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Land Suitability Criteria for Intensively Managed Cavendish Banana Crop in Way Kambas East Lampung, Indonesia

Ansyori[1], Sudarsono[2], Roedhy Poerwanto[3], and Darmawan[2]

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ABSTRACT

Land Suitability Criteria for Intensively Managed Cavendish Banana Crop in Way Kambas East Lampung, Indonesia (Ansyori, Sudarsono, R Poerwanto, and Darmawan): Banana as one of the pre-eminent products of horticultural crop has a very important role in the growth of agricultural sector. The research aimed to study the land characteristics which influence the Cavendish banana crop yield and proposing the land suitability classification criteria for the land utilization type of Cavendish banana crop with intensive management which has been tested based on the production rate in the field. For this purpose, there were 36 observation land units specifically designed by considering factors such as soil subgroups, slopes, land utilization types, and land productivity levels. At each observation land unit, the land utilization types and land characteristics were indentified. The relation between land characteristics and production was tested with correlation and regression analysis. The results of some statistical tests were contrasted and then selected as the basis to develop the land suitability classification criteria for Cavendish banana crop which was intensively managed. The research findings indicated that the banana crop yield levels were significantly influenced and determined by the land characteristics of soil bulk density, cation exchange capacity, soil permeability, total porosity, exchangeable sodium percentage, soil textural class, and soil erodibility.

Keywords: Cavendish banana, land suitability criteria, land utilization type

INTRODUCTION

Banana as one of the pre-eminent products of horticultural crops has an important role in the development of agricultural sub-sector especially in Indonesia. The average production and productivity of banana in Indonesia from 2004 until 2007 was approximately 5.1 million Mg yr^{-1} or 15.51 Mg ha^{-1} yr^{-1} (BPS, 2009; FAO, 2009) while according to Sys *et al.* (1993) banana crop yield that was commercially cultivated in rainfed and irrigation land can produce fresh bananas as much as 30 to 35 Mg ha^{-1} yr^{-1} and 40 to 60 Mg ha^{-1} yr^{-1}, respectively.

Problems that cause low banana production in Indonesia are as follows: (1) banana crops which are commercially cultivated are still vulnerable to pests and diseases; (2) most farmers still use low quality banana crop seeds; and (3) the technology used is still simple.

PT Nusantara Tropical Fruit (NTF) located in Way Kambas East Lampung Regency has been built since 1992. This company manages intensive banana plantation for domestic and export purposes whose area is 3,700 hectares. It cultivates Cavendish banana types which have high commercial values.

Its production target was 50 Mg ha^{-1} yr^{-1} fresh banana. However, the field reality showed that there was a yield level variety between one and other areas. Data from 2002 until 2006 showed that the fresh banana yield in the plantations ranged from 10 to 55 Mg ha^{-1} yr^{-1}. Therefore it is necessary to find the factors which determine the banana crop yield levels by conducting land suitability classification.

[1] Sekolah Tinggi Perkebunan Lampung, Jalan. Z.A. Pagar Alam No. 17A Bandar Lampung 35144 - Lampung, Indonesia Phone/fax: +62721700289, e-mail: ansyori2010@yahoo.co.id
[2] Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University, Jl. Meranti, Kampus IPB Darmaga, Bogor 16680 - West Java, Indonesia
[3] Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Jl. Meranti, Kampus IPB Darmaga, Bogor 16680 - West Java, Indonesia
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Land selection to achieve optimum productivity will be well if the land suitability classification criteria used can reflect the growing requirements of an optimum yield crop. Most land suitability classification criteria have been used in Indonesia, for example: *Parametric Land Classification* (Driessen 1971), *Land Capability Appraisal System for Agricultural Uses in Indonesia* (Soepraptohardjo and Robinson, 1975), *Classification of Land Suitability for Agricultural Research Project to Support Transmigration* (CSR 1983), *Classification of Land Suitability for Reconnaissance Land Resource Surveys* (CSR/FAO 1983), *Land Evaluation Computer System* (Wood and Dent 1983) and *Automated Land Evaluation System* (Rossiter and Wambeke 1994).

