

Biophysics and economic potential analysis of vertisols for maize in the humid tropics of Indonesia

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Abstract. The main objective of this study is to establish the potential of Vertisols both biophysical and economic found in the humid relatively dry tropics region in the southern part of Sulawesi to the development of maize. This study used a spatial approach for establishing research sites totalling in 3 observations units of soil profile and involved 30 farmers as respondents. Land potential analysis of was conducted using parametric approach while economic analysis using the benefit-cost (B-C) ratio. The results show that the growing period of the study sites was in November to June, or 240 days and classified as climate type E3. The locations potentially moderately suitable or S2s for maize with soil texture as limiting factors in the growing season from November to June. In the growing season from July to October, the locations are not suitable or Nc with limiting factors such as very limited rainfall in the period of crop ripening. Land suitability Index of study site during the growing season from November to June ranged from 52 to 72 with an average productivity of maize obtained by farmers ranged from 4.3 to 5.7 tons of dry grain per hectare. Analysis of B-C ratio indicates that cultivation of maize in the growing period at such study locations are feasible with the value of B-C ratio ranged from 1.8 to 2.5. These results show that Vertisols in the humid tropics of Indonesia are physically and economically potential for maize development.

1. Introduction

South Sulawesi, one of the major food-producing provinces in the eastern part of Indonesia produces a large amount of maize. This region has varied climate types. According to the criteria of Oldeman [1], the climate in South Sulawesi classified as B1, C1, C2, D1, D2, E1, E2, and E3. Average of maize production in South Sulawesi varies in the range of 3-5 tons/ha. The highest average productivity can be found in the southern region with relatively dry climate, while the lowest productivity is in the northern region with relatively wet (humid). Based on the exploratory map of Indonesia [2], one of the main soil types found in South Sulawesi is Vertisols (3.6 %) which has to swell and shrink properties. One of the maize-producing districts in South Sulawesi, Jenepono District has the most extensive land area of Vertisols. The vertic property can be one of the major growth inhibiting factors of maize growth at the time of shrinking which results in the breaking of plant roots. Maize productivity is strongly influenced by the quality/characteristics of the land, including soil and climate. Agricultural development always needs soil suitability evaluation that can be expressed as "land suitability index" measured on different types of soil. The types of soil formed by a certain pedogenesis process may provide information on the potential productivity of the soil [3]. Soils also provide several ecological and social functions [4, 5]. The soil characteristics such as fertility, water availability, and land management have not been to date under consideration by farmers in agricultural development. Land evaluation is necessary to produce recommendations for appropriate land management according to



land potential. To obtain production level according to land potential, crops should be grown under conditions of sufficient water and nutrients, while pest, weed, and disease should be controlled [6]. Therefore, land suitability classification needs to be taken into account in the development of high commodity because it is based on knowledge of the requirements of crops, soil characteristics, and soil management [7]. The result of land evaluation should reflect not only possible yield but also, more importantly, the ease or difficulty of management of the land parcels for a given purpose and ensure the land's sustained use for a long period of time [8]. The main objective of this study is to determine the potential of Vertisols found in the humid tropics relatively dry southern part of Sulawesi both biophysically and economically for the development of maize.

2. Methodology

2.1. Study Area and Data Collection

The study area located at 3 land units in District of Jeneponto (figure 1) which classified as Vertisols where maize is cultivated (existing land use). The three land units are characterized by high humidity range between 66.0% and 86.7%, mean annual rainfall distribution of 1.500 mm and mean temperature ranged between 26.5 °C and 27.1 °C. The study area is underlined by carbonate rocks, volcanic breccias. Ten-year meteorological data used in this study were collected from a climatology station to determine rainfall, temperature, relative humidity and daylength.

