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Land use planning of paddy field using geographic information system and land evaluation in West Lombok, Indonesia

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Abstract Planning analysis to increase rice production either through intensification of existing paddy field area or extensification in potential land area was conducted in West Lombok Regency, West Nusa Tenggara Province, Indonesia. Existing paddy field was delineated using high-resolution data from IKONOS imagery of 2012. Land use and land cover outside existing paddy field were interpreted using SPOT-5 imagery of 2012. The Automated Land Evaluation System (ALES) was used for land suitability analysis for paddy. The results are interpreted in terms of the potential of paddy field intensification in existing paddy field area and the potential of extensification in land potentially used for paddy field. The result of analysis showed that in West Lombok Regency, there are still possible to do intensification and extensification of paddy field to increase rice production in order to improve regional food security.

Keywords: Automated Land Evaluation System, soil survey, land quality, land characteristic, image interpretation.

Abstrak *Analisis perencanaan peningkatan produksi padi melalui intensifikasi pada lahan sawah eksisting dan ekstensifikasi pada lahan yang potensial disawahkan dilakukan di Kabupaten Lombok Barat, Provinsi Nusa Tenggara Barat, Indonesia. Penggunaan lahan dan tutupan lahan diinterpretasi menggunakan citra SPOT-5 tahun 2012. Sawah eksisting didelineasi menggunakan citra beresolusi tinggi IKONOS tahun 2012. Evaluasi lahan menggunakan Automated Land Evaluation System (ALES) digunakan untuk analisis kesesuaian lahan untuk padi sawah. Hasil analisis menunjukkan bahwa di Kabupaten Lombok Barat, masih dimungkinkan dilakukan intensifikasi pada lahan sawah eksisting dan ekstensifikasi pada lahan potensial sawah untuk peningkatan produksi beras dalam rangka peningkatan ketahanan pangan wilayah.*

Kata kunci: *Sistem evaluasi lahan otomatis, survey tanah, kualitas lahan, karakteristik lahan, interpretasi citra.*

I. Introduction

Indonesia's dependence on rice as staple food is very high, and even worrisome when viewed from the spatial distribution of rice production locations. According to recent statistical data [BPS, 2013a], the harvested area of paddy field in Java Island in 2012 is 6,165,079 Ha, constituted of 46.89% from the total Indonesian harvested area. Such harvested area produces rice as many as 34,404,557 tons, or constituted of 52.32% from the national rice production. In other words, Java Island, which is only about 6.9% of the land area of Indonesia, contributing to 52.32% of Indonesia's rice production.

On the other side, Java Island is an island with the highest population density, resulting high pressure on the existing paddy field. Land conversion, according to the analysis using the official statistical database from 1989 to 2000, has caused a reduction in paddy field area, from 3.48 million Ha in 1988 to 3.37 million Ha in 1999 [Abdurachman et al., 2005]. The Java paddy field which is converted during 1978-1998 reached 1.07 million Ha, which means that there was a depreciation of 8,000 Ha/year or 23% area/year [Irawan, 2004]. Such data illustrate the rice staple food insecurity. Land conversion which generally occurs in the fertile agricultural land would threaten the national food security [Irawan, 2005]. If this conversion trend continue, there will be a dramatic escalation of the country's dependence on imported rice. According to Agus et al. [2006], to maintain self sufficiency for the next twenty years, Indonesia has to curb the current conversion rate of above 100,000 Ha/year to less than 29,000 Ha/year. For each hectare of the converted paddy field in Java Island, 2.20 Ha, new paddy field has to be developed at the outside of the

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island to compensate the yield loss due to decreasing productivity of the current paddy fields.

Various efforts are needed to ensure Indonesian food security, such as by increasing rice production, controlling the rice consumption levels as well as control of rice needs. One of the efforts which can be done to increase the production are intensification of the existing paddy field and, if possible, extending paddy field to the potential land, especially in outside Java Island. Efforts to increase the production in a specific region are needed, at least so that an area will not depend on the other areas, which then will reduce the actual national food security in the aggregate. Even if possible, an area should provide a surplus which can contribute to national food security. However, such intensification and extensification often meet with many challenges. The main threats to the future food security include decreasing agricultural land, depleting water resources, declining trends in soil fertility and productivity, depletion of groundwater table [Devi & Ponnarasi, 2009] as well as, in case of Indonesia, inefficient land resources utilization.

