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A modification of land suitability requirements for maize in the humid tropics of South Sulawesi

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Abstract Evaluation of land suitability needs to be supported by site-specific approach including criteria of the land use type. One of the important food crops in the humid tropic of Indonesia is maize (Zea mays L.). The main aim of this study was to modification land suitability requirements for maize in the specific humid tropic of Indonesia. There were 3 representative districts in the South Sulawesi of Indonesia, consists of Jeneponto (dry zone,climate type E), East Luwu (wet zone, climate type A), and Bulukumba (relative dry, climate type D). There were 20 profiles in each district so that total of representative are 60 farmers and 60 profiles. This study used the deductive parametric approach on determine land suitability index (based on crops yield), the determination of observation's point was purposive sampling, data analysis was use Pearson correlation and linier regression analysis including on determination of interval value of land characteristics that have correlation and significant effect to maize yield. The result showed that land characteristics that have significant effect ($p<0.01$) to maize yield in the humid tropic of South Sulawesi were precipitation of growth cycle, soil pH, C-Organic, and base saturation. The range values of land characteristics which classified as optimal (S1) for humid tropic region of Indonesia were precipitation of growth cycle (650-900 mm), soil pH (6.8-7.0), C-organic (>2.2%), and base saturation (>62%), furthermore classified as marginal (S3) whether precipitation of growth cycle(<270 mm), C-organic (<1.15%), soil pH (<5.47 or >8.0), and base saturation (10-41%).

1. Introduction

Competition of using land use resources might happen due to conflict of interests between development sector due to increasing population. Consequently, inappropriate land use was increase so degradation of land often occurs and its impact to reduction of land productivity. The appropriate land use is right effort to ensure sustainable agriculture.

Land evaluation is an assessment of land performance when used for specific designation. Various methods of land suitability evaluation have been used in Indonesia, but the methods were various and not yet standardized, so if applied on the same land often showed a different result. This is mainly caused by differences of criteria and way of decision making on land suitability classification [1]. Land suitability criteria in Indonesia for various agriculture commodities is still general which is arranged by data complication and empirical experience referring on foreign publications such as FAO [2-3]. The existing range value is considered to be wide that is supposed due to varied data assessed because of various regions both tropic and sub-tropic/temperate or in other words isn't specific yet. Generally, land suitability assessment is qualitative and only based on physical properties of land. Criteria of land

suitability generally arranged based on empirical crop growth requirement, not the data of actual production. Land characteristics used and its indexing has not factually reviewed yet and connecting with the crop productivity on processing level that might be inappropriate between land potential and expected productivity [4]. The current criteria of land suitability have not built yet according to influence of each quality and land characteristics toward plant productivity. Land evaluation ought to use different criteria and range value for each area depend on land use supposed [5]. In line with [6] that to obtain appropriate land evaluation, so that land characteristics/quality (LC/LQ) should be reviewed and adjusted with local condition and variety of crops.

One of area maize produced in Indonesia is South Sulawesi that reach productivity of maize 1.34 million ton (7.3% from national productivity), the current mean productivity of maize of South Sulawesi (4.42 ton/ha) is still below the optimal productivity that could reached (yield prediction). Optimal productivity of maize could be reach for some maize produced area in Indonesia, according to [7] is 6 ton/ha, to DAICROS (daily crops simulation model) could be reach 8.1 ton/ha, and GCYI (good commercial yield under irrigation) is 9 ton/ha [8-9]. Maize productivity is less than optimal yield due to unjustified land resources use because of erroneous land use planning particularly related to requirements of specific location land use. Achieving optimal productivity of maize on area potential of maize needed support of land characteristics/land quality, proper land management, and government's policy support.

Geographically, South Sulawesi located in area which is classified as humid tropic [10-11]. The southern part of South Sulawesi had potential for maize development supposed due to climate factor (classified as type of climate D and E) particularly temperature and radiation length are high enough in this area (average of maize production is 4-5 ton/ha). Otherwise, on the Northern of South Sulawesi had wet climate (classified as A and B type), the mean of maize production is relatively lower than other area (< 4 ton/ha) [10-11]. Based on the recently explanation so it is necessary to do a research about characteristics and requirements of land specific location for maize on sufficient management level on the humid tropic of Indonesia.

