Land suitability index to estimate the land potential for arabica coffee plantation: A case of Tompobulu District, Bantaeng Regency

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Abstract. This study aims to estimate the potential of land in Tompobulu district, Bantaeng Regency for the development of Arabica coffee plantation based on the land suitability index. The criteria of land suitability based on Sys et al. (1993), the land suitability index (LSI) calculated by using the parametric methods with the Khiddir equation. The correlation analysis between LSI and coffee yield by using Pearson correlation analysis. The results show that the climate suitability index in the study areas was around 48 (marginally suitable) with a limiting factor is rainfall of 3,337 mm/year. The result of the study shows that the LSI values ranged from 15.2 to 37.5 and was classified marginally suitable (S3) and currently not suitable (N1). Class S3 covered the area of around 3,926.92 ha or 62.42% while class N1 around 2,364.67 ha or 37.8%. The limiting factors are climate, salinity, CaCO3, coarse fragments, soil depth and texture in single or in combinations. The correlation between the LSI and Arabica coffee yields is relatively strong with a correlation coefficient higher than 0.9 ($r > 0.9$).

1. Introduction
Bantaeng Regency is the third-largest coffee producing area in South Sulawesi after Pinrang Regency and Bulukumba Regency. The coffee production in Bantaeng, Pinrang, and Bulukumba Regency are 2,356 tons, 1,404 tons, 1,111 tons, respectively[1].

Based on the Bantaeng Regency governments strategic plan as seen in Regional Regulation No. 2 (2012) about the Regional Spatial Planning for the Bantaeng Regency 2012-2032, it is planned to develop plantation commodities, especially coffee plants in several districts, including Tompobulu, Uluere, and Eremerasa districts where a coffee plantation area of 4,500 ha. The development of this coffee plantation is based on the consideration that coffee production in the Tompobulu district increased from 1,029 tons in the year 2015 to 1,656 tons in the year 2016 [2].

According to [3], the optimal Arabica coffee productivity at the farm level is 1.2 tons/ha and associated with Arabica coffee productivity 2017 in Tompobulu district is 0.5 tons/ha. This indicates that the results of Arabica coffee in Tompobulu district is still classified below optimal.
2. Methods

Profile description and soil sampling were carried out in Tompobulu district, Bantaeng Regency, South Sulawesi province (figure 1). Analysis of soil physical and soil chemical properties were carried out in the Soil Chemistry Laboratory, Department of Soil Science, Faculty of Agriculture, Universitas Hasanuddin.

The research was used quantitative methods. A parametric approach according to the khiddir (1986) method was used for estimating the land suitability for Arabica coffee plantations. The stages of research were preparation (data collection), making a land unit map (figure 1), soil sampling and questionnaire data, soil samples analysis in the soil laboratory, climate and land suitability analysis, and lastly was the correlation analysis between productivity and land index of Arabica Coffee plants.

![Figure 1. Map of land unit in Tompobulu district](image)

3. Results and discussion

3.1. Climate characteristics of the study area

Based on the last 10 years of rainfall data (2008-2017), the study area has a monthly rainfall with an average of 2,420 mm/year. Therefore, the climate in Tompobulu district according to Oldemen is classified as B2 climate type with eight (8) of wet months.

The study area has an average temperature of 24°C, with a minimum temperature of 14°C and a maximum temperature of 36°C. The temperature in the study area is suitable for coffee plant growth. According to [4], the ideal temperature for growing coffee plants ranges is 15°C to 24°C. The humidity in research area was 79%, this value is quite suitable for the growing requirements of arabica coffee plants. According to [3], the desired humidity of coffee plants is around 30-80%.

3.2. Land suitability analysis

3.2.1. Climate suitability analysis of arabica coffee plants. Based on the results of the analysis using the Khiddir equation in the study area which has a climate index of 48 with a climate rating of 60 (table 1). Climate suitability class is classified as marginal (S3) for the development of Arabica coffee plantation with rainfall is as a limiting factor. Rainfall in the study area is 3,337 mm/year, which is quite high for coffee. Arabica coffee plants require rainfall growth requirements less than
2,420 mm/year. According to [3], Arabica coffee plant growth optimally if rainfall is in the range of 1,000-2,000 mm/year.

**Table 1.** Classification of climate suitability classes in the study area

| Parameter                        | Rating | Class |
|----------------------------------|--------|-------|
| Rainfall                         | 60     | S3    |
| Long dry month                   | 95     | S1    |
| Average maximum temperature      | 95     | S1    |
| Average min temperature of the coldest month | 95 | S1    |
| Average annual temperature       | 95     | S1    |
| Average humidity in the driest month | 82.5 | S2    |
| Long irradiation of 5 dry months | 95     | S1    |

3.2.2. *Land suitability index of arabica coffee plants.* Based on the land index of 10 land units, two land classes are obtained, which are marginal (S3) and not temporarily (N1). Six land units are classified as marginal land classes (S3) that is land units 1, 3, 4, 7, 8, 10. While four land units are classified as temporary land classes (N1), that is land units 2, 5, 6, and 9. The highest land index is shown in land unit 1 with a land index of 37.5 (climate limiting factor) and for the lowest land index is shown in land unit 9 with a land index of 15 (land depth limiting factor) (tables 2, 3 and 4). The land suitability map can be seen in Figure 2.

