that it increased to 598,503 ha in 2013. The data of Statistics Indonesia (2013b) indicate that Indonesian cashew production increased from 84,200 tons in 2000 to 117,400 tons in 2013. This commodity has apparently attracting farmers' attention because of its high economic value, and as a perennial crop, it does not require as intensive maintenance as many other food crops.

One of the problems agriculture faces all over the world is land availability. The extensive and rapid conversion of productive lands around the world in response to multiple demands for land raises the concern that globally, we risk running out of productive land (Lambin, 2012). In the world, land is limited, whereas the number of people who need the land continues to grow. From 2010 to 2014, the average population growth from 212 countries was at the speed of 1.325% per year (The World Bank, 2014); and even in developing countries, its speed reached more than 3% per year (Soubbotina, 2004; The World Bank, 2014). Increased development and population pressure in future will impact the land competitiveness causing land utilization conflicts. Land allocation for various purposes thus needs to be regulated. This land allocation setting is also part of sustainable land resources utilization (Ma *et al*., 2011; Feizizadeh and Blaschke, 2012; Akinci *et al*., 2013). In this setting, the selection of available land with high suitability for a specific use is important. This is valid for cashew because of its long-lived perennial nature, planting in an unsuitable land will lead to lower production, which means an unoptimal investment for a long time, inefficient use of capital investment as well as inefficient land utilization (Hallam *et al*., 2001; Bell, 2013).

Another problem Indonesia faces in cashew cultivation is low productivity. Currently, the average productivity of cashews in Indonesia is less than 500 kg ha^{-1} (Statistics Indonesia, 2013b). This productivity is much lower than the productivity of cashews in other countries (Widiatmaka *et al*., 2014a). In India, cashew productivity has reached 1,180 kg ha^{-1} (Rao, 2013), and even in Nigeria the cashew productivity has reached 1,970 kg ha^{-1} (FAO, 2011). Indonesia's low productivity can indeed be caused by many factors such as seeds, fertilizer, plant maintenance, eradication of pests and diseases (Nair, 2010), and other factors, but also land suitability. The suitable land for a commodity should be reflected in high productivity (FAO, 1976; Nair *et al*., 2010). Therefore, when agricultarist expand area under a crop, there is a need to consider land suitability as an important factor in site selection for high productivity.

Indonesia has many cashew production regions, among which is West Nusa Tenggara Province. In this province, Lombok Island, which had an actual total area of cashews in 2012 of 21,834.8 ha (Statistics of West Nusa Tenggara Province, 2013), has the potential to expand the planting of cashews, especially on land which is available for use. In this region, the cashew plant has a high economic contribution for local people, so its expansion areas is of great interest to the local people.

Natural resource use on small islands needs to be managed on a sustainable basis (WCED, 1987; Lallianthanga and Sailo, 2013) because small islands have limited resource capacities (Cushnahan, 2001; Reenberg *et al*., 2008). Small islands must also contend with ongoing developmental pressures in addition to growing pressures from risks associated with global environmental change and economic liberalization that threaten their physical and economic security (Pelling and Uito, 2001). The sustainability of resources on small islands is very dependent on the asset management of their resources, which are generally under pressure (UNGA, 1994). Therefore, efforts should be made to avoid usage that exceeds their natural carrying capacities. When agriculturalists want to plan cultivation, they should choose a commodity that provides not only economic gain, but also ecological protection to the island. Cashew plants, in addition to providing economic benefits, are also conservation plants widely used in Indonesia for greening and afforestation (Daras, 2007; Hadad, 2008) because they can adapt to various agroclimatic conditions; therefore, the ecological aspect of sustainability is reached. Thus, the development of cashews on a small island, in addition to providing economic benefits, will also enhance the social aspect, as well as the island's ecological protection, in line with the concept of sustainable agriculture (Salazar-Ordonez *et al*., 2013; Fauzi and Oxtavianus, 2014).

The objectives of this study were to analyze the potential expansion areas for cashew plants on Lombok Island based on the following: (i) land availability, (ii) land suitability for cashew plants, and (iii) spatial delineation and prioritization of potential land for cashew expansion areas, based on land availability and land suitability.

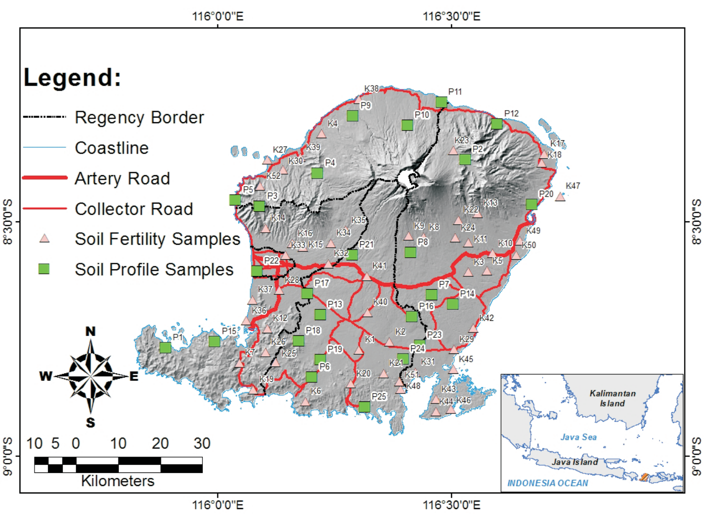

Fig. 1. The research areas of Lombok Island, West Nusa Tenggara Province and the soil sampling point, including soil fertility and soil profile sampling (Widiatmaka *et al*., 2013, 2014b)

Materials and methods

The study was carried out on Lombok Island, West Nusa Tenggara Province, Indonesia (Fig. 1). Geographically, the island is located in 115.46°-116.20°E, and 8.25°-8.55°S. This island covers an area of 5,435 km².