2. Methodology

The research was be held on 3 (three) districts which are produce maize on South Sulawesi, Indonesia, consists of Districts of Jeneponto, Bulukumba, and East Luwu. The maize production was obtained from two growing period in each district which is start from November-February and March-June for Jeneponto District and Bulukumba District whereas East Luwu on December-March and June-September. These are stages of research that expanded as:

1. Determine the representative area. The representative district as determined based on difference of climate type using classification of Oldeman, specifically Jeneponto District (classified as E3 and D3), Bulukumba District (classified as D1 and C2), and East Luwu District (Classified as A), and criteria of average of maize production each district divided into high, medium, and low.
2. Determination unit of observation area. Unit of observation land was determined according to land characteristics homogeneity, namely slope, soil type, and parental rock type. In addition, was considered that the land unit could be found absence of maize cultivation activity with the homogenous management, such as growing time, varieties, dose of fertilizer, and history of land use.
3. Identification of land use. The identification of land use type had necessary to know the needed of land use requirements for maize development in the study areas according to LUT attribute of FAO [2].
4. Characterization of maize-producing land in the study area. On each unit land of observation was made representative soil profile based on Guideline for Soil Profile Description [12-13]. In addition, determination of growing time is necessary which is begin from

evapotranspiration determination based on Penman method and further determine the growing period with the equation as follows:

GP is P^' s months ≥1/2 ETP ..... (1)

Where:

GP = growing period

P = precipitation (mm)

ETP = evapotranspiration (mm)

5. Field validation is done by determine actual Maize production on the field using square area method 2.5 m x 2.5 with the equation as follows:

The Wc_ha=1,600 x Wc_spl.....(2)

Where:

Wc_ha = maize weight (kg/ha)

Wc_spl = maize weight in 2.5 m x 2.5 m

= coefficient of 10.000/(2.5 x2.5)

6. Determination of maize predicted yield follows the procedure by [3] which is for S1 has supposed to reach >75%; S2 ≥50-75; S3 ≥25-50%; and N<25% of optimal production. Determination of optimal production is according to Radiation Thermal Production Potential (RTPP) [8]. Marginal result showed that the level of productivity is causing balance of total profit and total expenditure [14].
7. The arrangement of modification criteria of land suitability for maize appropriate with actual maize production. Determination of maize's requirements criteria on land use type was arranged based on relevant land characteristics on dry land and its effect toward maize growth and production. The range of each land characteristics was determined by quadratic regression analysis from correlation between land characteristics and maize production with optimal production range of each land suitability class. Analysis of correlation between land index and land characteristics with observed maize yield using Pearson correlation analysis which has value 0-1 and quadratic regression analysis to know impact on each land characteristics toward Maize production. The result of statistics analysis would be determining sort and amount of determined land characteristics for land suitability class and its rating. Range of value each characteristic is determined using trial and error method, that is based on linier or quadratic regression equation between land characteristics and maize production.

3. Results and Discussion

3.1 Land characteristics and maize production correlation

3.1.1Climate, The research showed that land characteristics had significant correlation with maize yield are precipitation of growing period, precipitation of first month, precipitation of third month, length of radiation on generative stage of plant (Table 1). Optimal precipitation of growing season for crops growth and productivity based on Sys [3] is 600-900 mm/growing period, while the marginal one is <400 mm and/or >1600 mm/ growing period. If precipitation <300 mm/ growing period will be classified as inappropriate for maize. Except precipitation, length of radiation on generative stage also had significant correlation with maize yield, in order the value of r are 0.762 and 0.735.

3.1.2. Soil and Terrain, The result of correlation analysis showed that land characteristics (soil and terrain) had significant correlation with Maize yield, specifically drainage, flooding, base saturation, sum of basic cations, soil pH, and C-Organic, whereas other characteristics such as slope, coarse fragment, soil depth, soil texture, $CaCO_3$, CEC are not have significant correlation with maize production on study area. The following table showed analysis of correlation between land characteristics with maize yield on study area (Table 2).