**Table 2.** Scale, harkat, index and land suitability classes of the study area

| Land characteristics                        | 1 | 2 | 3 | 4 | 5 |
|---------------------------------------------|---|---|---|---|---|
| Climate weight                             | Score | R | Score | R | Score | R | Score | R | Score | R |
| Topography (t) slope (%)                    | 0% | 100 | 2% | 100 | 2% | 100 | 5% | 85 | 7% | 85 |
| Wetness (w)                                | Flood | Fo | 100 | Fo | 100 | Fo | 100 | Fo | 100 | Fo | 100 |
| Soil physical characteristics (s)           | Drainage | good | 100 | good | 100 | good | 100 | good | 100 | good | 100 |
| texture / structure                         | CL | 100 | SCL | 85 | SC | 95 | L | 95 | SCL | 85 |
| coarse fragments (vol%)                     | 10% | 95 | 50% | 60 | 50% | 60 | 30% | 85 | 50% | 60 |
| soil depth (cm)                             | 60 | 60 | 60 | 60 | 110 | 85 | 110 | 85 | 60 | 60 |
| CaCo3 (%)                                   | 2 | 85 | 3 | 60 | 3 | 60 | 4 | 60 | 3 | 60 |
| Soil fertility characteristics (f)           | CEC (cmol+/kgclay) | 34.2 | 100 | 70.4 | 100 | 41.6 | 100 | 47.5 | 100 | 80.4 | 100 |
| Base saturation (%)                         | 41.8 | 85 | 59.4 | 95 | 51 | 95 | 66.8 | 95 | 67 | 95 |
| amount of basic cations (cmol+/kg soil)     | 7 | 100 | 9 | 100 | 10 | 100 | 100 | 100 | 9 | 100 |
| pH H2O                                      | 5.8 | 100 | 6.2 | 100 | 6.3 | 95 | 6.1 | 100 | 6.1 | 100 |
| organic carbon (%)                          | 2.2 | 95 | 1 | 85 | 2.2 | 95 | 1.8 | 85 | 1.6 | 95 |
| Salinity and alkalinity (n)                 | Ece(dS/m) | 0.3 | 100 | 0.1 | 100 | 0 | 100 | 0.8 | 60 | 0.2 | 100 |
| Land index                                  | 37.5 | 23.1 | 30 | 25 | 23 |
|                                             | S3 | N1 | S3 | S3 | N1 |
Table 3. Scale, harkat, index and land suitability classes of the study area

| Land characteristics | 6 | 7 | 8 | 9 | 10 |
|----------------------|---|---|---|---|----|
| Climate weight       | Score | R | Score | R | Score | R | Score | R | Score | R |
| Topography (t)       |       |   |       |   |       |   |       |   |       |   |
| slope (%)            | 5% | 85 | 13% | 60 | 4% | 95 | 3% | 95 | 4% | 95 |
| Wetness (w)          | Flood | Fo | 100 | Fo | 100 | Fo | 100 | Fo | 100 | Fo |
| Drainage             | good | 100 | good | 100 | good | 100 | good | 100 | good | 100 |
| Soil physical        | texture / structure | SL | 60 | L | 95 | CL | 100 | CL | 100 | SC |
| characteristics (s) | coarse fragments (vol%) | 50% | 60 | 10% | 95 | 10% | 95 | 10% | 95 | 10% |
| soil depth (cm)      | 100 | 60 | 160 | 95 | 130 | 85 | 40 | 25 | 60 | 60 |
| CaCO3 (%)            | 3   | 60 | 4   | 60 | 2   | 85 | 2   | 85 | 2   | 85 |
| Soil fertility       | CEC (cmol(+)/kg clay) | 82.7 | 100 | 61.9 | 100 | 72.9 | 100 | 35.6 | 100 | 48.3 |
| characteristics (f) | Base saturation (%) | 57.4 | 95 | 61.4 | 95 | 51 | 95 | 40.8 | 85 | 44.3 |
| amount of basic      | 10 | 100 | 9 | 100 | 9 | 100 | 5 | 100 | 9 | 100 |
| cations (cmol(+)/kg   | pH H2O | 5.9 | 100 | 6 | 100 | 5.6 | 95 | 5.9 | 100 | 6 | 100 |
| soil)                | 1.5 | 95 | 1.9 | 95 | 1.8 | 95 | 2 | 95 | 1.6 | 95 |
| Salinity and         | Ec (dS/m) | 0.4 | 100 | 0.4 | 100 | 1.4 | 60 | 0.4 | 100 | 0.3 |
| alkalinity (n)       |       |   |       |   |       |   |       |   |       |   |
| Land index           |       |   |       |   |       |   |       |   |       |   |
|                     | N  | S3 | S3 | N | S3 |