West Lombok Regency is one of regencies in Lombok Island where its natural resources provide high possibilities for paddy field intensification as well as extensification. According to the latest statistical data [BPS, 2013b], West Lombok Regency is able to produce 152,686 tons of rice from irrigated paddy fields. That amount, when added with 4,833 tons from non-irrigated paddy field production, and with a population of 606,044 people in 2011, is expected to be adequate for self-sufficiency of the regency, and even it can still provide a surplus as an addition to the regional and national food security. However, an increasing number of population which is faster than the growth of production in the future, may cause a productivity reduction, which in turn can reduce the regional food security. Similar phenomena has been reported in previous study in Nusa Tenggara Province [Nazam et al., 2011]. Therefore, efforts to increase the production should be implemented, at least to keep pace with population growth.

Both intensification and extensification need to be coupled with knowledge of the land properties. Efforts to increase rice production should be done by site-specific management. For example, Phosphate (P) fertilizer needs to be done only on land with P deficiency. In term of precision, land management should be done in the right time, amount, and place [Robert et al., 1994], as well as the source and manner [Khosla, 2010].

The objective of this paper is to present an analysis and planning to increase rice production, either through intensification on existing paddy fields or extensification on potential land in West Lombok Regency, West Nusa Tenggara, Indonesia. The plan is determined based on land suitability for paddy fields and site-specific biophysical factors. This research can provide an important input for the government since increasing the productivity of rice remains to be the major challenge for local governments and researchers in this countriy.

2. The methods

The research was conducted in West Lombok Regency, West Nusa Tenggara Province, Indonesia. Geographically, the regency is located at 115.46°-116.20°E, and 8.25°-8.55°S. The research location is presented in Figure 1. Average annual rainfall of the region is 1,586 mm, and average monthly rainfall is 132.2 mm, while average number of rainy days is 14.1 days in a year [BPS, 2013b].

Land cover of the regency was first delineated using SPOT-5 imagery acquired in 2012. Image classification was done by supervised classification, followed by field checking. The classification was done using ERDAS Imagine software. Imagery analysis produces 28 type of land use and land cover. However, to simplify the result, the land use and land cover were grouped into 13 type of land use and land cover. For existing paddy field, a more accurate data were used for map correction based on Ministry of Agriculture agricultural data. This data was produced from paddy field measurement activity using high resolution imagery IKONOS acquired in 2012.

A soil survey was conducted in 2013 in the study area as a part of survey conducted in the whole island of Lombok, initiated by Geospatial Information Agency, Indonesia. In that survey, 103 soil samples were taken from whole Lombok Island. The site sample locations in West Lombok Regency, as well as in other regencies in whole Lombok Island are given in Figure 1.

The analysis of physical and chemical [Widiatmaka et al., 2013a] soil properties was performed in Laboratory of the Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University and Laboratory of Center for Agricultural Land Resources, Bogor, Indonesia. The results of the survey were drawn on 1:25,000 map available at Geospatial Information Agency, Indonesia. In this paper, only the result in West Lombok Regency is presented.

The land suitability for paddy field was analyzed using Automated Land Evaluation System (ALES) [Rossiter, 2001]. Maximum limitation method was used for the land evaluation. In this method, degree of limitation of the land use was imposed by land characteristics on the basis of its permanent properties and required criterias [De la Rosa and Van Diepen, 2002; Armanto et al., 2012]. Land suitability criteria for paddy field was structured by bibliographical studies [Hardjowigeno and Widiatmaka, 2007; Djaenudin et al., 2003; FAO, 1983; Ritung et al., 2007]. The criterias are presented in Table 1.

In this system, land was classified into S1 (highly suitable), S2 (suitable), S3 (marginally suitable), N1 (currently not suitable) and N2 (permanently not suitable) according to the FAO framework [FAO, 1976].

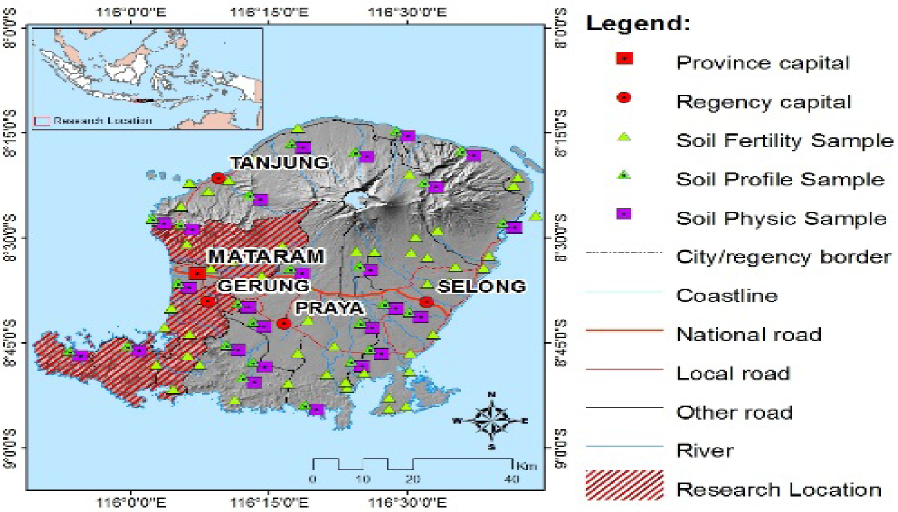

Figure 1. Research location of West Lombok Regency and soil sampling points in whole Lombok Island

Table 1. Criteria of land suitability for paddy used in this research.