The existing land suitability criteria for various agricultural commodities in Indonesia are still too general and they are not for specific locations. The parameters and their ratings in the criteria have not been tested and verified in the field. They are also not connected to crop yields in a particular management level; therefore, the land suitability classification results were not often suited to the potential land and expected crop yields (Sutaatmadja 2005).

Therefore, it is important to conduct research about the land suitability classification criteria. The research aimed at (1) finding out the land characteristics which influence the Cavendish banana crop yield and (2) proposing the land suitability classification criteria for the land utilization type of intensively managed Cavendish banana crop which has been tested based on the yield levels in the field.

MATERIALS AND METHODS

A study was conducted from January 2007 to September 2008. The research objects were the planted areas with intensively managed Cavendish banana crop (*Musa cavendishi*) by PT Nusantara Tropical Fruit in Way Kambas East Lampung, Indonesia.

In order to achieve the purpose, it was necessary to compile the observation land units. They were formed based on the uniformity of permanently land characteristic components: the soil subgroup and the land slope. It was also important to consider the aspect of the previous yield levels and their continuity, the applied irrigation systems, the cultivation techniques which were applied, the planting times, and the land use histories.

Based on the factors combination were obtained 36 observation land units (Table 1). Then, the land utilization type (LUT) and the land characteristics were indentified at each land unit. The land characterization aimed to collect soil and climate characteristic data which were related to the land quality used in land suitability classification, i.e. air temperature, water availability, oxygen availability, nutrient availability, nutrient retention, rooting conditions, toxicity hazards, potential mechanisms, erosion hazards, and flood hazards (CSR/FAO 1983; Sys *et al.* 1993; LREP II 1994; and Djaenudin *et al.* 2003).

An observation to obtain the soil morphological properties for the purposes of land suitability classification, the soil classification, and the soil erodibility prediction has been done. At each land unit soil samples which represented in soil depth of 0-25 cm and 25-50 cm was taken. Determining erosion hazard levels needs field observation. In addition, calculating the soil erosion rate was also done using the *Universal Soil Loss Equation* (USLE) according to the concept of Wischmeier and Smith (1978), and the tolerable soil erosion was calculated using that of Hammer (1981).

Observing the banana crop yield components was done in 36 land units. Each land unit was divided into three observation plots whose measurement was 14 m x 28 m as replication. It was taken 16 sample plants at each observation plot which used the purposive sampling method. The observed yield components included the shooting ages, the banana yields per hectare, and the bunch weight.

Before compiling the new criteria, the land suitability classification using the existing criteria was conducted at each LUT. The existing criteria were taken from CSR/FAO (1983), Sys *et al.* (1993), LREP II (1994), and Djaenudin *et al.* (2003). The aim was to find out whether the existing criteria can be used to classify the land suitability in the research area correctly or not. Moreover, it was useful as an initial step to determine the land characteristics expected to be a limiting factor at each LUT in the research area.

Some tests done to develop the land suitability criteria included (1) comparing the land suitability classes obtained based on the existing criteria with the field yield levels; (2) conducting a correlation analysis to determine the land characteristics directly related to banana crop yields, and (3) using regression

Table 1. The factors combination forming land units in the research area.