Lombok Island has an average rainfall of 1,586 mm year^{-1}, with fairly diverse regions. The highest annual rainfall of 2,855 mm year^{-1} is reached in Sembalun District in East Lombok, while the lowest annual rainfall of 281 mm year^{-1} is recorded in Keruak District in East Lombok (Statistics of East Lombok Regency, 2012). The topography of the island is dominated by Mount Rinjani in the northern part, whose height reaches 3,726 meters above sea level, making it the third highest mountain in Indonesia. The southern part of the island consists mostly of flat land that can be used for agriculture.

Data: Land use and land cover were delineated using SPOT-6 imagery from 2013, with an accuracy of 2.5 m (Widiatmaka *et al*., 2013; 2014b). Image interpretation and classification was performed by supervised classification using ERDAS Imagine software, followed by field checking. Field checking was performed for each type of land use and land cover. The technique of field checking involves the observation of land use and land cover characteristics in the field, which were then matched with their appearance in the image. Interviews with the community were also conducted to gather information that could not be identified from the image, such as the type of plants, plant canopy strata, and historical land use changes. The results of field checks were used as a basis for reinterpretation in order to obtain the final land use and land cover map. Imagery interpretation of SPOT-6 produced 28 kinds of land use and land cover based on standard national of imagery interpretation (SNI, 2010), but for the purposes of simplification in this article, land use and land cover are grouped into 14 kinds of land use and land cover. Especially for paddy fields, verification was done using IKONOS imagery from 2012, as interpreted by the Indonesian Ministry of Agriculture (Widiatmaka *et al*., 2014b).

Land Mapping Units (LMUs) were obtained from a soil survey and land evaluation project conducted in 2013 on the initiative of the Geospatial Information Agency, Indonesia. The soil survey was performed in an area of 289,049 ha outside the forest area and settlement area. Morphological observation of the soil was conducted by auger observation following the soil survey method of Soil Survey Division Staff (1993). In total, there were 842 morphological observations of the soil, which were input to delineate LMUs'. The 103 soil samples representing LMUs were then taken for laboratory analysis (Fig. 1.). Physical and chemical soil properties were analyzed in the laboratory of the Department of Soil Science, Bogor Agricultural University using standard laboratory methods (Tan, 2009). The survey results were outlined in a soil map at a scale of 1:25,000, which is currently available in the Geospatial Information Agency, Indonesia (Widiatmaka *et al*., 2013, 2014b).

Spatial data of the areas with different forest status was obtained from a map of Forest Area Status (FAS) at a scale of 1:250,000 and was provided by the Ministry of Forestry (Forestry Planning Agency, 2002). In this map, various states of the forest areas are presented, including information about the different areas'

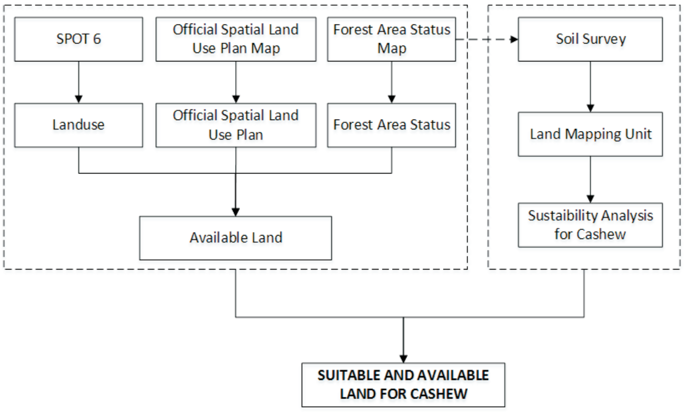

Fig. 2. Research steps followed to define suitable and available land for cashew plants in the island of Lombok, Indonesia

allowance for cultivation. The official land use plan was obtained from spatial data from the document of Official Spatial Land Use Plan (OSLUP) of West Nusa Tenggara Province, available at a scale of 1:100,000 (Regional Goverment of West Nusa Tenggara Province, 2010). In the OSLUP, land has been officially allocated for different uses.

Analysis: The analysis procedure used in this research is described in Fig. 2. Land availability analysis was done by overlaying land use and land cover maps resulting from the SPOT-6 interpretation, a map of FAS and a map of OSLUP. The land suitability analysis for cashews was conducted using soil survey data. Both were then spatially overlaid to obtain spatial data for the suitability of the available land.

The land suitability analysis for cashews was conducted using Automated Land Evaluation System (ALES) (Rossiter, 2001). The maximum limitation method (FAO, 1976; De la Rosa and van Diepen, 2002) was used for land evaluation. In this method, the degree of limitations of land use is imposed by land characteristics on the basis of permanent properties, a criterion is so needed (De la Rosa and van Diepen, 2002).

Theoretically, there are two approaches in land evaluation, *i.e.* direct land evaluation and indirect land evaluation (FAO, 1976). In direct land evaluation, the assessment is done directly to the growth or production of plants: lands in which a plant produces a high yield are described as suitable for such a plant, while lands in which plants produce lower yields are described as less suitable. These classifications can further be delineated as very suitable, suitable, marginally suitable and not suitable. In indirect land evaluation, the suitability of specific lands for specific plants is described according to land quality, based on experience and previously known empirical data. In this case, land suitability assignments needed a criteria of a land's requirement for a specific plant, which criteria was established based on experience in various other places. Assessment was then carried out, using the maximum limitation method, by matching the criteria of land characteristics of the area being assessed, compared to the land requirements of the plant (De la Rosa and van Diepen, 2002). Such a method is the most widely practiced in Indonesia because it can be done quickly (Ritung *et al*., 2007). Nevertheless, one of the weaknesses in land evaluation in Indonesia is the lack of criteria. Several criteria are available; however, they have not been

