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THE COMBINATION OF LAND RESOURCE EVALUATION APPROACH AND GIS APPLICATION TO DETERMINE PRIME COMMODITIES FOR AGRICULTURAL LAND USE PLANNING AT DEVELOPED AREA (A CASE STUDY OF CENTRAL KALIMANTAN PROVINCE, INDONESIA)

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ABSTRACT

Land use planning based on land resource evaluation and spatial orientation of planning as part of GIS may ensures appropriate land allocation in order to achieve sustainable agriculture. The combination of some land resource evaluation can provide final results on rational land allocation and land utilization based on land capability and suitability. Land capability evaluation (LCE) and land suitability evaluation (LSE) approach rooted from USDA and FAO was used in this study to allocated arable land as agricultural developed areas and determine prime commodities spatially. The principle of limiting condition was used for LCE to define land class and determine land availability for agriculture. While, for LSE, procedure of matching between land quality/characteristics and crop requirement will be scored according to limitation method and class criteria of land suitability in order to define the most suitable crop considered as prime commodity. The objective of this study was to determine prime commodities at developed areas on the basis of information of land resources at regional scale of 250, 000. With GIS application, the result of evaluation were then integrated into spatial information as basic consideration for agricultural land use planning and further spatial analysis for agricultural land allocation as well. This study was conducted in Central Kalimantan province with total areas of 15, 451, 287 hectares in order to support policy of Indonesian Government for agricultural development especially for spatial agricultural land use planning. The results of this studies showed that based on LCE approach, almost 61.94% of total areas (9, 571, 231 hectares) is arable land indicating that lands geographicaly have an opportunity to be developed. While based on LSE approach and GIS application, there are 3 (three) prime commodities including their geographical distribution pattern that suitable to be developed in Central Kalimantan involving wetland rubber (7, 355, 390 hectares), rice (2, 141, 539 hectares), and oil palm (1, 722, 806 hectares). Appropriate programs in the scoupe of land use planning can then be formulated to support agricultural development at certain areas.

Keywords: land use planning, land resource, land evaluation, GIS, Central Kalimantan province.

INTRODUCTION

Not all the lands can be used optimally for agricultural development. Sustainable agriculture can be attained only when proper land utilization is practiced. When the land is utilized improperly, productivity rapidly decreases and the ecosystems become jeopardized. In an agricultural land region, determination of the most suitable commodity can then be considered as an effort to achieve sustainable agriculture based on its land resources. In the scoupe of sustainable agriculture, proper land use ensure people obtaining benefit from nature during lifetime and also ensure the resources can be used for future generation (Amien, 1998). In addition, the future productivity and profitability of farming would depend increasingly on measures taken from now on to conserve resources and protect the environment (Schaller, 1993).

The policy of Indonesian Government for agricultural development has been implemented through intensification and diversification of agriculture as well as extensification of lands. In Central Kalimantan province, known as one of three largest provinces in Indonesia, agriculture plays a very important role especially in economic development and has also become a key area in increasing the income of the people. By the end of 2012, the current land use showed that the lands that have been utilized for agricultural purposes such as food crop, horticulture, and estate is only 2.848.905 hectares or 18,44% of total area of Central Kalimantan. The other is mainly covered by forest with total areas 12, 602, 382 hectares (81, 56%). At regional province level, by implementing the policy of agricultural extensification, Central Kalimantan still has great opportunity to be developed.

The need for land resources evaluation as part of land use planning become apparent when the region has an opportunity to be developed and decisions on land use have always been part of the evolution of human society. By assessing land resources for alternative uses relative to the land - related requirements or goals of society, it should be possible to identify certain areas which are strategically important for particular activities (Flaherty and Smit, 1982). In order to achieve sustainable agriculture through proper land use, determination of prime agricultural commodity on the basis of land suitability can then be considered as initial step toward at developed areas. Spatial concepts for land use planning involving land allocation for agriculture can then be planned and performed accuratelly. It can then support regional development policy and common agricultural policy (Alexiadis *et al*., 2013).

Planning is underpinned by the assumption that adequate information exists for those exercising public authority to make decisions regarding the best use of land in the future (Flaherty and Smit, 1982) and it is concerned with the rational allocation of resources and with the resolution of conflicts between competing land uses (Selman, 1982). Moreover, it must be based on an understanding of both the natural environment and kinds of land use envisaged (FAO, 1976). The function of land use planning for agricultural purposes is therefore to guide decisions on land use in such way that the resources of environment are put to the most beneficial use, while at the same time conserving those resources for the future.

The evaluation of land resources can be considered as a basic tool for land use planning (Arshad, 1999 and Abdullah, 1993) and the assessment of land potentialities for agriculture purposes should be primarily based, not only on the appreciation of the important part which soil plays in plant growth (anchorage, storage of water and nutrients) but on a much wider basis, the ecological approach (Kowal, 1978). In addition, land management system and quality of land resource need to be evaluated in the term of productivity and sustainability as well (Latham, 1994). It can therefore be summarized that land evaluation is a vital link in the chain leading to sustainable management of land resources (FAO, 2007).

Initially, the basic concepts of land evaluation refer to "Land Evaluation Framework" proposed by FAO 1976. However, the guidelines of the Framework were then further developed in diverse publications for specific kinds of land uses such as irrigated agriculture, forestry, rain fed farming and applied in many countries without calling for significant changes in the overall methodology (FAO, 2005). In Indonesia, the procedure of land evaluation was also adopted from "Land Evaluation Framework" through matching process between land characteristics/land qualities and crop requirements (Indonesian Soil Research Institute, 2005). Mostly, qualitative evaluation was carried out by means of simple limitation and comparing land and climate characteristics with crop requirements (Behzad *et al*., 2009).

For specific kind of commodity, any crop can be evaluated based on its land resources suitability. However, for group of crop or several commodities, it is then need to be further evaluate specific commodity that is most suitable comparing to the others crops. In this study, any related land evaluation methods was than considered in order to determine sequence of suitability for each commodity. The most suitable commodity can then be considered as prime commodity at developed area based on land resources availability.

The main objective of this study was to determine prime commodities at developed areas on the basis of information of land resources at scale of 250, 000 using several land resources evaluation methods involving 1) land capability and 2) land suitability classification. With GIS application, the result of evaluation were then integrated into spatial information as basic consideration for agricultural land use planning and further spatial analysis for agricultural land allocation as well. The location selected for this case of study is Central Kalimantan province, Indonesia with total areas of 15, 451, 287 hectares (Figure-1).

MATERIALS AND METHODS

Land resources evaluation as main component for land use planning process was conducted on the basis of information at reconnaissance level with scale of 250, 000. This level refers to guidelines provided by Indonesian Government Regulation No. 100/2000 about mapping scales for spatial land use planning. The relevant information considered as basic data involves land (soil) resources and climatic data. Specifically, these includes land system maps, soil maps, agroclimatic map, peatland distribution map, countour map and other relevant data such as land quality/characteristic data and crop requirements for some selected crops.