Land Unit Code	Location Coordinate		Banana Clone	Irrigation System	Soil Subgroup	Land Slope	Previous Yield Level (Mg ha^{-1})
	EL	SL	(V)		(T)	(L)	(P)
$V_1T_1L_1P_2$	105°36'51.8"	5°01'49.6"	DM2	*Drip*	*Xanthic Eutrustox*	0-2%	20-30
$V_1T_1L_1P_3$	105°38'53.2"	5°01'11.0"	DM2	*Drip*	*Xanthic Eutrustox*	0-2%	30-40
$V_1T_1L_1P_4$	105°39'33.4"	5°03'14.2"	DM2	*Drip*	*Xanthic Eutrustox*	0-2%	40-50
$V_1T_1L_2P_2$	105°37'40.8"	5°03'10.3"	DM2	*Drip*	*Xanthic Eutrustox*	2-4%	20-30
$V_1T_1L_2P_3$	105°39'59.2"	5°02'10.9"	DM2	*Drip*	*Xanthic Eutrustox*	2-4%	30-40
$V_1T_1L_2P_4$	105°37'34.9"	5°03'39.3"	DM2	*Drip*	*Xanthic Eutrustox*	2-4%	40-50
$V_1T_2L_1P_2$	105°38'55.9"	5°02'07.7"	DM2	*Drip*	*Plinthic Eutrustox*	0-2%	20-30
$V_1T_2L_1P_3$	105°40'16.8"	5°02'01.2"	DM2	*Drip*	*Plinthic Eutrustox*	0-2%	30-40
$V_1T_2L_1P_4$	105°38'43.1"	5°01'46.1"	DM2	*Drip*	*Plinthic Eutrustox*	0-2%	40-50
$V_1T_2L_2P_2$	105°39'09.6"	5°03'10.8"	DM2	*Drip*	*Plinthic Eutrustox*	2-4%	20-30
$V_1T_2L_2P_3$	105°39'16.7"	5°01'47.8"	DM2	*Drip*	*Plinthic Eutrustox*	2-4%	30-40
$V_1T_2L_2P_4$	105°37'55.9"	5°03'23.4"	DM2	*Drip*	*Plinthic Eutrustox*	2-4%	40-50
$V_2T_1L_1P_1$	105°41'27.7"	5°02'54.3"	DM2	*Sprinkler*	*Xanthic Eutrustox*	0-2%	10-20
$V_2T_1L_1P_2$	105°39'33.9"	5°02'48.8"	DM2	*Sprinkler*	*Xanthic Eutrustox*	0-2%	20-30
$V_2T_1L_1P_3$	105°38'27.7"	5°02'45.3"	DM2	*Sprinkler*	*Xanthic Eutrustox*	0-2%	30-40
$V_2T_1L_2P_1$	105°41'44.4"	5°03'00.3"	DM2	*Sprinkler*	*Xanthic Eutrustox*	2-4%	10-20
$V_2T_1L_2P_2$	105°38'16.5"	5°03'11.5"	DM2	*Sprinkler*	*Xanthic Eutrustox*	2-4%	20-30
$V_2T_1L_2P_3$	105°39'08.5"	5°02'34.9"	DM2	*Sprinkler*	*Xanthic Eutrustox*	2-4%	30-40
$V_2T_2L_1P_1$	105°37'31.2"	5°02'38.6"	DM2	*Sprinkler*	*Plinthic Eutrustox*	0-2%	10-20
$V_2T_2L_1P_2$	105°37'24.1"	5°03'17.8"	DM2	*Sprinkler*	*Plinthic Eutrustox*	0-2%	20-30
$V_2T_2L_1P_3$	105°38'13.6"	5°02'42.4"	DM2	*Sprinkler*	*Plinthic Eutrustox*	0-2%	30-40
$V_2T_2L_2P_1$	105°40'05.6"	5°02'54.9"	DM2	*Sprinkler*	*Plinthic Eutrustox*	2-4%	10-20
$V_2T_2L_2P_2$	105°38'08.4"	5°03'39.3"	DM2	*Sprinkler*	*Plinthic Eutrustox*	2-4%	20-30
$V_2T_2L_2P_3$	105°39'34.9"	5°02'28.0"	DM2	*Sprinkler*	*Plinthic Eutrustox*	2-4%	30-40
$V_3T_1L_1P_1$	105°37'07.5"	5°02'25.9"	Cj20	*Sprinkler*	*Xanthic Eutrustox*	0-2%	10-20
$V_3T_1L_1P_2$	105°37'53.7"	5°02'24.6"	Cj20	*Sprinkler*	*Xanthic Eutrustox*	0-2%	20-30
$V_3T_1L_1P_3$	105°37'59.9"	5°02'43.4"	Cj20	*Sprinkler*	*Xanthic Eutrustox*	0-2%	30-40
$V_3T_1L_2P_1$	105°37'32.2"	5°02'14.2"	Cj20	*Sprinkler*	*Xanthic Eutrustox*	2-4%	10-20
$V_3T_1L_2P_2$	105°37'04.4"	5°02'05.3"	Cj20	*Sprinkler*	*Xanthic Eutrustox*	2-4%	20-30
$V_3T_1L_2P_3$	105°37'19.6"	5°02'52.6"	Cj20	*Sprinkler*	*Xanthic Eutrustox*	2-4%	30-40
$V_3T_2L_1P_1$	105°36'56.6"	5°03'05.6"	Cj20	*Sprinkler*	*Plinthic Eutrustox*	0-2%	10-20
$V_3T_2L_1P_2$	105°37'26.4"	5°01'56.3"	Cj20	*Sprinkler*	*Plinthic Eutrustox*	0-2%	20-30
$V_3T_2L_1P_3$	105°36'42.4"	5°02'45.8"	Cj20	*Sprinkler*	*Plinthic Eutrustox*	0-2%	30-40
$V_3T_2L_2P_1$	105°36'41.9"	5°02'06.8"	Cj20	*Sprinkler*	*Plinthic Eutrustox*	2-4%	10-20
$V_3T_2L_2P_2$	105°38'36.0"	5°02'16.3"	Cj20	*Sprinkler*	*Plinthic Eutrustox*	2-4%	20-30
$V_3T_2L_2P_3$	105°38'37.6"	5°03'15.7"	Cj20	*Sprinkler*	*Plinthic Eutrustox*	2-4%	30-40