Table 1. Land suitability criteria for cashew

Land Quality/ Land Characteristics	Symbol	Land suitability class			
		Very Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Not Suitable (N)
Temperature	t				
-Elevation (m asl)		<195.6	195.6-324.4	324.4-456.2	>456.2
Water availability	w				
- Rainfall (mm)		987-2.247	827-987	601-827	<601
			2,247-3,197	3,197-4,926	>4,926
- Dry month (number)		5.1-9.8	3.9-5.1	<3.9	
			9.8-10.5	10.5-11.4	>11.4
- Wet month (number)		0.5-3.3	<0.5		
			3.3-4.5	4.5-8.4	>8.4
Rooting media	r				
- Texture		clay loam, sandy clay loam, loam	sandy clay, clay loam, sandy loam	clay, silty clay, silty clay loam	heavy clay, silt, loamy sand, sand
- Effective depth (cm)		>39.7	21.1-39.7	6.6-21.1	<6.6
Nutrient retention	f				
- CEC (cmol(+) kg^{-1}		>12.40	8.54-12.40	2.56-8.54	<2.56
- Water pH (1:5)		5.4-6.4	5.1-5.4	4.6-5.1	<4.6
			6.4-6.9	6.9-7.7	>7.7
- Organic-C (%)		>0.78	0.49-0.78	0.11-0.49	<0.11
- Base Saturation (%)		>65.7	<65.7		
Available nutrient	n				
- Total-N (%)		>0.072	0.052-0.072	0.029-0.052	<0.029
- Avail.-P (ppm)		>39.69	10.84-39.69	1.02-10.84	<1.02
- Exch.-K (cmol (+).kg^{-1})		>0.37	0.27-0.37	0.10-0.27	<0.10
Terrain condition	p				
- Slope (%)		<11.9	11.9-23.1	23.1-77.4	>77.4
- Surface rock (%)		<14.5	14.5-28.8	28.8-75.5	>75.5

Source: Widiatmaka *et al*. (2014a)

Fig. 3. Survey region for establishing the land suitability criteria for cashews (Widiatmaka *et al*., 2014a). Lombok Island includes sampling locations, resulting in criteria that were then used to evaluate land suitability for this paper.

built based on empirical knowledge of production as required by the FAO (1976). As a result, often the use of inaccurate criteria causes diagnostic errors in land evaluation. Frequently, it has been found that commodities grow and produce well in a region, but the evaluation using improper criteria produce low suitability classes, and *vice versa*. Such phenomena are often found in land evaluation (Sutandi and Barus, 2009; Widiatmaka et al., 2014a).

To avoid such an error in land evaluation, various studies have been done to develop criteria that are relevant to crop production (Ritung *et al*., 2007; Sutandi and Barus, 2007). In the case of the cashew plant, a criterion that relates to land characteristics and production has been built and recently published (Widiatmaka *et al*., 2014a). In that research, the criterion was built with a soil survey, confronted with cashew production. Cashew plantations in five provinces and 12 regencies were sampled; Lombok Island is one of the areas that was used for establishing the criteria (Fig. 3). The data for production per tree per year were obtained from farmers, while the soil was sampled and analysed in the laboratory. Age-adjusted cashew production was used as the yield response and plotted against land characteristics. The criteria were then established using a projection of the intersection between the boundary line and yield interval. The resulting criterion (Table 1) is considered appropriate to be used in this study because it was constructed in the area that includes Lombok Island as a location of data retrieval for confrontation between land characteristics and production.

Using such criteria, we used the land evaluation concept of the FAO (1976) for this research, where land was classified as either S1 (very suitable), S2 (moderately suitable), S3 (marginally suitable), or N (not suitable). ALES ver. 4.65e, ArcGIS 10.2 and Microsoft Office were used as software tools. Analysis was performed by integrating Arc-GIS and ALES.

The land evaluation model using ALES consists of several steps (Rossiter, 2001). The Land Use Type (LUT), which in this case is the cashew, was established first. Land Use Requirement (LUR) for this LUT was then established. In the next step, choice and establishment of Land Characteristics (LCs) for each LUR and LUT were done. Finally, a Decision Tree (DT) was made according to the criteria. The land characteristics used for the land evaluation were stored in the ALES database. The land suitability evaluation was done for each LMU. The results of ALES analysis were then transferred to the ArcGIS 10.2 for geographical reference and are described in the form of maps and tables.

Results and discussion

Land use and land cover: The results of the land use and land cover analysis are presented in Fig. 4a and Table 2A. The main land use and land cover in Lombok Island are the following: forest, paddy field, shrub, dry land agriculture, and plantation. Forest cover is the widest, located in the northern part of the island from the hilly part of the region, climbing to the direction of Mount Rinjani. The south part of the region is dominated by farms and plantations. Settlements are concentrated in the capital, Mataram, and the surrounding region.

Soil and land mapping unit: The overall area of Lombok Island is divided into 52 LMUs. The components of LMU used in this study include the soil classification in the sub-group categories, parent material, slope, and physiography (USDA, 2010). A map of Lombok Island based only on soil sub-group is presented in Fig. 4b. A summary of the soil distribution in the study area is presented in Table 2B. The soil in Lombok Island comprises five soil orders (USDA, 2010), including Alfisols, Inceptisols, Entisols, Andisols and Aridisols, and there are 13 soil sub-groups. Inceptisols occupy the largest area, covering 268,226.2 ha, or 58.7% of the area. Another soil order that is also quite widely spread is Alfisols, which covers an area of 117,357.4 ha