Land Quality/ Land Characteristic	Land Suitability Class				
	S1	S2	S3	N1	N2
Temperature (t)					
• Yearly average (°C)	24-29	>29-32 22-<24	>32-35 18-<22	-	>35 <18
Water availability (w)					
• Dry month (<75 mm)	<3	3-<9	9-9.5	-	>9.5
• Yearly rainfall (mm)	>1500	1200-1500	800-<1200	-	<800
Rooting media (r)					
• Soil drainage	poor	poor	medium, well	rapid	very rapid
• Texture[1)]	SCL, SiL, Si, CL	SL, L, SiCL, C SiC	LS, Str C	-	S
• Efective depth (cm)	>50	>40-50	>25-40	20-25	<20
Nutrient retention (f)					
• Soil Cation Exch. Capacity (me/100 g)	≥ medium	low	very low	-	-
• Base saturation (%)	>50	35-50	<35	-	-
• Soil pH	>5.5-7.0	>7.0-8.0 4.5-5.5	>8.0-8.5 4.0-<4.5	-	>8.5 <4.0
• Organic-C (%)	>1.5	0.8-1.5	<0.8	-	-
Nutrient retention (n)					
• Total-N (%)	≥ medium	Low	very low	-	-
• P_2O_5 (ppm)	≥ high	medium	low-very low	-	-
• K_2O (me/100 g)	≥ medium	Low	very low	-	-
Erosion (e)					
• Erosion hazard	very low	low	medium	high	very high
• Slope (%)	<3	3-8	>8-15	>15-25	>25

[1)]S: sand; Si: silt; C: clay; L: loam; Str: structural

Softwares which were used for land suitability analysis were ALES ver. 4.65e, Arc-GIS 10.1, and Microsoft Office. Analysis were performed by integrating Arc-GIS, ALES and expert knowledge.

Procedures for land evaluation model using ALES consist of: (i) establishing Land Use Type (LUT) (in this case is for paddy field); (ii) establishing Land Use Requirement (LUR) for LUT; (iii) choosing and establishing Land Characteristic (LC) for each LUR and LUT; and (iv) making Decision Tree (DT). Land characteristics used for the land evaluation was stored in ALES database. Furthermore, expert knowledge is used to evaluate the suitability of each Land Mapping Units (LMU). Expert knowledge describes the proposed land use in physical and economical terms. In this paper, only the results of physical land evaluation analysis were presented. An example of decision tree operation in ALES used in this research is shown in Figure 2. The results of ALES analysis were then transferred to Arc-GIS for geographical referencing and describing the results in form of maps and tables.

Mapping of soil and land suitability analysis were only done for non-forest area and area which officially allowed for cultivation, namely the Area for Other Uses (AOU). For that purpose, at the early stage, delineation was performed by using Map of Forest Area Status at scale of 1:250,000 from Ministry of Forestry. Special attention was given regarding the use of this map at

```
f (Nutrients Retention) >> Soil pH
-1. [Very Low] >> Soil pH
-                              -1. [<4.0]........ *5 (N2)
-                              -2. [4.0-<4.5].. *3 (S3)
-                              -3. [4.5-5.5].... =2
??
-                              -7. [>8.5]........ =1
-2. [Low] >> Soil pH
-                              -1. [<4.0]....... *5 (N2)
-                              -2. [4.0-<4.5].. *3 (S3)
-                              -3. [4.5-5.5].... *2 (S2)
-                              -4. [5.5-7.0].... =3
??
-                              -6. [8.0-8.5].... =2
-                              -7. [>8.5]........ =1
-3. [>Medium] >> Soil pH
-                              -1. [<4.0]........ *5 (N2)
-                              -2. [4.0-<4.5].. *3 (S3)
-                              -3. [4.5-5.5].... *2 (S2)
-                              -4. [5.5-7.0].... *1 (S1)
-                              -5. [7.0-8.0].... =3
-                              -6. [8.0-8.5].... =2
-                              -7. [>8.5]........ =1
```

Discriminating entities are introduced by ' >> ' and underlined.
Values of the entities are [boxed].
The level in the tree is indicated by the leader characteristics, ' - '.
The level in the branch is indicated by a numeric value.
Result values are introduced by ' ......* '.
At the same level, ' = ' indicate the same result as the branch with the numeric value that follows.
The cut part of the tree is indicated by '??'
Figure 2. Example of decision tree used in this research to obtain land suitability class according to limiting factor of nutrients retention (f) of soil pH.