Land resources evaluation approach as main methods used in this study consist primarily of land capability evaluation (LCE) and land suitability evaluation (LSE). The LCE approach was used in order to determine arable land considered as developed areas and non-arable land based on land capability classification. The methods of LCE approach refer to land capability classification proposed by USDA in which class I to IV, lands can still be utilized for agricultural purposes, while for class V to VIII, the lands are unsuited to cultivation (Panhalkar, 2011; USDA, 1973). Soil information provided by land mapping units involving slope classes, erossion, drainage, soil effective depth, texture, rock outcrop, and flooding were then evaluated referring to criteria for land capability classification. The principle of limiting condition, proposed by Dent and Young (1981), was used for LCE to define land class.

The methods of land suitability evaluation (LSE) used procedure of matching between land quality/characteristics and crop requirement. The minimum rule was used to determine limiting factors as land suitability class based on land use requirements and crop requirements (ISRI, 2005 and Sys *et al*., 1993). The criteria of land suitability for each crop refer to Tables 1-5 in order to define class S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable) and N (not suitable). The resulting land suitability classes were then scored according to limitation method and class criteria of land suitability proposed by Sys *et al.* (1991) in order to define the most suitability crop among slected crop within each land mapping unit. The use of limitation method refers to Table-6 to determine land suitability class based on number of limitation and total scores as well. While for land class criteria, it used Table-7 to determine land suitability class including its score. Land classes of each land mapping unit as a result of macthing process, limitation methods, and land class criteria were then scored. The lowest total score for each crop within certain land mapping unit was then considered as the most

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suitable crop or prime commodity comparing to the others. In this study, 5 (five) crops involving rice, maize, soybean, rubber, and oil palm have been selected because of highly economical value of agricultural commodities in Central Kalimantan province. The LSE approach was conducted by evaluating land mapping units suitable for cultivation or developed area for agriculture as a result of LCE.

Geographic Information System (GIS) application was used to process spatial data involving digitally mapping process and spatial analysis. The result of LCE and LSE were then integrated into GIS environment. The data input and results in the form of digitized map are component of GIS which facilitate future utilization, updating, improvement, storing, and displaying (Son and Rajendra, 2008; Andy *et al*., 2002; Eswaran, *et al*., 1992 and Tomlinson, 1968). A PC based GIS called Mapinfo Professional 9.0 and Globar Mapper 8.0 were employed for mapping process and spatial analysis as well. While for GPS (Global Positioning System), a device based GIS, it was used for field verification and ground checking based on resulting maps for correction and improvements. The general procedure of study is described at Figure-2.

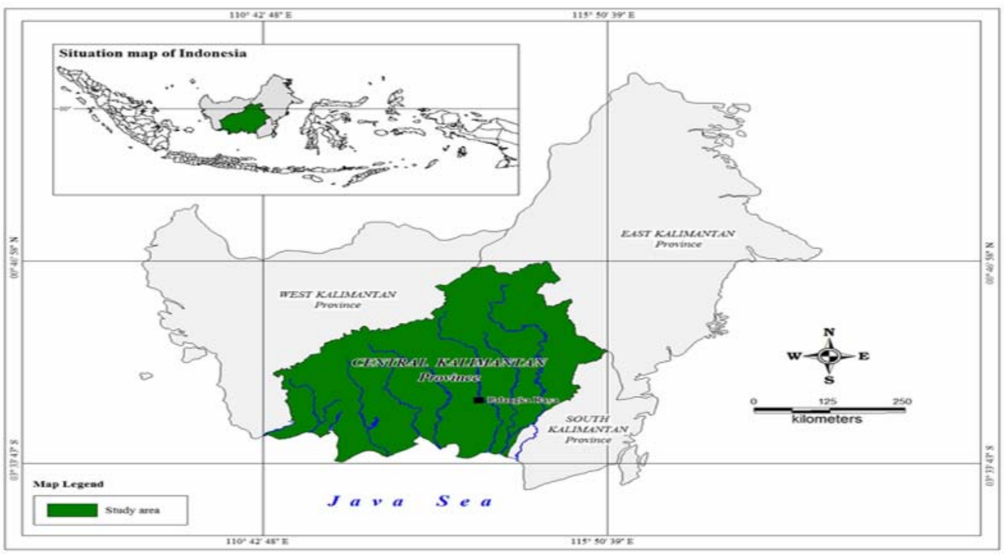

Figure-1. Map of study area.

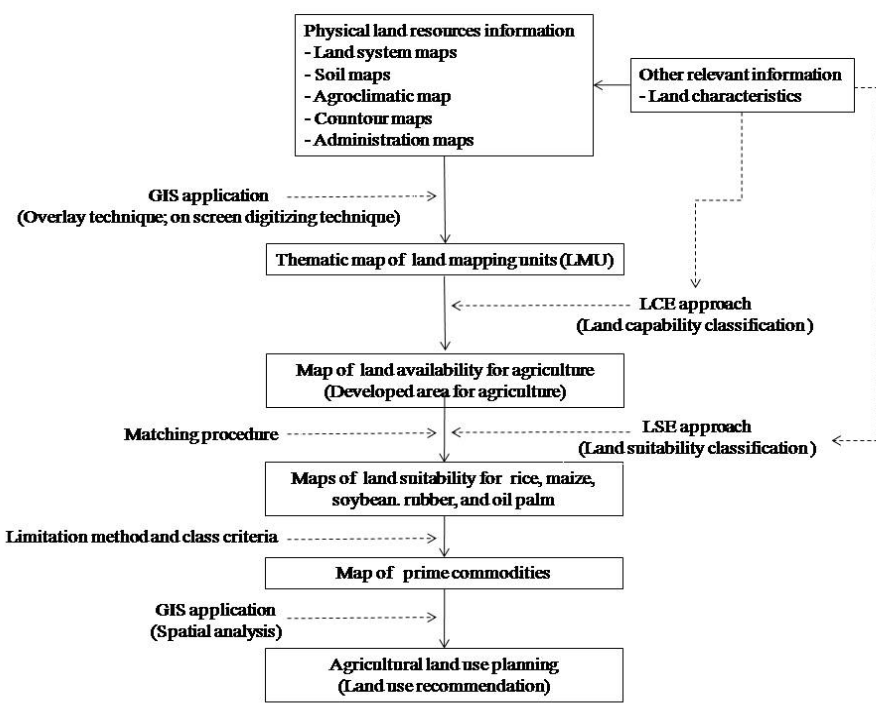

Figure-2. Flowchart of general procedure in this study.

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Table-1. The criteria of land suitability for wetland rice.