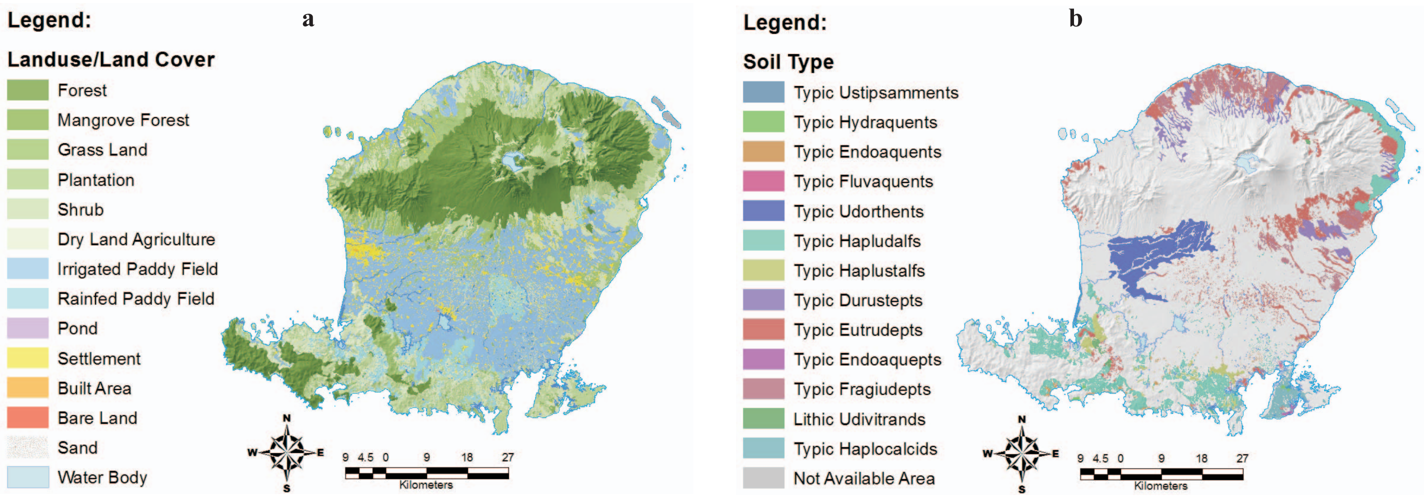

Fig. 4. Map of (a) the land use and land cover, interpreted from SPOT-6 imagery, and of (b) the soil class up to sub-group categories in the areas outside of Forest Area Status (Widiatmaka *et al*., 2013, 2014b)

or 25.7%. The dominancy of Inceptisols and Alfisols is related to soil development, which has been influenced by the local climate (Widiatmaka *et al*., 2014b). Alfisols is characterized by an accumulation of clay in a sub-soil horizon, namely the argillic horizon, and it has a high base saturation (>35%) (USDA, 2010). Inceptisols is a soil that is relatively young; the soil development is not very advanced. The development of Inceptisols and Alfisols is related to the relatively dry climate areas (Tan, 2009; Widiatmaka *et al*., 2014b).

Forest area status: The FAS map is presented in Fig. 5a, while the area of each forest's status within the map is presented in Table 3A. Land utilization for non-forest purposes in Indonesia is regulated by the Forestry Law No. 41/1999. The cultural activity (settlement, agriculture, industry etc.) is prohibited in forest areas. This regulation is intended to preserve the forests in Indonesia. These forests have a mega biodiversity status in the tropical zone and hence their protection is important, not only for the country but also for the earth's sustainability. This law, accompanied by the hard efforts of the Ministry of Forestry in suppressing the forest degradation, has resulted in diminishing the rate of forest degradation to about 1.08 million ha for the last three years from its level of about 2.8 million ha in the 1990s (Kusmana, 2011). The planning in this research is intended to be sustainable, and thus the regulatory status of these forests must be considered. For this reason, the areas that can be used for farming, including for cashew plantations, only include those of the 'Area for Other Uses' status in FAS. In a more detailed description, 'Area for Other Uses' means an area which is not officially included in other types of FAS such as protected forest, research forest, national park as well as production forest area. In the case of Lombok Island, this 'Area for Other Uses' includes 295,140.9 ha.

It should be noted, however, that actually, maps of FAS are

Table 2. Area distribution of Lombok Island according to (A) land use and land cover, interpreted from SPOT-6 imagery, and (B) soil class up to sub-group category in the area outside of Forest Area Status (Widiatmaka *et al*., 2013, 2014b)

A

No	Land Use/Land Cover	Area (ha)	Area (%)
1	Forest	123,687.8	27.1
2	Mangrove forest	755.4	0.2
3	Built area	110	0
4	Bare land	38.6	0
5	Grass land	9,639.7	2.1
6	Sand	785.8	0.2
7	Plantation	51,738.5	11.3
8	Settlement	20,855.6	4.6
9	Irrigated paddy field	106,248.0	23.3
10	Rainfed paddy field	21,524.4	4.7
11	Shrub	58,335.7	12.8
12	Pond	36.9	0
13	Dry land agriculture	57,891.6	12.7
14	Water body	5,226.5	1.1
	Total	456,874.6	100

B

No	Soil Sub-Group	Area (ha)	Area (%)
1	Lithic Udivitrands	651.7	0.6
2	Typic Durustepts	10,242.2	9.9
3	Typic Endoaquents	1,615.4	1.6
4	Typic Endoaquepts	312.6	0.3
5	Typic Eutrudepts	25,915.7	25.0
6	Typic Fluvaquents	106.5	0.1
7	Typic Fragiudepts	12,005.4	11.6
8	Typic Haplocalcids	4,108.0	4.0
9	Typic Hapludalfs	26,674.0	25.8
10	Typic Haplustalfs	4,094.9	4.0
11	Typic Hidraquents	979.9	0.9
12	Typic Udorthents	16,277.5	15.7
13	Typic Ustipsamments	538.6	0.5
	Total	103,522.4	100