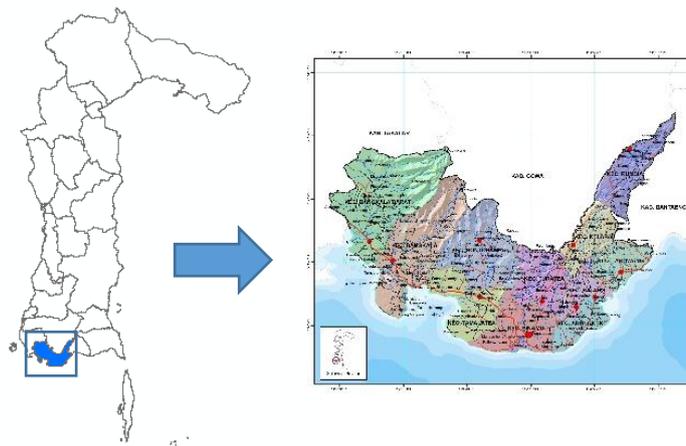


Figure 1. Location of study area, in the box, is Jeneponto Regency

2.2. Field Survey and Laboratory Analysis

Soil characteristics surveyed in 2016 was analyzed using purposive sampling method. Identification of land under traditional maize cultivation in the study area was undertaken during cultivation period (November to February and March to June). As many as 30 farmers (focusing on maize cultivation) were sampled and 3 representative soil profiles were also made to examine soil horizons. Soil samples were collected and analyzed using standard procedures, as follows, soil particle size distribution was determined using hydrometer method [9]; soil organic carbon was determined using dichromate oxidation procedure [10]; exchangeable bases (Ca, Mg, K, Na) and cation exchange capacity (CEC) were determined with 1 N NH₄OAc, pH 7.0. Soil reaction (pH) was measured in water (1 : 2.5, soil water ratio). Maize harvested at a randomly determined unit sample of 2.5 x 2.5 sq meters, with 3 replications. The harvested seeds of maize were dried, then weighted and their weights were calculated by using (1) [11]:

$$W \text{ (tons/ha)} = 1.6 \times W \text{ sample} \quad (1)$$

2.3. Data Analysis

The soils were classified in a subgroup group level according to Keys to Soil Taxonomy [12]. The suitability classification was carried out separately for each soil unit identified in the survey area. Land

suitability evaluation was performed using the parametric method of [13]. The parameters used for land quality calculation include rainfall of growing cycle, mean temperature, relative humidity, length of radiation, slope, drainage, soil physics (texture, depth), soil fertility (pH, organic carbon, CEC, base saturation). In the evaluation, the soil characteristics were then compared with crop requirement of maize [14]. Land suitability index (I) calculated from the individual ratings was determined using Square Root method [15] with equation:

$$I = R_{\min} \times \sqrt{A/100 \times B/100 \times \dots} \quad (2)$$

where I = Land suitability index; R min = Minimum rating; A, B, .. = Other ratings beside the minimum rating.

An Economic analysis using the benefit-cost ratio can be defined as the ratio of the equivalent value of benefits to the equivalent value of costs. The equivalent values can be present values, annual values, or future values. The benefit-cost ratio (BCR) is formulated as:

$$BCR = B / C \quad (3)$$

where *B* represents the equivalent value of the benefits associated with the project and *C* represents the project's net cost [16]. A *B/C* ratio greater than or equal to 1.0 indicates that the project evaluated is economically advantageous.

3. Results and Discussions

3.1. Soil Classification

The three soil profiles were classified at Subgroup levels. The two of pedons classified as *Typic Calciusterts* and *Typic Haplusterts* show Vertisols characteristics which have slickensides and have more than 30 percent clay in the fine-earth fraction either between the mineral soil surface and a depth of 18 cm or in an Ap horizon. In addition, the pedons have cracks that open and close periodically and high base saturation (vary from 52 to 60%). *Typic Calciusterts* has calcic horizons within 63 cm. *Typic Haplusterts*, *Typic Calciusterts*, occupy the gently undulating lower slope, shallow with soil depth ranging from 20 to 65 cm, and well drained. They are found in climatology zones of E2 according to Oldeman classification [1]. Their parent materials are limestone and volcanic breccias.

3.2. Distribution of Maize Yields and Suitability Class

The results of field study show that maize yield variation ranges from 4.3 to 5.7 tons ha⁻¹ with land suitability index (I) ranges from 52 to 72. Based on [13], the index value (I) of land ranging from 75 to 100 is classified as highly suitable (S1); 50 to 75 as moderately suitable (S2), and 25 to 50 as marginal (S3). Their parent materials are mostly limestone and volcanic breccias which consist of a lot of basic cations such as calcium and magnesium. Therefore, soils formed from limestone minerals have high base saturation and soil pH tend to be around neutral [17]. Soil fertility characteristics like base saturation and soil pH as well as water availability influence maize yield [18]. In the period of November to June, 3 units of analysed land classified as an S2 class or sufficient according to soil texture limiting factors, whereas in the growing season July to October due to the problem of water availability, the land unit classified as unsuitable (N2).