Note: East Longitude (EL) and South Latitude (SL).

analysis to determine land characteristics that determine the banana crop yield levels, and its relationships were described in the regression equations.

The banana crop land suitability levels can be identified by looking at each yield level at each LUT. The identified results in reseach area showed that all of LUT applied was intensively managed with high inputs so that the optimal yield level was assumed to be achieved. The Cavendish banana crop yield potential of DM2 clone was 50.0 Mg ha^{-1} yr^{-1} while that of Cj20 clone was 60.0 Mg ha^{-1} yr^{-1}.

There were only three LUTs in the research area deserved to be discussed in this study. They were the DM2 clone with drip irrigation system (LUT1), DM2 clone with sprinkler irrigation system (LUT2), and Cj20 clone with sprinkler irrigation system (LUT3). All of LUTs were intensively managed with high inputs whereas their differences were crop clones, irrigation systems, fertilization times, and planting spacing patterns.

Further, the land suitability criteria based on yield potential can be arranged from relationship between the land suitability class and the Cavendish banana yield with referring to the Wood and Dent (1983), as presented in Table 2. By using the land suitability criteria, the land suitability class at each LUT in the research area can be determined based on yield data obtained from observation plots in the field. To differentiate land units in the research area, it was important to try the alternative classification criteria using the highest yield standard at each LUT in the research area, as presented in Table 3.

Based on the test results, it was then determined the land characteristic value range for each land suitability class. Its value range was determined by trial and error method based on linier or quadratic regression equation from relationship between land characteristic and specified yield range. The results were compared one another. Selecting and developing the land suitability classification criteria for the intensively managed Cavendish banana crop were then administered.

RESULTS AND DISCUSSION

Land Suitability Classes Based on the Existing Criteria vs Yield Levels

The land suitability classification classes using the existing criteria were presented in Table 4. The land suitability assessment results indicated the class differences among the land suitability criteria at the same LUT except for the criteria Sys *et al.* (1993) and Djaenudin *et al.* (2003). They were caused by differences in the land characteristic used, the land characteristic value range in each class as well as the soil depth used in the assessment.

The land suitability classification results based on yield potential (Table 4) showed that the LUT1 land in the research area were classified from *marginally suitable* (S3) to *very suitable* (S1) whereas LUT2 and LUT3 lands which were also intensively managed were classified from *currently not suitable* (N1) to *moderately suitable* (S2). None of the land units in LUT2 and LUT3 was categorized as *very*

Table 2. Land suitability criteria based on the Cavendish banana yield potential.

Land Suitability Classes		Production Index*	DM2 Clone (Mg ha^{-1} yr^{-1})	Cj20 Clone (Mg ha^{-1} yr^{-1})
S1	Very suitable	>0.80	>40.0	>48.0
S2	Moderately suitable	0.60-0.80	30.0-40.0	36.0-48.0
S3	Marginally suitable	0.40-0.59	20.0-29.9	24.0-35.9
N1	Currently not suitable	0.20-0.39	10.0-19.9	12.0-23.9
N2	Unsuitable	<0.20	<10.0	<12.00

* Wood and Dent (1983).