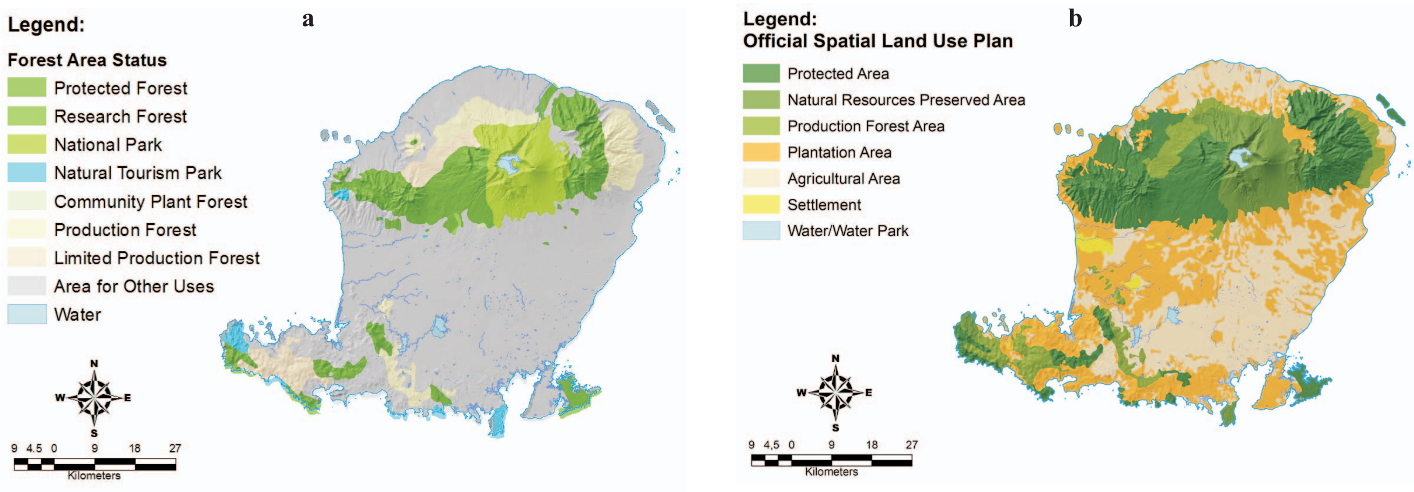

Fig. 5. Maps of (a) forest areas, according to the map of Forest Area Status (Forestry Planology Agency, 2002), and of (b) Official Spatial Land Use Plan (Government of West Nusa Tenggara Province, 2010)

available throughout Indonesia only at a scale of 1:250,000. Therefore, using such a small-scale map in this study, delineation had to be carefully viewed and only at the planning level. Operational use in the field concerning forest boundaries needs to be detailed in coordination with the Ministry of Forestry.

Allocation in official spatial land use plan: Planners should refer to the OSLUP, according to Law No. 26/2007. The map of OSLUP is presented in Fig. 5b and Table 3B. According to OSLUP, the areas that are allocated as cultural areas include 60.8% of the island area, and consist of plantation, agricultural and settlement areas. The rest, 39.2% of the area, is allocated as non-cultural areas, which include protected areas, natural resources-preserved areas, production forest areas and water bodies. The areas that can still be used for cashew expansion are the plantation areas and the agricultural areas. On Lombok Island, the total area of these two areas is 273,537.1 ha.

Land Suitability: The results of the soil analysis, used as land qualities and land characteristics in land evaluation are presented in Table 4, with only the analysis summary presented. The actual and potential land suitability maps were presented only in the areas that are allowed to be used for agricultural purposes according to FAS and OSLUP.

The results of the land suitability analysis show that the land suitability classes for cashews range from S2 (moderately suitable) to N (not suitable). In terms of actual land suitability, the total amount of suitable land for cashews (class S2 and S3) is 61,214.2 ha, consisting of 22,242.8 ha of S2 class and 38,971.4 ha of S3 class.

The land qualities that cause land to be as S2 class are those of water availability (w), nutrient retention (f), and available nutrients (n). For the land quality of water availability, the land characteristics that become limiting factors are rainfall and number of dry months. Lombok Island has a very wide range of climates, the rainfall ranges from very low to very high. Research indicates that climate factors relate to moisture availability variation in soil (Tolla, 2004). Management and soil moisture regimes are factors that determine the cashew plant's yield variability (Rejani and Yadukumar, 2010), the temporal variation of available soil moisture explained the yield variability of the cashew nuts. Gopakumar *et al.* (2005) also indicated that there was a decline in cashew productivity due to the warmest and drought conditions as a result of a decline in rainfall and an increase in temperature. The dry season is generally coincides with cashew flowering and nut development, when crop water requirements reach maximum values, and so, low nut yields are commonly associated with years of low rainfall (Oliveira *et al*., 2006).

Table 3. Distribution of (A) forest areas, according to the map of Forest Area Status (Forestry Planology Agency, 2002), and of (B) Official Spatial Land Use Plan (Government of West Nusa Tenggara Province, 2010)

A

No	Forest Area Status	Area	
		ha	%
1	Protected forest	70,798.2	15.5
2	Research forest	364.8	0.1
3	National park	34,057.5	7.5
4	Natural tourism park	6,804.5	1.5
5	Community plant forest	209.2	0
6	Production forest	30,096.1	6.6
7	Limited production forest	17,547.3	3.8
8	Area for other uses	295,140.9	64.6
9	Water	1,856.2	0.4
	Total	456,874.6	100

B

No	Official Spatial Land Use Plan	Area	
		ha	%
1	Protected area	103,814.5	22.7
2	Natural resources preserved area	40,421.4	8.8
3	Production forest area	32,611.3	7.1
4	Plantation area	139,673.8	30.6
5	Agricultural area	133,863.3	29.3
6	Settlement	3,925.5	0.9
7	Water/water park	2,564.9	0.6
	Total	456,874.6	100