Figure 2. Example of decision tree used in this research to obtain land suitability class according to limiting factor of nutrients retention (f) of soil pH.

scale of 1:250,000. In the current condition, Map of Forest Status in Indonesia only available at such scale, without detailed map. Thus, at the operational level, delineated boundary became a concern that required more detailed mapping.

Overlay of the maps and data available using Geographic Information System produced paddy field land classification in 3 groups: (i) the existing paddy field; this is the paddy field area delineated from IKONOS imagery, (ii) land which is currently not a paddy field area, but potentially developed as paddy field; this is the land beyond the existing paddy field, allows for the development of paddy field, have a paddy field land suitability at least marginally suitable (S3), and lies outside the forest area by Map of Forest Area Status, and (iii) land that is currently not paddy field area and is not possible or not potentially developed for developed as paddy field; this is the case for settlements, ponds, mangroves and water bodies.

For technical reason of paddy field development on relatively flat area, and since the data is available at 1:25,000 scale, additional criteria was applied to land that is currently not a paddy field, but has a potential to be developed as paddy field. A requirement of slope less than 3% was then applied. For this purpose, an overlay with the slope class map derived from contour map of 1:25,000 scale was done. The contour map was obtained from Geospatial Information Agency, Indonesia, which was used also as the base map for this research.

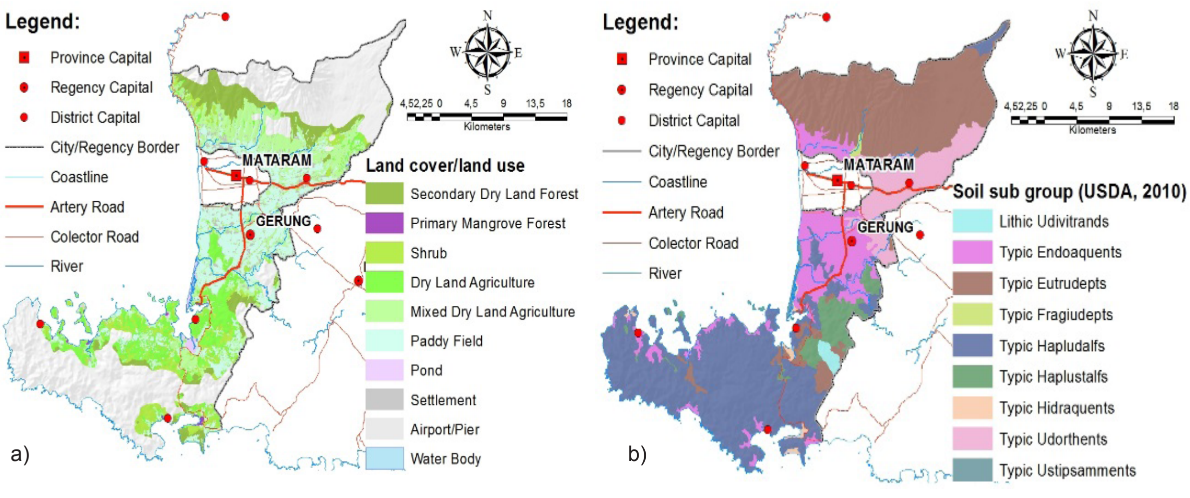

Figure 3. Map of land use and land cover of Area for Other Uses (AOU) (a) and map of main soil sub-group (b) in West Lombok Regency

Table 2. Land use and land cover in the area of Other Uses Area (OUA), West Lombok Regency

No	Land Use/Land Cover	Area	
		Ha	%
1	Primary Dry Land Forest	6,915.97	12.72
2	Mangrove Forest	162.15	0.30
3	Shrub	5,964.51	10.97
4	Dry Land Farming	8,858.11	16.29
5	Mixed Dry Land Farming	13,660.95	25.13
6	Paddy Field	14,987.26	27.57
7	Pond	741.72	1.36
8	Settlement	2,874.08	5.29
9	Airport	5.38	0.01
10	Water Body	191.81	0.35
	Total	54,361.94	100.00

3. Result and Discussion

From the results of the analysis of land use and land cover, only at the area with forest status of AOU are presented in Figure 3a and Table 2. The main land use and land cover in West Lombok Regency are paddy field, dryland mixed farming, dryland farming, primary dry land forest, shrub and settlements, respectively.

Results of overlay among paddy field area delineated from IKONOS image interpretation, area with non-paddy field resulting from SPOT-5 interpretation, and area of AOU, produce an area which is then analyzed its land suitability for paddy field.