Land characteristics	**Land suitability class**			
	S1 (highly suitable)	**S2** (moderately suitable)	**S3** (marginally suitable)	**N** (not suitable)
Average temperature (^{o}C)	24-29	29-32	32-35	>35
Rainfall (mm/year)	> 1500	1200-1500	800-<1200	-
Length of dry season (month)	<3	3-8	9-10	-
Drainage	Poor	Imperfectly drained	Moderately well drained	Well drained
Texture	Fine	Medium	Moderate coarse	Coarse
Soil effective depth (cm)	>50	40-50	25-40	<25
Peat depth (cm)	<60	60-140	140-200	>400
Peat ripeness	Saprists	Saprists/Hemists	Hemists/ Fibrists	Fibrists
CEC (cmol/kg)	>16	≤16	-	-
Base saturation (%)	>50	35-50	<35	-
Soil acidity (H2O)	5,5-8,2	4,5-5,5	<4,5	-
C-organic (%)	>1,5	0,8-1,5	<0,8	-
Slope class (%)	<3	3-5	5-8	>8
Erossion hazard	Very low	Low	Medium	High
Floofing hazard	Slight	Moderate	Severe	Very severe
Rock outcrop (%)	<5	5-15	15-40	>40

Table-2. The criteria of land suitability for maize.

Land characteristics	**Land suitability class**			
	S1 (highly suitable)	**S2** (moderately suitable)	**S3** (marginally suitable)	**N** (not suitable)
Average temperature (^{o}C)	20-26	26-30	30-32	>32
Rainfall (mm/year)	500-1200	1200-1600	>1600	-
Length of dry season (month)	1-6	7-8	8-9	-
Drainage	Well drained	Moderately well drained	Imperfectly drained	Poor
Texture	Fine	-	Moderate coarse	Coarse
Soil effective depth (cm)	>60	40-60	25-40	<25
Peat depth (cm)	<60	60-140	140-200	>200
Peat ripeness	Saprists	Saprists/Hemists	Hemists/ Fibrists	Fibrists
CEC (cmol/kg)	>16	≤16	-	-
Base saturation (%)	>50	35-50	<35	-
Soil acidity (H_2O)	5,8-7,8	5,5-5,8	<5,5	-
C-organic (%)	>0, 4	≤0, 4	-	-
Slope class (%)	<8	8-16	16-30	>30
Erossion hazard	Very low	Low	Medium	High
Floofing hazard	Slight	Moderate	Severe	Very severe
Rock outcrop (%)	<5	5-15	15-40	>40

Table-3. The criteria of land suitability for soybean.

Land characteristics	Land suitability class			
	S1 (highly suitable)	**S2** (moderately suitable)	**S3** (marginally suitable)	**N** (not suitable)
Average temperature (^oC)	23-25	25-28	28-32	<18; >32
Rainfall (mm/year)	350-1100	1100-1600	1600-1900	>1900
Length of dry season (month)	3-7	8-9	9-10	>10
Drainage	Well drained	Moderately well drained	Imperfectly drained	Poor
Texture	Fine	Medium	Moderate coarse	Coarse
Soil effective depth (cm)	>75	50-75	20-50	<20
Peat depth (cm)	<60	60-140	140-200	>200
Peat ripeness	Saprists	Saprists, Hemists	Hemists, Fibrists	Fibrists
CEC (cmol/kg)	>16	≤16	-	-
Base saturation (%)	>35	20-35	<20	-
Soil acidity (H2O)	5,5-7,5	7,5-7,8	>7,8	-
C-organic (%)	>1,2	0,8-1,2	<0,8	-
Slope class (%)	<8	8-16	16-30	>30
Erossion hazard	Very low	Low-medium	Medium	High
Floofing hazard	Slight	-	Moderate	Severe
Rock outcrop (%)	<5	5-15	15-40	>40

Table-4. The criteria of land suitability for oil palm.

Land characteristics	Land suitability class			
	S1 (highly suitable)	**S2** (moderately suitable)	**S3** (marginally suitable)	**N** (not suitable)
Average temperature (^oC)	25-28	28-32	32-35	<20; >35
Rainfall (mm/year)	1700-2500	2500-3500	3500-4000	<1250; >4000
Length of dry season (month)	<2	2-3	3-4	>4
Drainage	Well drained	Moderately well drained	Imperfectly drained	Poor
Texture	Fine	-	Moderate coarse	Coarse
Soil effective depth (cm)	>100	75-100	50-75	<50
Peat depth (cm)	<60	60-140	140-200	>200
Peat ripeness	Saprists	Saprists, Hemists	Hemists	Fibrists
CEC (cmol/kg)	>16	≤16	-	-
Base saturation (%)	>20	≤20	-	-
Soil acidity (H2O)	5,0-6,5	4,2-5,0; 6,5-7,0	<4,2; >7,0	-
C-organic (%)	>0,8	≤0,8	-	-
Slope class (%)	<8	8-16	16-30	>30
Erosion hazard	Very low	Low-medium	High	Very high
Floofing hazard	Slight	Moderate	Severe	Very severe
Rock outcrop (%)	<5	5-15	15-40	>40

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Table-5. The criteria of land suitability for rubber.

Land characteristics	Land suitability class			
	S1 (highly suitable)	S2 (moderately suitable)	S3 (marginally suitable)	N (not suitable)
Average temperature (^oC)	26-30	30-34	22-24	>34
Rainfall (mm/year)	2500-3000	3000-3500	3500-4000	>4000
Length of dry season (month)	1-2	2-3	3-4	>4
Drainage	Well drained	Moderately well drained	Imperfectly drained	Poor
Texture	Fine	Medium	Moderate coarse	Coarse
Soil effective depth (cm)	>100	75-100	50-75	<50
Peat depth (cm)	<60	60-140	140-200	>200
Peat ripeness	Saprists	Saprists/Hemists	Hemists/Fibrists	Fibrists
CEC (cmol/kg)	-	-	-	-
Base saturation (%)	<35	35-50	>50	-
Soil acidity (H2O)	5,0-6,0	4,5-5,0	<4,5	-
C-organic (%)	>0,8	≤0,8	-	-
Slope class (%)	<8	8-16	16-30	>30
Erossion hazard	Very low	Low	Medium	High
Floofing hazard	Slight	Moderate	Severe	Very severe
Rock outcrop (%)	<5	5-15	15-40	>40

Table-6. Relationship between level of limitation and land suitability class.

Limitation level	Score number	Land Suitability class
No limitation	0	S1 (highly suitable)
Slight	1	S2 (moderately suitable)
Moderate	2	S3 (marginally suitable)
Severe/very severe	3	N (not suitable)

Table-7. Relationship between criteria and land suitability class.