Table 4. Results of the soil analysis used as land characteristics for land evaluation for cashew plants

Soil Order	n		CEC cmol (+).kg[-1]	Base saturation (%)	pH	Organic-C (%)	N-Total (%)	P_2O_5 (ppm)	K_2O (ppm)	Texture (%) Sand	Silt	Clay
Alfisol	8	Min	7.6	92.9	6.0	0.6	0.05	1.97	36.0	17	28	9
		Ave	22.6	99.1	6.7	0.9	0.08	34.69	146.4	34	38	28
		Max	47.5	100.0	7.9	1.4	0.13	94.28	201.0	46	47	55
Andisol	2	Min	16.8	99.2	5.9	0.9	0.07	4.61	168.4	43	29	25
		Ave	17.8	99.6	5.9	0.9	0.08	20.20	173.0	44	30	27
		Max	18.8	100.0	6.0	1.0	0.09	35.78	177.5	45	30	28
Aridisol	2	Min	31.3	100.0	6.7	1.1	0.11	15.36	163.0	16	41	35
		Ave	34.7	100.0	7.2	1.3	0.13	17.68	222.8	20	44	36
		Max	38.0	100.0	7.6	1.6	0.15	20.00	282.6	24	47	37
Entisol	11	Min	2.6	52.7	4.7	0.2	0.02	5.88	52.3	22	-	5
		Ave	18.1	93.3	6.8	0.8	0.07	22.03	151.6	51	26	22
		Max	43.5	100.0	8.2	1.3	0.11	73.18	347.5	94	53	44
Inceptisol	29	Min	2.2	89.4	5.4	0.4	0.04	4.81	40.7	26	8	4
		Ave	11.7	99.1	6.2	1.4	0.13	26.35	88.8	56	27	17
		Max	31.5	100.0	8.5	4.6	0.41	81.40	259.3	84	50	36

For land quality of nutrient retention (f), the determining land characteristics can be the soil's Cation Exchange Capacity (CEC), its base saturation, its C-organic content and its pH (Table 1). The analysis results indicate that the dominant limiting factor for cashew growth on Lombok Island is a low soil CEC. There was only one sampling point that had too high pH, and two sampling points that had too low a quantity of C-organic content as limiting factors and putting this land into the S2 class. However, there was not a sampling point that indicated the soil's base saturation as a limiting factor. On Lombok Island, the soil's CEC generally is not high enough to enter into class S1 for cashews. The pH appeared to be a limiting factor for assigning the land to the classes of S3 and N for cashews. A high pH can be a serious limiting factor and even make the land not suitable (N) for cashews. However, a too low pH could be a limiting factor for cashews as well. Ngatunga *et al*. (2003) observed that continued use of sulphur on the Makonde plateau is likely to result in a decline of the soil pH, which affects the cashew nut production. Furthermore, Owaiye and Olunloyo (1990) reported that the best growth of cashews is obtained between the pH ranges of 4.5 and 5.0, a pH of 4.5 being optimal. The similar tendency has been found in whole Nusa Tenggara Province by Widiatmaka *et al*. (2014a)

For the land quality of available nutrient (n), the land characteristics that were taken into account were nitrogen (total-N), phosphorous (available-P) and potassium (exchangeable-K). The analysis results indicated that the land characteristics that limit cashew growth from being in the S2 class on Lombok Island were generally total-N. There was only one point sample that had a low value of P_2O_5, making these samples S2 class, and there were no samples that showed exchangeable-K as a limiting factor. Even in classifying the land as S3 or N class, exchangeable-K remained not a limiting factor. The soil on Lombok Island appears to have sufficient K_2O levels for the growth of cashews. For classifying S3 and N classes, the total N together with P_2O_5 content appear to be limiting factors. The research of O'Farrel (2010) showed that high yields of cashew nuts can be achieved from intensively managed trees. This was achieved when N was applied at the rate of 17 g N/m^2. The timing of N fertilizer is critical, and should be applied during the main vegetative growth period. Nitrogen appears necessary during the vegetative phase of the cashew tree. Application of a high-nitrogen fertilizer was responsive in this vegetative phase.

In cashews, phosphorus is an essential component of the genetic material of the cell nucleus. Phosphorus deficiency causes stunting, delayed maturity, and shriveled seeds (Thompson and Troeh, 1978; Aikpokpodion *et al*., 2009; Widiatmaka

Table 5. Land suitability for cashew plants on Lombok Island: (a) actual land suitability, and (b) potential land suitability

No	Actual Land Suitability Sub-Class	Area ha	%
1	S2-f	3,276.8	0.7
2	S2-wf	2,233.5	0.5
3	S2-wn	566.4	0.1
4	S2-fn	798.7	0.2
5	S2-wfn	15,367.4	3.4
6	S3-f	149.9	0.0
7	S3-n	1,993.2	0.4
8	S3-r	32,251.0	7.1
9	S3-rf	2,149.7	0.5
10	S3-rn	2,216.7	0.5
11	S3-fn	210.9	0.0
12	N	44,322.1	9.7
13	na	351,338.3	76.9
	Total	456,874.6	100.0