Table 3. Land suitability criteria based on the Cavendish banana highest yield level in the research area.

Land Utilization Types (LUT)	Highest Yield	Land Suitability Classes			
		S1	S2	S3	N
	(………………….………….Mg ha^{-1} yr^{-1}……………………………………)				
LUT1	49.58	>39.66	29.75-39.66	19.83-29.74	<19.83
LUT2	42.07	>33.66	25.24-33.66	16.83-25.23	<16.83
LUT3	40.14	>32.11	24.08-32.11	16.06-24.07	<16.06

Table 4. Land suitability classes based on the existing criteria and the yield level.

Land Unit Code	Yield ($Mg\ ha^{-1}\ yr^{-1}$)	Class Based on the Existing Criteria				Class Based on the Yield Level	
		CSR/FAO	Sys	LREP	Djaenudin	Potential Yield	Highest Yield in Research Area
		Land of DM2 Clone Cavendish Banana with Drip Irrigation					
$T_1L_1P_2$	27.20	S3	S3	S3	S3	S3	S3
$T_1L_1P_3$	35.66	S3	S2	S3	S2	S2	S2
$T_1L_1P_4$	40.86	S3	S2	S3	S2	S1	S1
$T_1L_2P_2$	35.64	S3	S2	S3	S2	S2	S2
$T_1L_2P_3$	38.33	S3	S2	S3	S2	S2	S2
$T_1L_2P_4$	45.81	S3	S2	S3	S2	S1	S1
$T_2L_1P_2$	30.13	S3	S2	S3	S2	S2	S2
$T_2L_1P_3$	40.17	S3	S2	S2	S2	S1	S1
$T_2L_1P_4$	45.35	S3	S2	S3	S2	S1	S1
$T_2L_2P_2$	28.62	S3	S2	S3	S2	S3	S3
$T_2L_2P_3$	36.38	S3	S2	S3	S2	S2	S2
$T_2L_2P_4$	45.86	S3	S3	S3	S3	S1	S1
		Land of DM2 Clone Cavendish Banana with Sprinkler Irrigation					
$T_1L_1P_1$	18.52	S3	S3	S3	S3	N1	S3
$T_1L_1P_2$	32.11	S3	S2	S2	S2	S2	S2
$T_1L_1P_3$	33.24	S3	S3	S2	S3	S2	S2
$T_1L_2P_1$	16.01	S3	S2	S3	S2	N1	N1
$T_1L_2P_2$	21.43	S3	S3	S3	S3	S3	S3
$T_1L_2P_3$	23.52	S3	S2	S3	S2	S3	S3
$T_2L_1P_1$	26.39	S3	S2	S3	S2	S3	S2
$T_2L_1P_2$	32.56	S3	S2	S2	S2	S2	S2
$T_2L_1P_3$	35.13	S3	N1	S2	N1	S2	S1
$T_2L_2P_1$	17.07	S3	S3	S3	S3	N1	S3
$T_2L_2P_2$	21.58	S3	S2	S3	S2	S3	S3
$T_2L_2P_3$	32.14	S3	S2	S2	S2	S2	S2
		Land of Cj20 Clone Cavendish Banana with Sprinkler Irrigation					
$T_1L_1P_1$	18.44	S2	S2	S3	S2	N1	S3
$T_1L_1P_2$	25.68	S2	S2	S2	S2	S3	S2
$T_1L_1P_3$	39.92	S2	S2	S2	S2	S2	S1
$T_1L_2P_1$	18.34	S2	S3	S2	S3	N1	S3
$T_1L_2P_2$	26.43	S2	S2	S3	S2	S3	S2
$T_1L_2P_3$	33.89	S2	S2	S2	S2	S3	S1
$T_2L_1P_1$	18.14	S2	S2	S3	S2	N1	S3
$T_2L_1P_2$	33.70	S2	S2	S2	S2	S3	S1
$T_2L_1P_3$	39.35	S3	S2	S2	S2	S2	S1
$T_2L_2P_1$	25.78	S3	S2	S3	S2	S3	S2
$T_2L_2P_2$	33.33	S2	S2	S2	S2	S3	S1
$T_2L_2P_3$	40.14	S3	S2	S3	S2	S2	S1