Criteria	Land suitability class
LMU with no limitation or ≤ 4 S2 classes	S1 (highly suitable)
LMU with > 4 S2 classes or/and or ≤ 3 S3 classes	S2 (moderately suitable)
LMU with > 3 S3 classes or/and or ≤ 3 N1 classes	S3 (marginally suitable)
LMU with > 3 N classes or/and or ≤ 2 N classes	N (not suitable)

Note: LMU = land mapping unit

RESULTS AND DISCUSSIONS

Land resource and climate information

The region of Central Kalimantan province consists primarily of upland and lowland areas. Upland areas are located in central to northern part with elevation range 100 to 500 meters above sea level, while lowland areas are found in the Southern part at elevation below 100 meters. Most of the upland areas are highly weathered, acidic, infertile and poorly buffered soils (Adiningsih *et al*., 1988). While in the southern part dominated with lowland areas also known as wet land, they consist of swamp and peat land. In general, with appropriate land management, the agricultural land region is potential for crop cultivation ranges from low to high for wetland rice and moderate for dry land food crops and perennial crops (Sawiyo *et al*., 2000).

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The major landform groups of Kotawaringin Barat Regency are alluvial, terraces, peat, marine, karstic, intrusion, uplifted, and folded. Alluvial group as typical landform of Central Kalimantan consist of several sub-groups such as streambelts, waterlogged plain, backswamp, and valleys occur on central to southern parts at main river stream belts. For terrace, peat and marine group, in the south, it is also found subgroup point bar and tidal flat. While for group of karstic, intrusion, uplifted, and folded, they occur in the central to the nothern part. The predominant parent materials that develop this landform are old and recent alluvium, peat, sandstone, schist, phyllite, quartzite, granite, and limestone (Centre for Soil and Agroclimare Research, Bogor, 2000).

The topography of Central Kalimantan province is hillocky plain and mountainous in the northern part with an elevation between 150-500 meters above sea level. While, in the Southern part, it is flat consisting of swamp and coastal beach, affected by tidal, with the elevation between 0 - 50 meters. In the central part, the topography is flat to hilly (undulating) with elevation from 50 to 150 meters.

The major soil types found in Central Kalimantan that have been classified according to Soil Survey Staff (2010) include Entisols, Inceptisols, Spodosols, Mollisols, Alfisols, Ultisols, dan Histosols. Geographically, orders of Mollisols, Alfisols and Ultisols are mainly found in the central to nothern part. While for Entisols, Inceptisols, Spodosols, and Histosols, they are found in central to southern part, recognized as wetlands.

The climate of Kalimantan Island where Central Kalimantan lies on is determined by its geographical position on the equator. Geographically, it is considered as wet equatorial climates that occur mainly within 5^o north and south of the equator. It is dominated during most of the year by deep, moist, equatorial air masses and frequent heavy convectional rainfall (Webster and Wilson, 1980). The same with other principle islands in Indonesia, it has two monsoons. The wet monsoon usually starts from October to March, while dry monsoon occurs on April to September (Oka, 1982). By the end of 2012, based on the last ten years record, annual precipitation of this region is 2449 mm to 3229 mm. Period of consecutive wet months ranged between 10-12 months while dry months occur between 0-2 months. The high precipitation is influenced by temperature resulting in high evaporation intensity, causing water-saturated air conditions and potentially active rain cloud. For soil temperature and moisture regime, they have fairly homogeneous conditions for each climatic regime. Since the elevation of the whole areas of Central Kalimantan is less than 70 meters above sea level, the temperature regim is isohyperthermic, while moisture regime is udic in which the number of consecutive dry months is less than 3 months per year.

The basic map for LCE, LSE, and land use planning

In this study, basic information was used based on reconnaisance survey with scale of 250, 000. At this scale, both approach and method can be utilized as a basis for further land evaluation and land use planning in large teritories including at regional province level (Bocco *et al*., 2001, Djomantara and Naniek, 2000; Gerald *et al*., 1977). Basic information involving soil maps, land system maps, agroclimatic map, peatland distribution map, and countour maps was processed with aid of GIS application through overlay technique to develop new map with new delineated homogeneous polygons known as thematic map of land mapping units (LMU). For mapping process, this technique play a central role in many GIS applications because of its simplicity for the implementation in vector and raster GIS (O'Sullivan and Unwin, 2003). The identification and delineation of land units was then verified through field verification.

Cartographically, based on the result of mapping process, there are 24 LMU's, (LMU 1 to LMU 24). As part of GIS, the map of LMU provide sistem database in the form of spatial and tabular data. Additional land characteristic data was then integrated into database system stored in Mapinfo software for updating, analysis, and displaying during land evaluation process.

Land capability evaluation (LCE)

In the term of sustainability, the use of land is primarily determined by land capability through land allocation for arable land and non arable land so that LCE approach is suitable for farmland (Panhalkar, 2011; Davidson, 1992; Dent and Young 1981). On the basis of biophysical land resources and land capability classification method proposed by USDA, the region of Central Kalimantan province was primarily classified into 5 land capability classses i.e., class II, class III, Class IV, class VI, and class VII. This classification can help ascertaining agricultural production potential of land on a sustain basis (Pandey *et al*., 2006). Therefore, it lead to determining land allocation for non-arable land and arable land as developed areas for agricultural development and basic consideration for land use planning as well.

Based on thematic map of LMU, 21 land units were classified into arable land while the remaining 3 land units falls into non-arable land. For class I, the excellent class for arable use was not found because of no land parameter suitable with land criteria. This condition was also found for class V and class VIII. Some criteria, not suitable with general condition of land resources in Central Kaimantan involve land slope more than 65%, present of rock outcrop, and flooding hazard. While for five major land classes as a result of LCE the main limiting factors involve slope, drainage, peat depth, and texture. For each land class, it can be described in Table-8.

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Table-8. Land capability classification in central Kalimantan province.

Land capability class	**Limiting factors**	**Area** (Hectares)	**% of total area of Central Kalimantan province**
II	Slope (>3-8%)	2, 639, 935	17,09
III	Slope (>3-8%); drainage (poor)	3, 899541	25,24
IV	Slope (>15-30%)	3, 031, 755	19,62
VI	Slope (>30-45%); peat depth (>1,5meters); texture class (coarse)	4, 874, 043	31,54
VII	Slope (>3-8%)	1,006,013	6,51
Total areas		15, 451, 287	100,00

Further evaluation was then conducted in order to define land allocation for arable land and non-arable land. Based on relative degree of limitation, the classes fall into two groups. Classes' I-IV can be used for cultivation, whilst classes V-VIII are not suitable (Pandey *et al*., 2006; Dent and Young, 1981). In this case study of Central Kalimantan province, the region with land classes II, III, and IV was defined as arable land considered as developed area available for agriculture, while for region with land classes VI and VII falls into non-arable land and not recommended for agriculture because of very severe permanent limitations (Figure-3).