3.3. Benefit-Cost Ratio of Land Unit at Study Area

Based on the analysis of the B-C ratio on 30 respondents in the research location, it can be seen that the feasibility of maize farming attempted by farmers in Vertisols soil was still economically feasible with B-C ratio range between 1.8 and 2.5. The B-C ratio indicates that the investment of maize in this area is economically viable and on an average 1 investment brings 1.8 to 2.5 returns.

4. Conclusion

The growing period of the study sites was in November to June, or 240 days and classified as climate type E3. The location potentially moderately suitable or S2 for maize with soil texture as limiting factor in the growing season from November to June. In the growing season from July to October, the location is not suitable or Nc with limiting factors such as limited rainfall at the period of fruit

ripening. Land suitability index of the study site during the growing season from November to June ranged from 52 to 72 with an average productivity of maize was obtained by farmers ranges from 4.3 to 5.7 tons of dry seed per hectare. Analysis of B-C ratio shows that the cultivation of maize in the growing period at locations such studies are feasible with the value of B-C ratio ranges from 1.8 to 2.5.

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References

- [1] Oldeman 1977 *The Agroclimatic Map of Sulawesi* (Bogor: Contr. Centr. Res. Ins. Agric.) No. 33. 30p+map.
- [2] Subagyo H, Suharta N and Siswanto A B 2000 *Agriculture soils in Indonesia* (Bogor: Indonesian Center for Soil and Agroclimate Research and Development, Ministry of Agriculture of Indonesia)
- [3] Mueller L, Schindler U, Mirschel W, Shepherd T G, Ball B C, Helming K, Rogasik J, Eulenstein F and Wiggering H 2010 Assessing the productivity function of soils A Review *Agron. Sustain. Dev.* **30** 601-614 INRA.EDP Sciences
- [4] Lal R 2008 Soils and sustainable agriculture. A review *Agron. Sust. Dev.* **28** 57-64
- [5] Jones A, Stolbovoy V, Rusco E, Gentile A R, Gardi C, Marechal B and Montanarella L 2009 Climate change in Europe. Impact on soil. A review *Agron. Sust. Dev.* **29** 423-432
- [6] Verdoort A, and van Ranst E 2003 *Land Evaluation for Agricultural Production in The Tropics* (Gent, Belgium: Laboratory of Soil Science, Ghent University)
- [7] Ande O T 2011 Soil suitability evaluation and management for cassava production in the derived savanna area of South Western Nigeria *Int. J. of Soil Sci.* **6** (2) 142-149
- [8] Baja S 2009 *Land Use Choice and Land Resources Assessment in Agriculture. A review (CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources)*
- [9] Bouyoucos G J 1962 Hydrometer method improved for making particle size analysis of soils *Agron. J.* **54** 464-465
- [10] Walkley A and Black G A 1934 An examination of Degtjareff NHO for determining soil organic matter and a proposed modification of chronic acid titrate *Soil Sci. Battinose* **37** 29-38
- [11] Baja S, Amrullah A, Ramli M, and Ramlan A 2011 *Spatial-based fuzzy classification of land suitability index for agriculture development: A model validation perspective (Proc. of 3rd International Joint Conference on Computational Intelligence-International Conference on Fuzzy Computation Theory & Applications IJCCI-FCTA)* Paris, France, 24-26 October 2011 p 435-440
- [12] Soil Survey Staf 2010 *Keys to Soil Taxonomy. Eleventh Edition* (United States Department of Agriculture, Natural Resources Conservation Service)
- [13] Sys C, van Ranst E and Debaveye J 1991 *Land Evaluation. Part I. Principles in Land Evaluation and Crop Production Calculations Agricultural Publications No. 7* (Brussel-Belgium: General Administration for Development Cooperation)
- [14] Sys C, van Ranst E and Debaveye J 1993 *Land Evaluation. Part III. Crop Requirements. Agricultural Publications No. 7* (Brussel-Belgium: General Administration for Development Cooperation)
- [15] Khiddir S M 1986 *A Statistical Approach in the Use of Parametric System Applied to the FAO Framework for Land Evaluation* (Belgium: State University of Ghent) p 144
- [16] Ulukan Z and Ucuncuoglo C 2010 Economic analyses for the evaluation of is projects *J. of Inform. Sys. and Tech. Manag.* **7** (2) 233-260
- [17] Sys C 1977 *Regional Pedology. Agricultural Publications No. 7* (Brussel-Belgium: General Administration for Development Cooperation)

- [18] Calvino P A, Andrade F H and Sadras V O 2003 Maize yield as affected by water availability, soil depth, and crop management *Agron. J.* 2750 **95** (2) 275-281