No	Potential Land Suitability	Area ha	%
1	S1	4,075.6	0.9
2	S2-w	18,167.3	4.0
3	S2-f	149.9	0.0
4	S2-n	1,993.2	0.4
5	S2-fn	210.9	0.0
6	S3-r	36,617.4	8.0
7	S3-f	4,611.4	1.0
8	N	39,710.7	8.7
9	na	351,338.3	76.9
	Total	456,874.6	100.0

na: not available area

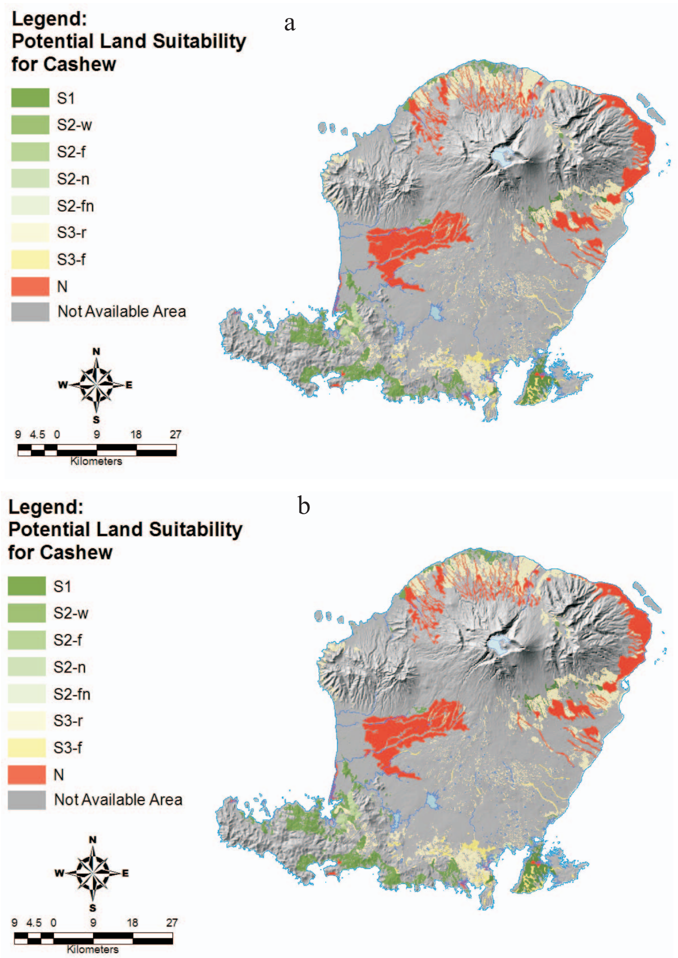

Fig. 6. Map of land suitability for cashew: (a) actual land suitability, and (b) potential land suitability

et al., 2014a). Ibiremo *et al*. (2012) reported that the rock phosphate treatment significantly improved nut sizes in Ibadan soil. Additionally, Sathiyamurthi (2013) indicated the need of improving the soil's phosphorus in cashew orchards' soil.

In the S3 class, the land qualities that become limiting factors are rooting media (r), nutrient retention (f), and available nutrients (n). Land qualities that determine an N class are rooting media (r) and nutrient retention (f). For the S3 and N classes, other than the limiting factors of pH, total-N and P_2O_5, the soil texture emerges as the dominant limiting factor. This result shows that cashew is not tolerant to poor soil drainage. Previous studies indicated that soil texture is critical for cashew production (Duncan, 2001). Cashew production relates to well-drained soil with a sandy loam texture (Duncan, 2001). Cashews seem to flourish in a free-draining and light-textured soil (Widiatmaka *et al*., 2014a).

Land suitability can be defined as actual land suitability and potential land suitability (FAO, 1976). Potential land suitability is land suitability when limiting factors in actual land suitability are improved (FAO, 1976). However, several limiting factors are permanent as some soil textures cannot be improved. On Lombok Island in general, the improvement of actual land suitability to become potential land suitability increases the extent of the suitable area by only a small amount. The total actual suitable land is 61,214.2 ha (58% of land being assessed for its suitability), while the total potential suitable land is 65,825.7 (62% of land being assessed for its suitability) (Table 5 and Fig. 6). This is because the good land on Lombok Island has mostly been cultivated for planting cashews.

Area priority for cashew expansion: Land availability for cashew expansion areas was analyzed using a matrix of land use allocation (Table 6). In this allocation matrix, according to FAS, the only available land for cashew development planning fell under Area for Other Uses forest status. Based on the OSLUP, the lands that allowed for cashew development were agricultural and plantation areas. Based on the existing land use, land that can be developed is land in which the current land use/land cover is bare land, shrub, and dryland agriculture. Forest and mangrove forests are not recommended to be used in order to protect the environment. Law No. 26/ 2007 contains a provision that in any region, at least 30% of the area should be forest area. In the case of Lombok Island, the current forest cover is 124,443 ha, or only 27.3%, although based on the FAS, the forest area is 159,878 ha or 35%. The existing forest land cover must be maintained so as not to be used for cultivation. The existing plantation is also not suggested in the calculation of the area that can be used for the expansion. Pasture is not recommended for cashew development because Lombok Island is also a breeding area in Indonesia, which requires sufficient sources for animal feed. Paddy fields, both irrigated and rainfed paddy fields are not recommended for use for food security reasons. Thus, in this case of cashew expansion, there was an area of 103,522.4 ha, taking FAS, OSLUP and existing land use into account for the available land for agricultural development.