Geographically, majority of the area is arable lands considered as agricultural developed areas with total area of 9, 571, 231 hectares or 61.94% of entire Central kalimantan province. The remaining non-arable land covers 5, 880, 056 Ha (38.06%). Developed areas for agriculture can be evenly found at almost all location in Central Kalimantan. In the central to nothern part, the lands are suitable for cultivation with minor limitations in slope, while in the south; minor limitations involve slope and drainage. However, appropriate land management should be taken into account in order to utilize the land on a sustain basis.

The LCE approach in this study can then provide spatial information that can be used as basic consideration for land use planing. The spatial orientation of planning as part GIS may ensures optimum land use and optimum distribution of investment as well as avoids (land use) conflicts (Wehrmann, 2011; Coleman and Galbraith, 2000). In addition, the LCE approach can also be implemented in soil conservation and crop management practices (Martin and Saha, 2009).

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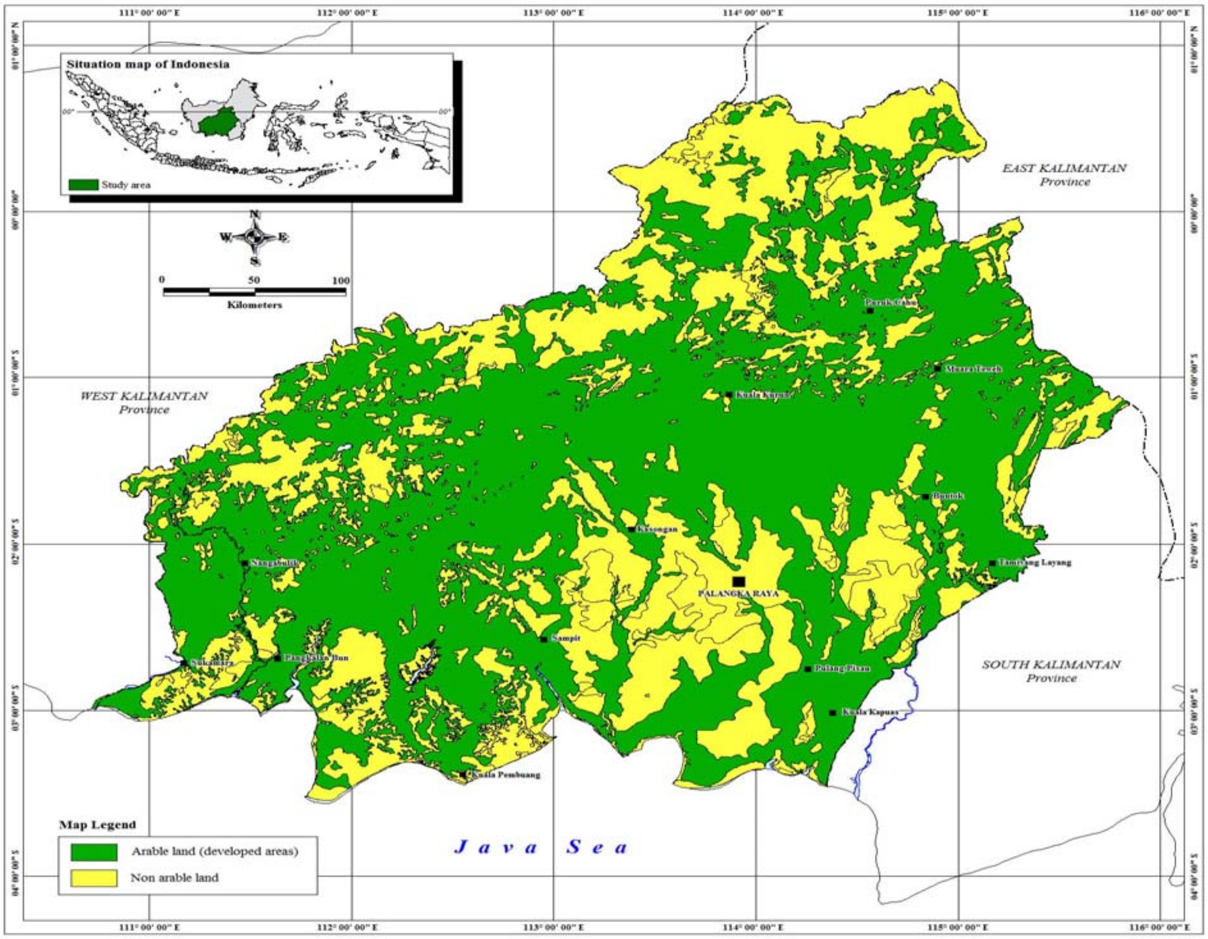

Figure-3. The map of land availability for agricultural development

Land suitability evaluation (LSE)

Based on map of LMU and land availability for agricultural developed areas, land parameters for arabel land were then further evaluated through LSE approach in order to define land suitability for selected crops. Initially, the matching procedure was carried out to define land suitability class for each crop. The principle of limiting condition as minimum rule was used in this procedure taking the lowest individual rating as limiting to the overall suitability (ISRI, 2005; Sys *et al*., 1993; Dent and Young, 1981). The result of suitability evaluation was then compared and evaluated using limitation methods, and land class criteria to be scored.

Twenty one major LMU's as arable lands were evaluated and delineated in order to determine the most suitable crops as prime commodities including their geographical distribution pattern as part of GIS (Table-9 and Figure-4). The LSE approach was addressed to agricultural developed areas based on the result of LCE. The combination of LSE and LCE approach for assessing land resource is expected to ensure the resources can be used for future generation because the land is utilized on sustainable development that is appropriate to the environment.

On the basis of LCE and LSE approach, three major prime commodities with highly prospect involving wetland rice, rubber and oil palm can then be developed in Central Kalimantan province. However, there some limiting factors as a result of evaluation that indicate the need of land (soil) management such as oxygen available, nutrient retention, water availability, and slope. The land evaluation process was conducted not only for actual condition but for potential also. It allows that certain land units have opportunity to be improved to higher suitability class level through some management inputs.

Table-9. The result of land evaluation for each land mapping unit (LMU) at agricultural developed areas.