Overall, Lombok Island is divided into 52 LMU, however in West Lombok Regency there are only 27 LMU. The LMU components used in this study include soil class data (in sub-group categories) [USDA, 2010], parent material, slope, and physiography. Soil map of West Lombok Regency, based only on soil sub-group is presented in Figure 3b. Summary of the soil distribution from the study area is presented in Table 3.

In West Lombok Regency, the paddy field area reached 14,987.26 Ha, or 27.57% of the total area. According to statistical data [BPS, 2013b], the total area of paddy field is 16,754 Ha, constituted of irrigated paddy field area of 10,538 Ha, semi irrigated paddy field area of 554 Ha, simple irrigated paddy field area which cover 399 Ha, village irrigation paddy field area which cover 1,537 Ha and rainfed paddy field area of 3,726 Ha. There is a difference of 1,767 Ha between the statistical data and the data from image interpretation. Several reasons can cause this difference. First, it is possible that in image analysis, different types of paddy field were not identified, so all of the types were simply identified as paddy field. Secondly, the difference can also be due to different measurement accuracy, as has been found in previous studies. Remote sensing technique is very useful for the detection of paddy field [Wahyunto, et al., 2004]. The accuracy of the previous analysis is 89.4%. With increasing slopes, paddy field deviation detection will be higher. In this study, the accuracy of the image interpretation with statistical data is 89.5 % of the statistical data. As a comparison, the analysis in East Lombok Regency, where the area is relatively flat, the data accuracy reaches 97.14% [Widiatmaka et al., 2013].

The soil in West Lombok Regency comprises 4 soil orders [USDA, 2010], covering Alfisols, Inceptisols, Entisols and Andisols. In the sub-group category, there are 9 sub-groups. Alfisols occupies the largest area, covering 38,261.41 Ha, or 41.4% of the area. Another soil order which is also quite widely spread is Inceptisols, which covers 29,174.14 Ha or 31.6%. The dominancy of Inceptisols and Alfisols are related to soil development which was influenced by local climate. Alfisols is characterized by an accumulation of clay namely argillic horizon and has a high base saturation (>35%). Inceptisols is a soil which is relatively young, the soil development is not too advanced, characterized by the presence of cambic horizon. Development of Inceptisols and Alfisols are related to the relatively dry climate areas [Tan, 2009].

Result of soil analysis, used as land qualities and

Table 3. Summary of main soil sub-groups in LMU of West Lombok Regency

No	Soil Class (soil group)	Land Mapping Unit	Area	
			Ha	%
1	Typic Hapludalf	2; 6	33,663.08	36.40
2	Typic Fragiudept	3	242.51	0.26
3	Typic Haplustalf	7; 12; 27	4,598.33	4.97
4	Typic Eutrudept	8; 13; 14; 15; 16; 34; 35; 38; 40; 51; 52	28,931.63	31.30
5	Typic Hidraquent	19	687.62	0.74
6	Lithic Udivitrand	25; 26	704.78	0.76
7	Typic Endoaquent	28	12,961.38	14.00
8	Typic Udorthent	32; 33	10,352.52	11.20
9	Typic Ustipsamment	36; 37; 45; 48	34.34	0.47
	Total		92,576.19	100.00

Table 4. Result of soil analysis, used as land qualities and land characteristics for land evaluation