Table 1. Correlation value (r) between climate and maize yield on the study area

Characteristics of Climate	r
Precipitation of growing period	0.491*
Precipitation of first month	0.390*
Precipitation of second month	0.316
Precipitation of third month	0.409*
Precipitation of fourth month	0.044
Mean temperature of growing season	0.285
Minimum temperature of growing season	0.317
Relative humidity of vegetative stage	0.270
Relative humidity of generative stage	0.341
n/N vegetative stage	0.762**
n/N generative stage	0.735**

**Correlation is significant at the 0.01 level (2-tailed) ; * Correlation is significant at the 0.05 level (2-tailed)

Table 2. Correlation value between land characteristics with maize yield on study area

Land Characteristics	r
Slope	0.022
Drainage	0.290*
Flooding	0.298*
Texture	0.213
Soil depth	0.174
Coarse fragment	0.098
Cations Exchange Capacity (CEC)	0.189
Base saturation	0.603**
Sum of basic cations	0.352*
Soil pH H_2O	0.584**
C-Organic	0.552**

**Correlation is significant at the 0.01 level (2-tailed) ; * Correlation is significant at the 0.05 level (2-tailed)

3.2 Effect of land characteristics toward maize yield (regression analysis)

Effect of climate to maize yield on study area was determined based on regression analysis in various factors that have correlation value with maize yield on level $P<0.05$. Regression analysis showed that climate characteristics influence maize yield consist of precipitation of growing period, n/N on vegetative stage, and n/N on generative stage. The analyze of regression showed that maize yield was effected significantly by precipitation of a growing season (110 days). The best maize yield is on precipitation 750-850 mm. According to Sys et al. [3], optimal precipitation along a maize growing season is about 600-900 mm. According to [15] explained that requirements of optimal precipitation for maize is about 500-1.200 mm/year. Limiting factors for maize cultivation are water availability. Water deficits often occurs during the growing period of the crops. According to [3] water deficits will greatly affect plants primarily on the period of germination (emergence), flowering and initial generative compared to vegetative periods and fruit ripening. Otherwise the torrential precipitation on maturation phase of seeds will affect the physiological processes of the plant which is causing the less optimal maturation process which can reduce the quality of the seeds produced. According to [16], dry climate is ideal for the process of ripening, and excess

of rainwater will be reducing the quality of seeds. The impact of precipitation characteristics on maize yield is shown in Table 3.

Table 3. The regression analysis of climate characteristics toward maize yield at the research location

Land Characteristics	R^2	Regression Equation
Precipitation of growing period	0,241*	$Y = 0{,}008\text{-}0{,}0000514X + 0{,}408X^2$
Precipitation of first month	0,152	$Y = 4{,}012\text{-}0{,}007X\text{+}0{,}00000717X^2$
Precipitation of third month	0,099	$Y = 1{,}176 + 0{,}021\ X\ \text{-}0{,}000475X^2$
n/N vegetative stage	0,580**	$Y = 8{,}974 - 18{,}004X + 12{,}773X^2$
n/N generative stage	0,540**	$Y = 24{,}924 - 77{,}639X + 67{,}67X^2$

**Correlation is significant at the 0.01 level (2-tailed) ; * Correlation is significant at the 0.05 level (2-tailed)
R^2 : coefficient of determination

The significant land characteristics with maize yield were further analyzed to know the effect toward maize yield at the study site. The results of linear/curvilinear regression showed that significant land characteristics (level <0.05) were precipitation of growing cycle, n/N vegetative stage, n/N generative stage, base saturation, soil pH H_2O, and organic carbon. The results of the regression are shown in Table 4. The results of the quadratic regression analysis between the significantly correlated characteristics indicate that the influence of the characteristics of the land is suitable varied as seen from the R^2 value ranging from 0.088 to 0.580.