Land mapping units (LMU)	**Commodity**	**Result of land evaluation**					
		Matching procedure		**Limitation method**	**Class criteria**	**Total score**	**Score rangking**
		Actual	**Potential**				
LMU 1	Wetland rice	S3 oa;nr (1)	S2 oa;nr (1)	5 (1)	S2 (2)	(5)	1
	Maize	N oa (2)	S3 wa;oa (3)	9 (4)	S2 (2)	(11)	5
	Soybean	N oa (2)	S3 wa;oa (3)	8 (3)	S2 (2)	(10)	4
	Oil palm	N oa (2)	S3 oa (2)	7 (2)	S3 (3)	(9)	3
	Rubber	N oa (2)	S3 oa (2)	5 (1)	S1 (1)	(6)	2
LMU 2	Wetland rice	S3 nr (1)	S2 nr (1)	4 (1)	S1 (1)	(4)	1
	Maize	S3 wa;oa;nr (2)	S3 wa (2)	8 (4)	S3 (3)	(11)	5
	Soybean	S3 wa;oa;nr (2)	S3 wa (2)	7 (3)	S2 (2)	(9)	4
	Oil palm	S3 oa (1)	S2 wa; oa (3)	5 (2)	S1 (1)	(7)	3
	Rubber	S3 oa (1)	S2 oa (1)	4 (1)	S1 (1)	(4)	2
LMU 3	Wetland rice	S3 nr (1)	S2 nr (1)	4 (1)	S2 (1)	(4)	1
	Maize	S3 wa;oa;nr (2)	S3 wa (2)	8 (5)	S3 (2)	(11)	5
	Soybean	S3 wa;oa;nr (2)	S3 wa (2)	7 (4)	S2 (1)	(9)	4
	Oil palm	S3 oa (1)	S2 wa; oa (3)	6 (3)	S2 (1)	(8)	3
	Rubber	S3 oa (1)	S2 oa (1)	5 (2)	S2 (1)	(5)	2
LMU 4	Wetland rice	S3 nr (1)	S2 nr (1)	5 (2)	S2 (1)	(5)	1
	Maize	S3 wa;oa;nr (2)	S2 wa (1)	8 (4)	S3 (2)	(9)	5
	Soybean	S3 wa;oa;nr (2)	S2 wa (1)	7 (3)	S2 (1)	(7)	3
	Oil palm	N oa (3)	S3 oa (3)	5 (2)	S2 (1)	(9)	4
	Rubber	S3 oa (1)	S2 oa;nr (2)	4 (1)	S2 (1)	(5)	1
LMU 5	Wetland rice	S3 nr (1)	S2 nr (1)	5 (1)	S2 (2)	(5)	1
	Maize	S3 wa;oa;nr (2)	S2 wa (1)	8 (4)	S3 (3)	(10)	5
	Soybean	S3 wa;oa;nr (2)	S2 wa (1)	7 (3)	S2 (2)	(8)	4
	Oil palm	S3 oa (1)	S2 wa;oa (2)	6 (2)	S1 (1)	(6)	2
	Rubber	S3 oa (1)	S2 wa;oa;nr (3)	5 (1)	S2 (2)	(7)	3
LMU 6	Wetland rice	S3 nr (3)	S2 nr;s (2)	5 (3)	S1 (1)	(9)	3
	Maize	S3 wa;nr (4)	S3 wa (3)	6 (4)	S2 (2)	(13)	5
	Soybean	S3 wa;nr (4)	S3 wa (3)	5 (3)	S2 (2)	(12)	4
	Oil palm	S2 wa;rn (2)	S2 wa;oa (2)	3 (2)	S1 (1)	(7)	2
	Rubber	S2 (nr) (1)	S1 (1)	1 (1)	S1 (1)	(4)	1
LMU 7	Wetland rice	N s (3)	N s (3)	10 (5)	S2 (2)	(13)	5
	Maize	S3 wa;nr;s (2)	S3 wa;s (2)	8 (4)	S3 (3)	(11)	4
	Soybean	S3 wa;nr;s (2)	S3 wa;s (2)	7 (3)	S2 (2)	(9)	3
	Oil palm	S3 s (1)	S3 s (1)	5 (2)	S1 (1)	(5)	2
	Rubber	S3 s (1)	S3 s (1)	3 (1)	S1 (1)	(4)	1
LMU 8	Wetland rice	S3 nr (1)	S2 nr (1)	5 (1)	S1 (1)	(4)	1
	Maize	S3 wa;nr;s (2)	S3 wa;s (3)	8 (2)	S3 (3)	(10)	5
	Soybean	S3 wa;oa;nr (2)	S3 wa;s (3)	8 (2)	S2 (2)	(9)	4
	Oil palm	S3 oa (1)	S2 wa; oa (3)	6 (3)	S1 (1)	(8)	3
	Rubber	S3 oa (1)	S3 oa (2)	5 (1)	S1(1)	(5)	2
LMU 9	Wetland rice	S3 nr (1)	S2 nr (1)	5 (2)	S2 (1)	(5)	1
	Maize	S3 wa;nr;s (2)	S3 wa;s (4)	6 (3)	S3 (2)	(11)	3
	Soybean	S3 wa;oa;nr (2)	S3 wa;s (4)	8 (4)	S2 (1)	(11)	3
	Oil palm	S3 oa (1)	S2 wa; oa (2)	5 (2)	S2 (1)	(6)	2
	Rubber	S3 oa (1)	S3 oa (3)	4 (1)	S2 (1)	(6)	2
LMU 10	Wetland rice	S2 oa;nr,s (2)	S2 s (2)	3 (2)	S1 (1)	(7)	3
	Maize	S3 wa (3)	S3 wa (3)	4 (3)	S2 (2)	(11)	5
	Soybean	S3 wa (3)	S3 wa (3)	3 (2)	S2 (2)	(10)	4
	Oil palm	S2 wa (1)	S2 wa (2)	1 (1)	S1 (1)	(5)	2
	Rubber	S2 nr (1)	S1 (1)	1 (1)	S1 (1)	(4)	1
LMU 11	Wetland rice	N s (5)	N s (4)	8 (5)	S3 (3)	(17)	5
	Maize	S3 wa;nr (4)	S3 wa (3)	7 (4)	S2 (2)	(13)	4
	Soybean	S3 wa (3)	S3 wa (3)	5 (3)	S2 (2)	(11)	3
	Oil palm	S2 wa;nr;s (2)	S2 wa;s (2)	3 (2)	S1 (1)	(7)	2
	Rubber	S2 s (1)	S2 s (1)	1 (1)	S1 (1)	(4)	1

Table-10. The result of land evaluation for each land mapping unit (LMU) at agricultural developed areas (continued).