Prioritizing the land utilization for cashew plantations is based on land suitability for cashews. First priority is given to land with potential land suitability for cashews S1, second priority is given to land with potential land suitability for cashews S2, and third priority is land with potential land suitability for cashews S3. Land with N potential land suitability for cashews is not suggested to be used for cashew development. With this analysis, an area of 4,075.6 ha can be assigned as priority I for cashew extension, a land area of 18,167.3 ha can be assigned as priority II, and a land

Table 6. Matrix of land use allocation for cashew expansion area

Land Use/Land Cover	Official Spatial Land Use Plan	Forest Area Status	Land Suitability	Land Use Recommendation
Bare Land, Shrub, Dryland Agriculture	Plantation Area, Agricultural Area	Area for Other Uses	S1	Priority I
			S2	Priority II
			S3	Priority III
			N	Not recommended
Forest, Mangrove Forest, Grassland, Sand, Plantation, Settlement, Irrigation Paddy Field, Rainfed Paddy Field, Pond, Water Body	Protected Area, Natural Area, Production Forest Area, Settlement Area, Water	Protected Forest, Production Forest, Limited Production Forest, National Park, Natural Park, Community Forest Plant, Research Forest, Water	Not recommended	

Table 7. Area priority of cashew expansion on Lombok Island

No	Use direction for cashew	Area	
		ha	%
1	Priority I	4,075.6	0.9
2	Priority II	18,167.3	4.0
3	Priority III	43,582.8	9.5
4	Not Recommended	391,049.0	85.6
	Total	456,874.6	100.0

area of 43,582.8 ha can be assigned as priority III. Thus, in total on Lombok Island, the extension of cashew can be developed in the total potential area of 65,825.7 ha (Table 7 and Fig. 7).

Based on the concept of economic land suitability (FAO, 1985; Rossiter, 2001), land suitability class S1 has the potential to produce 80 to 100% of the maximum production; land suitability class S2 has the potential to produce 60 to 80% of the maximum production. Land suitability class S3 has the potential production of 24 to 60% of the maximum production (Widiatmaka *et al*., 2014a). When referring to the highest production potential in Nusa Tenggara, based on the data of Statistics Indonesia (2013b) that is 367 kg ha^{-1} at the maximum production rate, so if using a lower limit on the production of each class of land suitability, additional potential production will be obtained from lands of S1, S2 and S3, respectively, with the potency of 1,196 tons.year^{-1} on land S1, 4,000 tons year^{-1} on S2 land and 3,838 tons year^{-1} in S3 land, or a total additional production of 9,036 tons year^{-1}. As information, the actual production of cashew in Lombok Island is 3,116 tons year^{-1} (Statistics of West Nusa Tenggara Province, 2013). This rough estimation can be added to the potential use of the degraded forest land, which may also be used for the plant because cashew nut is one of the greening plants (Hadad *et al*., 2008). However, it is necessary for other more detailed analysis.

The analysis presented is the potency of Lombok Island from point of view of land suitability and land availability. Certainly for the realization, many other parameters still need to be considered, one of them being the use of land for other commodities. According to the land tenure regime in Indonesia, the land is owned (with legal certificate) by individuals, by entities, or by the State. The ability to use land owned by individuals or entities would depend on the owners' economic interest. The analysis from this point of view is not included in the scope of this article; however, such consideration can be used for further land use planning and analysis.

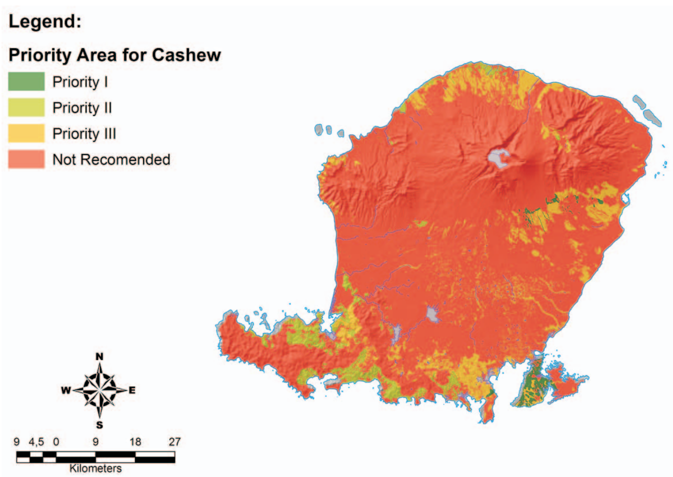

Fig. 7. Map of priority area for cashew expansion according to land suitability and land availability on Lombok Island

Finally, it can be highlighted that the analysis in this research, conducted on the small island of Lombok, Indonesia has been performed by taking into account the available land for agriculture in terms of forest area status, official spatial land use planning and existing land utilization. Taking into account such factors is important, considering that land is a non-renewable resource which is needed by many sectors. Our research calculates that there was 103,522.4 ha of available land. From this available land, the actual suitable land with different suitability classes for cashews could then be delineated using land suitability analysis; in this case it was 61,214.20 ha. The choice of cashew is guided by the fact that this plant meets the requirements for sustainable use in a small island in terms of ecology and economy as well as the needs of the population. From the land suitability analysis, the limiting factors for cashew development were obtained by analysing the data from soil characteristics resulting from a soil survey. These consist of the land characteristics of water availability (based on rainfall and dry months in several regions), nutrient retention (soil CEC and soil pH), nutrient availability (total N and P_2O_5 content) and rooting media (soil texture). Several limiting factors can be improved to increase the number of suitable land areas for cashews. The priority area for cashew expansion was then established according to its potential land suitability. In total, an area of 65,825.7 ha with different classes of land suitability for cashews can be recommended. With the addition of these cashew areas, the potential cashew production from this island can increase.

The preciseness of this mapping methodology has to be also taken into consideration. This research used different maps at various precisions; the soil map and topographical map were at a scale of 1:25,000, while the land use was interpreted using SPOT-6 imagery at a precision of 2.5 m. Through this interpretation, the obtained result can be defined as operational for land use planning at a middle scale of 1:25,000. Since however, the OSLUP map used was scaled at 1:100,000 and the FAS map at 1:250,000, the final results received should be viewed cautiously. The uncertainty at the middle scale land use planning may be derived from these two maps. Consequently, more attention and consideration have to be given to the border of the forest as well as the official land use plan border when the results for the middle scale land use planning are used for operational purposes.

The research steps shown in this paper can act as a step-by-step guide for other areas. It is important to note the importance of selecting suitable land, and on the other hand, to take into account the available land according to official regulation of land use planning.

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