Table 4. Results of regression characteristics of land with maize yield

Land Characteristics	R^2	Regression Equation
Precipitation of growing period	0.241*	$Y = 0{,}008\text{-}0{,}0000514X + 0{,}408X^2$
Precipitation of first month	0.152	$Y = 4{,}012\text{-}0{,}007X\text{+}0{,}00000717X^2$
Precipitation of third month	0.099	$Y = 1{,}176 + 0{,}021\ X\ \text{-}0{,}000475X^2$
n/N vegetative stage	0.580**	$Y = 8{,}974 - 18{,}004X + 12{,}773X^2$
n/N generative stage	0.540**	$Y = 24{,}924 - 77{,}639X + 67{,}67X^2$
Soil pH H_2O	0.341*	$Y = 21{,}77 - 7{,}67X + 0{,}754\ X^2$
Drainage	0.088	$Y = 3{,}613 - 0{,}620\ X$
Flooding	0.089	$Y = 3{,}666\ \text{-}0{,}678X$
Base saturation	0.363*	$Y = 1{,}838 + 0{,}039X$
Sum of basic cations	0.123	$Y = 2{,}011 - 0{,}148X + 0{,}004X^2$
C organic	0.305*	$Y = 1{,}493\ \text{+}0{,}132X + 0{,}506X^2$

**Correlation is significant at the 0.01 level (2-tailed) ; * Correlation is significant at the 0.05 level (2-tailed) ; R^2 : determination coefficient.

Criteria of land suitability for maize on the humid tropic

Criteria of land suitability for maize on dry land with humid climate at specific location that has various of climate, parent material, and soil types in South Sulawesi could be built based on quality/relevant land characteristics and appropriate with necessary of land use and crop production requirements. This criteria is also possible to use on the other area that has similar land Characteristics. In the previous discussion, the results of regression analysis revealed several significant characteristics affect maize production and determine the land suitability class, namely climate characteristics (growing cycle precipitation) with a value of $R^2 = 0.241$ ($P < 0.05$), the length of sun radiation at vegetative stage ($R^2 = 0.580$, $P < 0.01$) and generative stage ($R^2 = 0.540$ ($P < 0.01$), soil pH ($R^2 = 0.341$

($P < 0.05$), base saturation ($R^2 = 0.363$ ($P < 0.01$) and soil organic carbon ($R^2 = 0.305$ ($P < 0.05$). Other characteristics have no effect on maize production at study site, however, these characteristics still need to be considered for use, especially for other areas outside the study area.

Any further, based on the regression equation associated with maize production in the site at the optimal level, the criteria for new characteristics are produced, that the characteristics have a regression equation and the real R^2 value (level $P < 0.05$) is statistically influence the maize production in the study area, namely growing cycle precipitation, length of radiation at the vegetative stage (n / N_2) and generative stage (n / N_4), soil pH, base saturation and soil organic carbon. The criteria for the growth and production requirements of plants which are formed are divided into 4 classes namely highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable (N). The details are shown in Table 5.

Table 5. Criteria of land suitability for maize according to its yield in the type of management of land based on maize management in the wet tropics of South Sulawesi

Characteristics	Land Suitability Class			
	S1	**S2**	**S3**	**N**
n/N vegetative stage (2nd month)	0.50 - 0.55	0.45 - 0.50	>0.80	-
		0.55 – 0.80	<0.45	-
n/N generative stage (4th month)	>0.64	0.46 – 0.64	<0.46	-
Base saturation (%)	>62	41-62	10-41	<10
Soil pH H_2O	6.8 – 7.0	6.3 -6.8	5.47 -6.3	<5.47
		7.0 -8.0		>8.0
Organic Carbon (%)	>2.2	1.1 – 2.2	<1.1	-
Precipitation of growing cycle (mm)	650-900	550-650	270-550	<270
		900-1.200	>1.200	-

S1: very suitable; S2: moderately suitable; S3: marginally suitable; N: unsuitable

Conclusion

Based on the results in this study it can be concluded that:

The land characteristics which significantly correlated with maize yield were climate (precipitation during the growing season, length of radiation at the vegetative and generative phase), soil fertility (base saturation, soil pH and soil organic carbon). The range of land characteristics are considered optimal for maize production are precipitation during growing season is 650-900 mm, length of radiation at vegetative phase is 0.50-0.55 and the generative phase is > 0.64, then base saturation is > 62%, soil pH is about 6.8-7.0, and organic carbon is > 2.2%.

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