Land mapping units (LMU)	Commodity	Result of land evaluation					
		Matching procedure		Limitation method	Class criteria	Total score	Score rangking
		Actual	Potential				
LMU 12	Wetland rice	N s (4)	N s (3)	8 (4)	S3 (2)	(13)	**5**
	Maize	S3 wa;nr;s (3)	S3 wa;s (2)	8(4)	S3 (2)	(11)	**4**
	Soybean	S3 wa;s (2)	S3 wa;s (2)	6 (3)	S2 (1)	(8)	**3**
	Oil palm	S3 s (1)	S3 s (1)	4 (2)	S2 (1)	(5)	**2**
	Rubber	S3 s (1)	S3 s (1)	2 (1)	S2 (1)	(4)	**1**
LMU 13	Wetland rice	N s (4)	N s (4)	11 (5)	S3 (2)	(15)	**4**
	Maize	S3 wa;nr;s (3)	S3 wa;s (3)	9 (4)	S3 (2)	(12)	**3**
	Soybean	S3 wa;s (2)	S3 wa;s (3)	8 (3)	S2 (1)	(9)	**2**
	Oil palm	S3 s (1)	S2 wa (1)	6 (2)	S2 (1)	(5)	**1**
	Rubber	S3 s (1)	S3 s (2)	3 (1)	S2 (1)	(5)	**1**
LMU 14	Wetland rice	N s (4)	N s (4)	10 (5)	S3 (2)	(15)	**4**
	Maize	S3 wa;nr;s (3)	S3 wa;s (3)	9 (4)	S3 (2)	(12)	**3**
	Soybean	S3 wa;s (2)	S3 wa;s (3)	7 (3)	S2 (1)	(9)	**2**
	Oil palm	S3 s (1)	S2 wa (1)	6 (2)	S2 (1)	(5)	**1**
	Rubber	S3 s (1)	S3 s (2)	3 (1)	S2 (1)	(5)	**1**
LMU15	Wetland rice	N s (4)	N s (4)	10 (5)	S3 (2)	(15)	**5**
	Maize	S3 wa;nr;s (3)	S3 wa;s (3)	9 (4)	S3 (2)	(12)	**4**
	Soybean	S3 wa;s (2)	S3 wa;s (3)	7 (3)	S2 (1)	(9)	**3**
	Oil palm	S3 s (1)	S2 wa (1)	6 (2)	S2 (1)	(5)	**1**
	Rubber	S3 s (1)	S3 s (2)	3 (1)	S2 (1)	(5)	**1**
LMU 16	Wetland rice	N s (4)	N s (3)	8 (4)	S3 (2)	(13)	**5**
	Maize	S3 wa;nr;s (3)	S3 wa;s (2)	8 (4)	S3 (2)	(11)	**4**
	Soybean	S3 wa;s (2)	S3 wa;s (2)	7 (3)	S2 (1)	(8)	**3**
	Oil palm	S3 s (1)	S3 s (1)	4 (2)	S2 (1)	(5)	**2**
	Rubber	S3 s (1)	S3 s (1)	2 (1)	S2 (1)	(4)	**1**
LMU 17	Wetland rice	S3 nr (3)	S2 nr (3)	S2 (3)	S2 (2)	(11)	**3**
	Maize	S3 wa;nr (4)	S3 wa (4)	S2 (3)	S2 (2)	(13)	**4**
	Soybean	S3 wa;nr (4)	S3 wa (4)	S2 (3)	S2 (2)	(13)	**5**
	Oil palm	S2 wa;nr (2)	S2 wa (2)	S1 (2)	S1 (1)	(7)	**2**
	Rubber	S2 nr (1)	S1 (1)	S1 (1)	S1 (1)	(4)	**1**
LMU 18	Wetland rice	S3 nr (3)	S2 nr (2)	6 (3)	S2 (2)	(10)	**3**
	Maize	S3 wa;nr (4)	S3 wa (3)	6 (3)	S2 (2)	(12)	**4**
	Soybean	S3 wa;nr (4)	S3 wa (3)	6 (3)	S2 (2)	(12)	**5**
	Oil palm	S2 wa;nr (2)	S2 wa (2)	3 (2)	S1 (1)	(7)	**2**
	Rubber	S2 nr (1)	S1 (1)	1 (1)	S1 (2)	(4)	**1**
LMU 19	Wetland rice	S3 oa,nr (1)	S2 oa,nr (1)	8 (2)	S2 (1)	(5)	**1**
	Maize	N oa (2)	S3 wa;oa (1)	11 (5)	S3 (2)	(10)	**4**
	Soybean	N oa (2)	S3 wa;oa (1)	10 (4)	S3 (2)	(9)	**3**
	Oil palm	N oa (2)	S3 oa (2)	9 (3)	S3 (2)	(9)	**3**
	Rubber	N oa (2)	S3 oa (2)	7 (1)	S3 (2)	(7)	**2**
LMU 20	Wetland rice	S3 nr (1)	S2 rc;nr (1)	6 (1)	S2 (1)	(4)	**1**
	Maize	S3 wa;oa;n (2)	S3 wa (3)	10 (4)	S3 (2)	(11)	**5**
	Soybean	S3 wa;oa;nr (2)	S3 wa (3)	9 (3)	S2 (1)	(9)	**4**
	Oil palm	S3 oa (1)	S2 wa;oa;rc (2)	8 (2)	S2 (1)	(6)	**3**
	Rubber	S3 oa (1)	S2 wa;oa;rc (2)	6 (1)	S2 (1)	(5)	**2**
LMU 21	Wetland rice	S3 nr (3)	S2 rc;nr (2)	5 (1)	S2 (1)	(7)	**2**
	Maize	S3 wa;nr (4)	S3 wa (4)	8 (4)	S2 (1)	(13)	**5**
	Soybean	S3 wa;nr (4)	S3 wa (4)	7 (3)	S2 (1)	(12)	**4**
	Oil palm	S2 wa;oa;rc;nr (1)	S2 wa;rc (1)	7 (3)	S2 (1)	(6)	**1**
	Rubber	S3 oa (2)	S2 wa;oa;rc (3)	6 (2)	S2 (1)	(8)	**3**