No	Mapping Unit	Rooting Condition (r)			Nutrient Retention & Fixation (f)				Nutrient Availability (n)			Erosion Hazard (e)
		Drainage	Texture	Effective Soil Depth(cm)	CEC[1)] (me/100g)	Base Saturation[1)] (%)	pH[2)]	Organic Carbon[1)] (%)	Nitrogen total[1] (%)	P_2O_5[1)] (ppm)	K_2O[1)] (me/100g)	Slope (%)
1	SPL2	imperfectly	clay	>90	47.49/vh	>100/vh	7.03/n	0.61/vl	0.05/vl	21.10/m	201/vh	3-8
2	SPL3	moderatly	loam	>90	5.9/l	>100/vh	6.19/sa	0.63/vl	0.05/vl	66.30/h	106.59/vh	0-3
3	SPL6	well	clayey loam	90-50	33.31/h	>100/vh	6.04/sa	0.74/vl	0.07/vl	7.65/l	93.54/vh	0-3
4	SPL7	well	loam	90-50	13.3/l	>100/vh	6.16/sa	0.9/vl	0.09/vl	61.63/h	196.86/vh	3-8
5	SPL8	moderatly	sandy clayey loam	>90	13.89/l	>100/vh	5.5/a	2.82/m	0.26/m	8.22/l	56/h	0-3
6	SPL12	well	loam	90-50	7.59/l	>100/vh	6.14/sa	0.87/vl	0.07/vl	1.97/vl	36/m	0-3
7	SPL13	moderatly	clayey loam	>90	14.9/l	>100/vh	5.83/a	0.46/vl	0.04/vl	15.36/m	66/vh	0-3
8	SPL14	imperfectly	sandy loam	>90	8.64/l	>100/vh	5.95/sa	0.91/vl	0.09/vl	10/l	55.57/h	3-8
9	SPL15	well	loam	90-50	10.01/l	92,80/vh	5.37/a	1.13/l	0.11/l	61.36/vh	60.32/vh	0-3
10	SPL16	moderately	sandy loam	90-50	7.53/l	>100/vh	5.77/sa	0.99/vl	0.09/vl	4.81/l	63.89/vh	3-8
11	SPL19	poorly	loam	50-25	20.22/m	>100/vh	8.2/aa	0.85/vl	0.07/vl	29.17/h	347.50/vh	0-3
12	SPL25	well	clayey loam	90-50	16.79/m	99,16/vh	5.88/sa	0.97/vl	0.09/vl	35.78/h	168.36/vh	0-3
13	SPL26	moderately	loam	90-50	18.8/m	>100/vh	5.96/sa	0.88/vl	0.07/vl	4.61/l	177.54/vh	3-8
14	SPL27	well	loam	>90	17.03/m	>100/vh	6.48/sa	1.01/l	0.09/vl	62.63/h	179.96/vh	0-3
15	SPL28	well	loam	>90	9.2/l	>100/vh	6.53/sa	0.84/vl	0.07/vl	15.66/m	52.34/h	0-3
16	SPL32	well	clayey loam	>90	31.52/h	>100/vh	7.4/n	1.92/l	0.2/l	7.79/l	173.78/vh	3-8
17	SPL33	poorly	clayey loam	50-25	25.48/h	52,71/vh	4.7/a	1.21/l	0.11/l	0.35/vl	67.52/vh	0-3
18	SPL34	well	sandy loam	>90	7.81/l	>100/vh	5.8/sa	1.47/l	0.12/l	16.76/m	52.59/h	0-3
19	SPL35	imperfectly	sandy loam	90-50	5.45/l	>100/vh	5.82/sa	1.56/l	0.13/l	14.05/m	40.67/h	3-8
20	SPL36	well	sand	50-25	2.63/vl	>100/vh	7.1/n	0.18/vl	0.02/vl	5.88/l	139.90/vh	0-3
21	SPL37	imperfectly	sand	50-25	9.4/h	73,83/h	5.09/a	0.3/vl	0.03/vl	17/m	88.64/vh	3-8
22	SPL38	well	sandy loam	>90	7.24/h	>100/vh	5.8/sa	1.14/l	0.11/l	27.66/h	77.30/vh	0-3
23	SPL40	imperfectly	loam	50-25	8.69/l	>100/vh	6.5/sa	0.98/vl	0.07/vl	29.11/h	56/h	0-3
24	SPL45	well	clayey loam	90-50	29.48/h	>100/vh	7.34/n	1.3/l	0.1/l	7.95/l	199.52/vh	0-3
25	SPL48	well	sand	90-50	8.94/l	>100/vh	7.94/aa	0.46/vl	0.04/vl	9.67/l	146.57/vh	0-3
26	SPL51	well	loam	90-50	15.16/l	>100/vh	6.57/n	0.96/vl	0.08/vl	19.62/m	126.91/vh	0-3
27	SPL52[4]	well	sandy loam	>90	12.57/l	>100/vh	6.16/sa	0.91/vl	0.09/vl	55/h	65/vh	3-8

[1)]After slash, fertility status according to [CSR, 1983]: vl= very low; l= low; sl= slightly low; h= high; vh= very high.;
[2)]After slash, pH status according to [CSR, 1983]: a= acid; sa= slightly acid;

land characteristics for land evaluation, are presented in Table 4. The actual and potential land suitability maps resulting from land evaluation analysis in the area of existing paddy field are presented in Figure 4a and 4b. Results of land suitability analysis show that the existing paddy field has land suitability class ranged from S2 (suitable) to S3 (marginally suitable). In both land suitability classes of S2 and S3, the main limiting factors include land qualities of w (water available), r (rooting medium), f (nutrient retention) and n (available nutrients).