Note: *Xanthic Eutrustox* (T_1) and *Plinthic Eutrustox* (T_2) soil subgroups; 0-2% (L_1) and 2-4% (L_2) land slopes; 10-20 $Mg\ ha^{-1}$ (P_1), 20-30 $Mg\ ha^{-1}$ (P_2), 30-40 $Mg\ ha^{-1}$ (P_3), and 40-50 $Mg\ ha^{-1}$ (P_4) previous yield levels; *very suitable* (S1), *moderately suitable* (S2), *marginally suitable* (S3), and currently not *suitable* (N1) land suitability classes.

suitable (S1). The classification results based on highest yield level in the research area indicated that its land suitability class was better than those based on the LUT2 and LUT3 lands yield potential, while those in the LUT1 land were similar.

The fact above was due to differences in irrigation system. LUT1 land used drip irrigation with double row planting spacing pattern so that it allowed the crop yield to be optimal. Its yield was 45.86 Mg ha^{-1} yr^{-1} approaching the DM2 clone yield potential which was 50.0 Mg ha^{-1} yr^{-1} while the LUT2 and LUT3 lands using sprinkler irrigation system with square planting spacing pattern was difficult to achieve an optimal yield. Sprinkler irrigation systems were not suitable for the easily formed crust soil (Brouwer *et al.* 1989) and more suitable for sand-textured soil with high infiltration rate (Prastowo 2002). Providing water to the sprinkler irrigation system caused the soil dispersed into finer grains. It corked the soil pores at the sub surface that resulted in the inhibited infiltration rate. Consequently, many crusting and moss were seen on the soil surface. The soil order in the research area was Oxisol which was hard if it was dry (Soil Survey Staff 1998; Hardjowigeno 1993).

Land suitability classification results (Table 4) showed that the land suitability classes formed based on existing criteria were not matched with banana crop yield levels in the field for all of the criteria used, for example the enough various banana yield levels (16.01-45.86 Mg ha^{-1} yr^{-1}) at the research area. Most of the land units were classified by Sys *et al.* (1993) and LREP II (1994) criteria into *moderately suitable* (S2) while those by CSR/FAO (1983) and Djaenudin *et al.* (2003) criteria were classified as *marginally suitable* (S3). Despite of showing various land suitability classes, they were not matched with the field banana crop yield levels. It was caused by the four criteria above formulated for the semi-detailed land evaluation scales and the general banana crop whereas the study was conducted on the detailed scale with specified land utilization types.

The cases above often occurred in the field. The land suitability assessment results were not in accordance with the actual yield potential because of the map scale differences (Bregt and Stoorvogel, 1992). Therefore, it was necessary to improve the existing land suitability criteria. The amount and value ranges of the land characteristics must be improved in accordance with their land use requirements for LUT applied in the research area.

The New Land Suitability Classification Criteria

The land suitability criteria for intensively managed Cavendish banana crops with some land utilization types should be built for the land units in the research area and other areas whose land characteristics were similar. The new land suitability classification criteria were used for specified land utilization types with the DM2 or Cj20 clone Cavendish banana crop derived from tissue culture using a drip or sprinkler irrigation system. The specified LUT was intensively managed by fertilizing, liming, providing organic matter, controlling crop pest organisms, using mechanical equipment, and making drainage channels**.**

To develop the new land suitability criteria, it was important to track the land qualities or characteristics crucial to the Cavendish banana yield levels. Based on the land characteristic value ranges in all land units related to the banana crop land use requirements and the land improvements that were implemented in each LUT, it was shown that the land qualities of air temperature, oxygen availability, water availability, nutrient availability, flood hazards, and potential mechanisms didn't limit to its land use. The land qualities of rooting condition, nutrient retention, toxicity and erosion hazard were varied enough and they would really determined the banana yield levels in the research area.