Note: Number in the brackets is score of resulting evaluation

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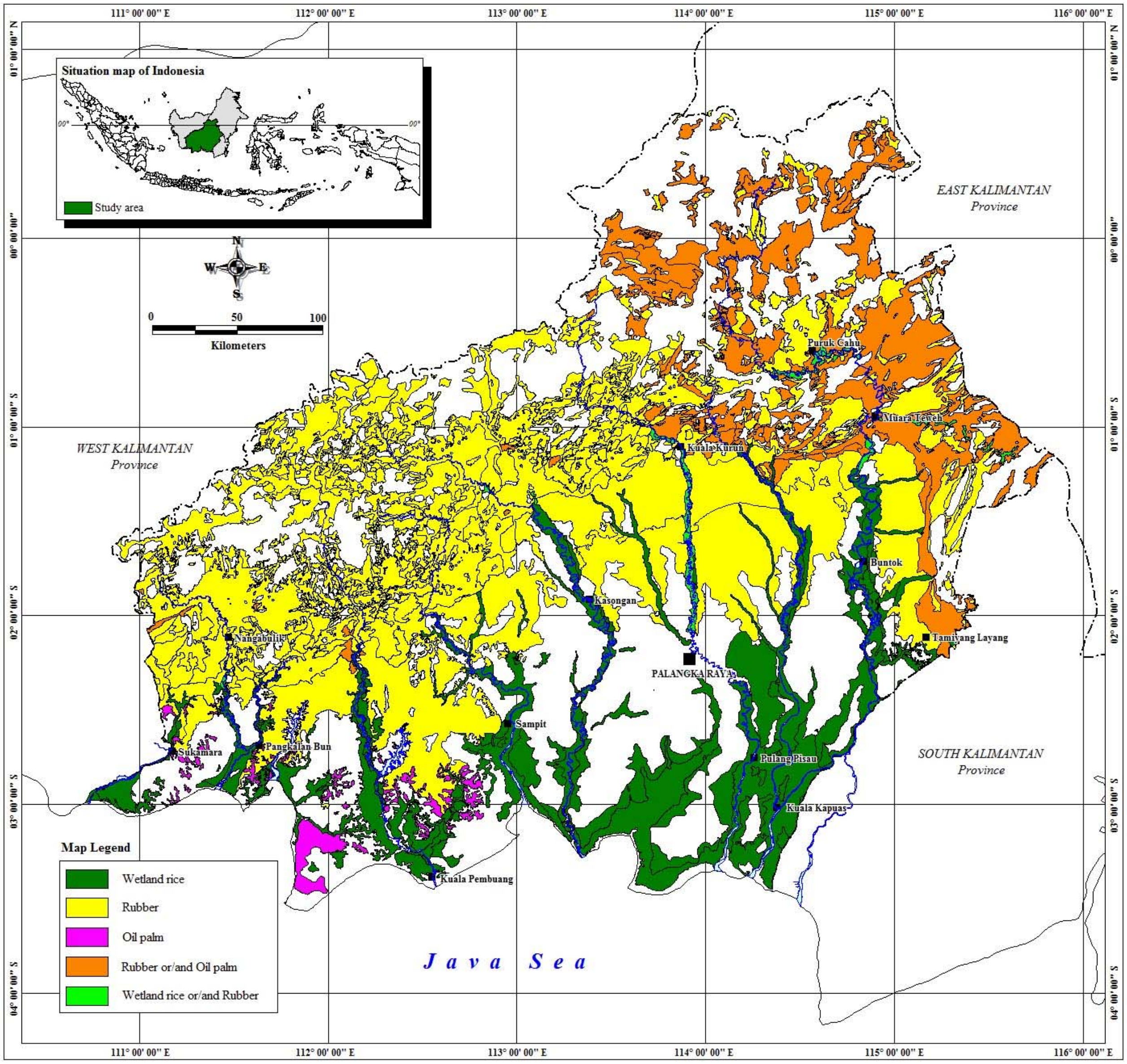

Figure-4. The map of prime commodities zonation in Central Kalimantan province.

The prime commodity of wetland rice with suitability class S3 (actual) and S2 (potential) can be found at *LMU 1*, *LMU 2*, *LMU 3*, *LMU 4*, *LMU 5*, *LMU 9*, *LMU 19*, and *LMU 20* respectively. While for rubber, it is found at *LMU 4*, *LMU 6*, *LMU 7*, *LMU 10*, *LMU11*, *LMU 12*, *LMU 13*, *LMU 14*, *LMU 15*, *LMU 16*, *LMU 17*, and *LMU 18*. The remaining oil palm can then be found at LMU *13*, *LMU 14*, *LMU 15*, and *LMU 21*. Based on the result of evaluation, it was also found that there is couple crop with same value of score rangking such as wetland rice-rubber (*LMU 4*) and oil palm-rubber (*LMU 13*, *LMU 14*, and *LMU 15*). This is indicates that land is suitable for both of these commodities so that any programs related to land use planning need to be further discussed.

For spatial orientation of land use planning, the development of agriculture for rice as staple food in Central Kalimantan can be directed at wetlands in the southern part especially at areas located along the main rivers. It covers 2, 141, 539 hectares or 13.86% of total area of Central Kalimantan, with predominant soil types involving Entisols (great groups: Fluvaquents), Inceptisols (great groups: Endoaquepts) and Histosols (great groups: Haplohemists).

Prime commodity of oil palm and rubber, spatially tend to be developed in the central to the northern part at lands dominated by Ultisols (great groups: Hapludults and Paleudults), Inceptisols (great groups: Dystrudepts) and Alfisols (great groups: Hapludalfs). Total area of land potential for rubber is 7, 355, 390 hectares (47.60%) while for oil palm, it constitutes 11.15% or 1, 722, 806 hectares. Geographically, in the southern part, both of these crops as estate commodities can be developed at undulating plains with slope class 15-25%. Environmentally sound land management should then be considered in land use. In order to keep the land from erosion, perennial tree crops with cover crops beneath are suitable to be developed because they have the potential to reduce erosion (Simpson, 2009).

Although the evaluation was performed at arable lands suitable for cultivation, however, there is several not suitable (N) class found. The presence of N class for each crop shows that for some limiting factors such as drainage and slope, they are main requirement for specific crop. However, highly management inputs can then be considered in order to cultivate the land with certain crop.

The other selected crops such as maize and soybean in this study can be considered as commodities support for food crop. They can be developed together with main commodity through some farming techniques such as intercropping with annual crop (wetland rice) and inter culture with estate crop (oil palm and rubber). For LMU 1 and LMU 19, both maize and soybean have minor limiting factor such as oxygen available so that they then was classified into class N. However, some improvements such as drainage can be performed in order to improve land quality.

CONCLUSIONS

- Determination of prime commodities as the most suitable crops on the basis of land resources can provide an option for land use planning at regional scale in order to achieve sustainable agricultural development. In the form of digitized maps, the result of land use allocation provide spatial information as part of geographic information system (GIS) for agricultural developed areas including land suitability for prime commodities suitable to be developed.
- Land capability evaluation (LCE) and land suitability evaluation (LSE) approach rooted from USDA and FAO’s Framework of Land Evaluation can be used to assess land resource according to its capability and suitability in order to ensure proper land use with land management that is appropriate to the environment. LCE and LSE approach was then used to identify land availability for arable land and non-arable land followed by determination of prime commodities suitable at agricultural developed areas.
- The application of GIS can be used to provide spatial information in the form of spatial and integrated database as a result of land resource capability and suitability evaluation in addition to mapping process and spatial analysis. The spatial orientation of planning as part GIS may ensures land allocation precisely in order to utilize the lands based on their capability and suitability. Additional programs to support agricultural policy can then be formulated in order to utilize agricultural developed areas.
- In the case of Central Kalimantan province, this region consists primarily of arable land considered as agricultural developed areas and non-arable land with total area of 9,571,231 hectares (61.94%) and 5, 880, 056 hectares (38.06%) respectively. The potency of land availability for agriculture then indicates that land geographically has an opportunity to be developed.
- Based on LSE approach and GIS application, there are 3 (three) prime commodities including their geographical distribution pattern that suitable to be developed in Central Kalimantan involving wetland rubber (7, 355, 390 hectares), rice (2, 141, 539 hectares), and oil palm (1, 722, 806 hectares)
- The other selected crops in this study such as maize and soybean can still be developed because of their suitable class. These crops can then are planted together with main commodity through some farming techniques such as intercropping with annual crop (wetland rice) and inter culture with estate crop (oil palm and rubber).

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