The limiting factor of water available (w) is generally caused by the length of dry month and the amount of monthly rainfall. The climate in the study area is relatively dry, although still wetter than its neighbour regency, East Lombok Regency for example. If rainfall is classified by number of dry months (<75 mm) used in the criteria (Table 1), then the number of dry month is 8 months. Such long dry season is still situated in the S2 class for paddy field. The limiting factor of rooting medium (r) is generally caused by land characteristic of soil texture. Texture in most soil samples ranged from loam, sandy clay loam to sandy loam, and even sand. Thus, rough textures restrict the efficiency of water availability for paddy field. The limiting factor of nutrient retention (f) are generally determined by cation exchange capacity (CEC) and soil organic Carbon (organic-C) content. Only a few samples showed high pH properties that become a limiting factor. CEC values of the samples ranged from very low to high when it is clasified based on the assessment criteria of soil chemical properties [CSR, 1983]. Lowest value of soil CEC in West Lombok samples is 5.9 me/100 g (low), while the highest value is 47.49 me/100 g (high). Organic-C content of the samples ranged from 0.61% (very low) to 2.82 (high). Meanwhile, the limiting factor fof available nutrient (n) is the content of P_2O_5 and total Nitrogen (total-N) which is generally low. P_2O_5 content of the samples range from 1.97 ppm (very low) to 61.63 ppm (high). Total-N values ranged from 0.04 (very low) to 0.7 (moderate). Of course, for samples with CEC and nutrient levels moderate to high, these parameters do not become limiting factors.

To overcome some limiting factors, improvement can not be done at farming scale. Examples for this are limiting factor of water availability (w) caused by the number of dry month and rooting medium (r) caused by the soil texture. Other limiting factors can be improved by some improvement efforts. Nutrient retention (f), caused by low CEC can be improved through application of organic manures. Nutrients available (n) can be improved through application of Phosphate (P) fertilizer and application of organic manures. Such improvement efforts can be expressed as an intensification of paddy field.

Land suitability classes can be increased by the improvement. Besides the improvements according to each limiting factor identified by land suitability analysis, almost all existing paddy field production can be increased by development of irrigation canals.

Based on statistical data [BPS, 2013b], from the total area of 16,754 Ha paddy field in West Lombok Regency, area that technical irrigated is 10,538 Ha, or 62.9%. The rest (about 37.1%) are half irrigated or rainfed paddy fields. Based on the statistical data [BPS, 2013b], it is also known that from 16,754 Ha of paddy field, the harvested paddy area in 2011 was 28,386 Ha, or an average of 1.69 Farming Index. Improvement of irrigation infrastructure is expected to increase the Farming Index, which in turn increase the production.

Figure 4a presents the actual land suitability map [Widiatmaka, 2013b] of the existing paddy field, while Figure 4b presents the potential land suitability map for the existing paddy field under condition that improvement has been made according to each limiting factor. Table 5 presents the coverage area of land suitability in the existing paddy field area. In this table, recommedations for the improvements are given based on limiting factor, coupled with improved irrigation treatment needs. Thus, this table presents the potential intensification that may be suggested in existing paddy field area in West Lombok Regency.

Results of land suitability analysis at non-paddy field area which are considered as potential area for paddy field development show that the main limiting factors in non-paddy field area includes land qualities of w (water

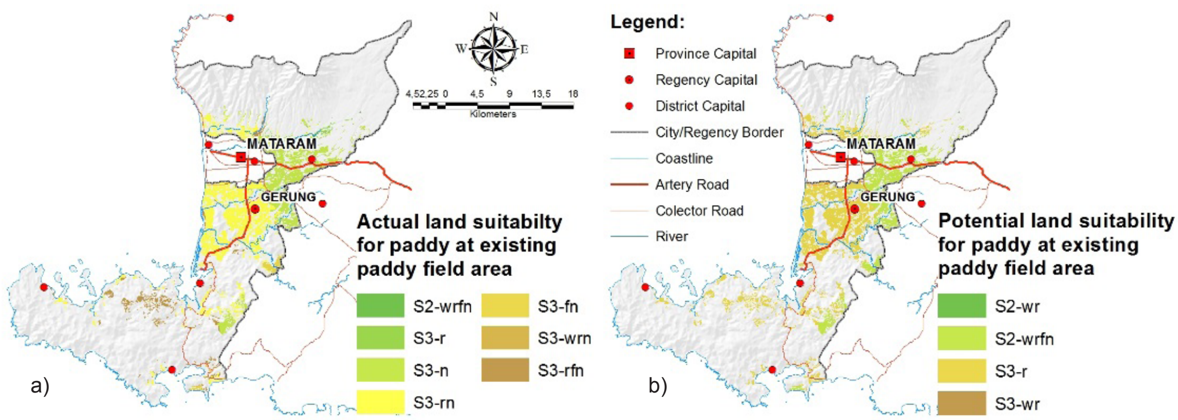

Figure 4. Map of actual (a) and potential (b) land suitability for paddy field in existing paddy field area in West Lombok Regency.

Table 5. Actual land suitability for paddy in existing paddy field area and improvement needed for paddy field intensification.