The correlation and regression analysis results (Table 5) showed that the land characteristics considered to be making up the criteria parameters for LUT1 land suitability were clay fraction percentage, soil bulk density, total porosity, clay cation exchangeable capacity (CEC), and exchangeable sodium percentage (ESP) (r = 0.73-0.89 and R^2> 0.65); those to the LUT2 land were soil bulk density, total porosity, clay CEC, soil CEC, erodibility index, and soil permeability (r = 0.78-0.98 and R^2> 0.63); and those to the LUT3 land were soil textural class, soil bulk density, total porosity, clay CEC, ESP, and soil permeability (r = 0.74-0.98 and R^2> 0.66).

Based on the value ranges of each land characteristic at each yield level, the land suitability criteria for Cavendish banana crop in research area were composed, as presented in Table 6 to 8. The land suitability criterion of DM2 clone Cavendish banana crop intensively managed with drip irrigation system (LUT1) was compiled by two land characteristics which was very influential the yield level. They were soil bulk density and clay CEC at soil depth of 0-50 cm (Table 6).

Table 5. The data regression analysis results of the land characteristics with banana yields.

No.	Land Characteristic	R^2	Regression Equation
1.	*Land of DM2 clone, Drip Irrigation (LUT1)*		
	- Clay fraction (%)	*0,76*	$y = 34.227 + 1.262\,x - 0.032\,x^2$
	- Soil bulk density (g cm^{-3})	*0,80*	$y = -63.440 + 202.90\,x - 94.945\,x^2$
	- Total porosity (%)	*0,81*	$y = -64.820 + 3.187\,x - 0.022\,x^2$
	- Clay CEC (cmol (+) kg^{-1} clay)	*0,95*	$y = -8.992 + 5.411\,x - 0.121\,x^2$
	- Exchangeable sodium percentage (%)	*0,65*	$y = 74.490 - 6.897\,x + 0.059\,x^2$
2.	*Land of DM2 clone, Sprinkler Irrigation (LUT2)*		
	- Soil bulk density (g cm^{-3})	*0,94*	$y = 16.606 + 74.512\,x - 48.651\,x^2$
	- Total porosity (%)	*0,85*	$y = -81.865 + 3.855\,x - 0.032\,x^2$
	- Clay CEC (cmol (+) kg^{-1} clay)	*0,89*	$y = -3.881 + 2.291\,x - 0.034\,x^2$
	- Soil CEC (cmol (+) kg^{-1})	*0,98*	$y = 7.018 + 1.722\,x + 0.471\,x^2$
	- Soil permeability (cm $hour^{-1}$)	*0,93*	$y = 15.729 + 0.382\,x - 0.082\,x^2$
	- Erodibility Index (K)	*0,63*	$y = 54.950 - 312.310\,x + 582.610\,x^2$
3.	*Land of Cj20 clone, Sprinkler Irrigation (LUT3)*		
	- Soil textural class	*0,66*	$y = -76.930 + 25.720\,x - 1.469\,x^2$
	- Soil bulk density (g cm^{-3})	*0,98*	$y = 119.460 - 91.259\,x + 15.840\,x^2$
	- Total porosity (%)	*0,95*	$y = 10.427 - 0.418\,x + 0.0165\,x^2$
	- Clay CEC (cmol (+) kg^{-1} clay)	*0,90*	$y = -25.745 + 4.536\,x - 0.061\,x^2$
	- Exchangeable sodium percentage (%)	*0,74*	$y = 75.325 - 12.949\,x + 0.687\,x^2$
	- Soil permeability (cm $hour^{-1}$)	*0,95*	$y = -15.930 + 10.344\,x - 0.476\,x^2$

Table 6. Land suitability criteria based on the highest and potential yields for the LUT1 in the research area.

Land Characteristic	Units	Land Suitability Classes			
		S1	S2	S3	N
The Criteria Based on Highest Yield					
- Soil bulk density (*b*)	g cm^{-3}	<1.31	1.31-1.47	>1.47	-
- Clay CEC (*c*)	cmol (+) kg^{-1} clay	>12.41	8.93-12.41	<8.93	-
The Criteria Based on Potential Yield					
- Soil bulk density (*b*)	g cm^{-3}	<1.29	1.29-1.46	>1.46	-
- Clay CEC (*c*)	cmol (+) kg^{-1} clay	>12.54	9.01-12.54	<9.01	-

The land suitability criterion of DM2 clone Cavendish banana crop intensively managed with sprinkler irrigation system (LUT2) was compiled by three land characteristics which were very influential in the yield level. They were soil bulk density, soil CEC and soil permeability at soil depth of 0-50 cm (Table 7).

The land suitability criterion of Cj20 clone Cavendish banana crop intensively managed with sprinkler irrigation system (LUT3) was compiled by three land characteristics which was very influential in the yield level. They were soil bulk density, clay CEC and soil permeability at soil depth of 0-50 cm (Table 8).

Table 7. Land suitability criteria based on the highest and potential yields for the LUT2 in the research area.

Land Characteristic	Units	Land Suitability Classes			
		S1	S2	S3	N
The Criteria Based on Highest Yield					
- Soil bulk density (*b*)	g cm^{-3}	<1,25	1,25-1,40	1,41-1,53	>1,53
- Soil CEC (*k*)	cmol (+) kg^{-1}	>5,92	4,65-5,92	3,08-4,64	<3,08
- Soil permeability (*p*)	cm $hour^{-1}$	>12,64	8,69-12,64	2,00-8,68	<2,00
The Criteria Based on Potential Yield					
- Soil bulk density (*b*)	g cm^{-3}	-	<1,32	1,32-1,48	>1,48
- Soil CEC (*k*)	cmol (+) kg^{-1}	-	>5,39	3,73-5,39	<3,73
- Soil permeability (*p*)	cm $hour^{-1}$	-	>11,07	5,26-11,07	<5,26

Table 8. Land suitability criteria based on the highest and potential yields for the LUT3 in the research area.

Land Characteristic	Units	Land Suitability Classes			
		S1	S2	S3	N
The Criteria Based on Highest Yield					
- Soil bulk density (*b*)	g cm^{-3}	<1.21	1.21-1.37	>1.37	-
- Clay CEC (*c*)	cmol (+) kg^{-1} clay	>16.38	13.42-16.38	<13.42	-
- Soil permeability (*p*)	cm $hour^{-1}$	>6.74	5.04-6.74	<5.04	-
The Criteria Based on Potential Yield					
- Soil bulk density (*b*)	g cm^{-3}	-	<1.14	1.14-1.38	>1.38
- Clay CEC (*c*)	cmol (+) kg^{-1} clay	-	>17.98	13.39-17.98	<13.39
- Soil permeability (*p*)	cm $hour^{-1}$	-	>7.88	5.02-7.88	<5.02

Other land characteristics were deemed suitable for LUT applied at the research area or they have been represented by the existing land characteristics in the new criteria. So, they were not considered in drafting the criteria. Because of less land characteristic data needs, the land suitability classification could be done easily, cheaper, and faster.

Further, assessing the land suitability classes were defined using maximum limiting factor method or minimum laws. The verification results showed that the land suitability classes using the criteria established in this study were suited to the field crop yield levels. The criteria could also be used for other regions that have similar land characteristics with Way Kambas area, *i.e.* the Xanthic Eutrustox and Plinthic Eutrustox soil subgroups and 0-4% land slopes.

All of the new criteria showed that the banana crop land suitability classes in the research areas were determined by soil bulk density and CEC. The fact explained that the intensively soil tillage and fertility were also supported by good quality land, especially land characteristics related with nutrient retention (Joussein *et al.* 2004) and rooting conditions in the subsoil (Coelho *et al.* 2000).

CONCLUSIONS

The banana crop yield levels in Way Kambas East Lampung Indonesia had significant influence and they were determined by the land characteristics of soil bulk density, CEC, soil permeability, total porosity, ESP, soil textural class, and soil erodibility. The land characteristics that significantly determined the Cavendish banana crop land suitability classes were as follows: LUT1 lands were soil bulk density and clay CEC; those to LUT2 lands were soil bulk density, soil CEC, and soil permeability; and those to LUT3 lands were soil bulk density, clay CEC, and soil permeability.

The land suitability classification criteria built still need to be standardized again on the climate and soil conditions that were more varied with the wider region scope in order to produce the standard land suitability criteria for the intensively managed Cavendish banana crop.

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