No	Land Suitability	Improvement	Area	
			Ha	%
1	S2-wrfn	Phosphate fertilizer, organic manures, irigation improvement	3.96	0.03
2	S3-r	Irigation improvement	204.18	1.36
3	S3-n	Phosphate fertilizer	5,264.67	35.13
4	S3-rn	Phosphate fertilizer, organic manures, irigation improvement	7,595.15	50.68
5	S3-fn	Phosphate fertilizer, irigation improvement	477.18	3.18
6	S3-rfn	Phosphate fertilizer, irigation improvement	1,440.46	9.61
7	S3-wrn	Phosphate fertilizer, organic manures, irigation improvement	1.66	0.01
	Total		14,987.26	100.00

availability), r (rooting medium), f (nutrient retention), and n (available nutrients). The improvement effort can be given to enhance the land suitability, including application of organic manures and P fertilizer to improve the limiting factors of nutrient retention. In addition to increase the its potential based on existing limiting factors, the improvements necessary for this non-paddy field area is of course irrigation canals development.

Figure 5 presents the land suitability of potential land which can be developed as paddy field. Table 6 presents land suitability classes on potential land which can be used as paddy field. From the table, it can be seen that there is an ample potential for extending the paddy field.

Theoritically, the potential land for paddy field extension in West Lombok Regency reaches 5,965 Ha. This potential is a theoretical potential, in terms of land suitability and several other factors which are considered in this study: the forest status and slope. In details, there are still other considerations needed, including the need for land utilization other than paddy,

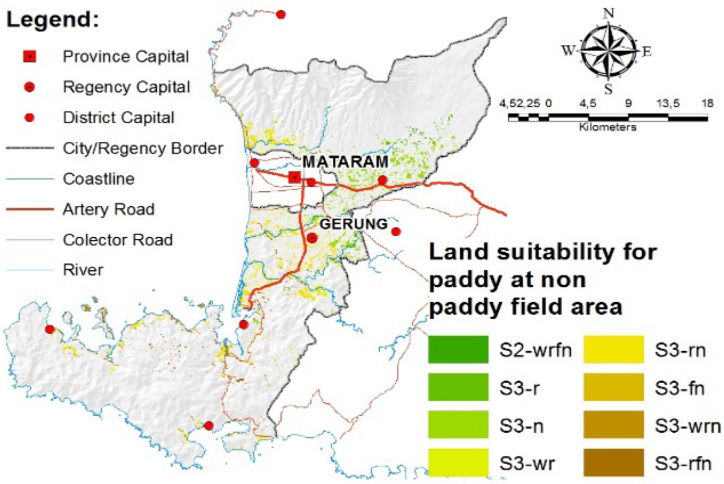

Figure 5. Map of land suitability for paddy in the non-paddy field land potentially used as paddy field in West Lombok Regency.

Table 6. Land suitability for paddy field in the non-paddy field area potential in West Lombok Regency.

No	Land Suitability	Improvement	Area	
			Ha	%
1	S2-wrfn	Phosphate fertilizer, organic manures, irigation building	29.48	0.49
2	S3-r	Irrigation building	151.87	2.55
3	S3-n	Phosphate fertilizer	1,961.49	32.88
4	S3-wr	Organic manures, irrigation building	35.29	0.59
5	S3-rn	Phosphate fertilizer, organic manures, irrigation	2,770.61	46.45
6	S3-fn	Phosphate fertilizer, irigation building	145.55	2.44
7	S3-rfn	Phosphate fertilizer, irigation building	713.20	11.96
8	S3-wrn	Phosphate fertilizer, organic manures, irigation building	157.59	2.64
	Total		5,965.08	100.00

the ability of governments to finance the paddy fields development, and other technical factors. Nevertheless, this research has indicated the potential land that can be used for increasing rice production. In addition, the implementation would also requires more detailed planning on a higher scale. The land use planning given in this research can be considered as a midle scale land use planning. The next macro scale land use planning should be done based on this research result.

4. Conclusion

In West Lombok Regency, there are still wide areas for intensification of existing paddy field. Improvement treatment necessary for this intensification may include providing input to overcome limiting factors identified in this study, as Phosphate fertilization, application of organic manures, and improvement of irrigation infra-structure in most areas. On the other hand, there are numbers of potential areas identified for extending paddy field. In theoretical calculations, the potential areas is 5,965 Ha. This information, which is accompanied by spatial information can be used as a reference to the next detailed planning of the regency to increase rice production. This research can be followed for more detailed planning. Operational intensification and extension can be mapped at a more detailed scale, with area prioritization. Calculations can also be done in more detail in increasing production with reference to the concept of FAO [FAO, 1976], which theoretically has described that there are different productivity of different land suitability classes.

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