Table 4. Land suitability class and limiting factor of Arabica coffee plants in the study area

| Land Unit | Suitability class | Limiting Factor | Area (Ha) | Percentage (%) |
|-----------|-------------------|-----------------|-----------|----------------|
| 1         | S3c               | Climate         | 2,326.62  | 36.98          |
| 2         | N1s               | Coarse fragments| 824.73    | 13.11          |
| 3         | S3cs              | Climate, CaCO3  | 762.45    | 12.12          |
| 4         | S3csn             | Climate, CaCO3, dan salinity | 128.63 | 2.04 |
| 5         | N1s               | Coarse fragments, soil depth | 478.77 | 7.61 |
| 6         | N1s               | Coarse fragments, soil depth, texture | 889.75 | 14.14 |
| 7         | S3cts             | Climate, slope, and CaCO3 | 287.9 | 4.58 |
| 8         | S3cn              | Climate, salinity | 212.85 | 3.38 |
| 9         | N1s               | Soil depth      | 171.42    | 2.72           |
| 10        | S3cs              | Climate         | 208.47    | 3.31           |
| Total     |                   |                 | 6,291.59  | 100            |

Information: s = Soil physical; t = Slope; c = Rainfall; n = Salinity and alkalinity

In general, the land suitability of Arabica coffee plants in the Tompobulu district is classified as marginal (S3) with the limiting factors are climate, slope, CaCO3, and salinity. Marginal land class (S3) is land that has a very heavy barrier if used for a particular land use. The limiting factor will reduce the value of productivity or the benefits obtained. Judging from the current land suitability index, land improvement should be carried out so that the land used for the cultivation of Arabica
coffee can grow optimally. However, even the marginal land (S3) is still allows plants to grow well, it may only require monitoring of the land.

![Figure 2. Land suitability class-map](image)

To improve the land suitability class, efforts should be made to improve it. According to [5] land that has an S3 (according to Marginal) suitability class has the opportunity to be improved. If the research location is carried out various efforts to land improvement, then the land that was in S3 class can be upgraded to S2 to S1. The land improvement efforts that can be carried out:

a. Minimum rainfall for growing Arabica coffee plants is 1,000-2,000 mm/year [3], while the rainfall obtained from BMKG for Tompobulu district is 2,040 mm/year, this makes rainfall as one of the limiting factors for Arabica coffee plant growth. One effort to deal with high rainfall is water management, that is making drainage channels [6].

b. Slope of Arabica coffee plants on flat to ramps up with slope <16%. Slopes in the study area range from 0 to 13% which can still be tolerated. Slope problems can be carried out in several ways, which is reducing the rate of erosion, making terraces, planting parallel contours, and planting cover crops [7].

c. CaCO$_3$ uptake in Arabica coffee plants <2% [3], while based on laboratory results for CaCO$_3$ at the study are >2%. The improvement effort that needs to be carried out is by adding ZA fertilizer. ZA fertilizer contains N and S elements, 21% nitrogen, and 24% Sulfur.

d. Soil salinity indicates the amount of salt that dissolves easily in the soil. High salinity levels in the soil prevent plants from growing properly. Increasing the concentration of dissolved salts (salinity) in the soil will increase osmotic pressure, thereby inhibiting the absorption of water and nutrients that take place through the osmosis process. Soil sample laboratory test results of the Tompobulu district show salinity levels in the soil 0.8 to 1.4 dS/m. The salinity content can be said to be low but has not yet reached the salinity standard desired for the growth of arabica coffee plants, so it needs to be improved. One improvement effort that can be done is to utilize local resources such as the addition of organic matter, organic material is also able to improve chemical
properties such as the addition of nutrients that can reduce levels of sodium salt (Na) and improve soil biological properties. Adding organic material such as straw can also improve soil biological properties. Soil biology that is microorganisms or biological fertilizers, is one of the local resources used to improve saline soils [8].

Based on local regulation of Bantaeng Regency No. 2 (2012) about the spatial planning (2012 – 2032) article 36 paragraph 4 point about the designation area of coffee plantations is stipulated in some areas of Tompobulu district. In part of Ulu Ere district, and part of Eremerasa district with an area of 4,500 ha. Tompobulu district is one of the districts planned for coffee plant development [2]. Based on the results, land suitability of Arabica coffee plants in Tompobulu district has marginal land classes (S3). This shows that Arabica coffee plants in Tompobulu district can grow but some limiting factors can affect the growth and production of Arabica coffee plants. The limiting factors at the study area are rainfall, slopes, and coarse fragments which are as limiting factors that cannot be repaired. Other limiting factors are CaCO₃ uptake and salinity which are as limiting factors that can be improved.

3.2.3. Analysis of the correlation between land suitability index and productivity of Arabica coffee plants. The land index will determine the land suitability class for the area being analysed. Production data obtained from interviews with farmers in each land unit (Table 5). The correlation between the land index and productivity shows there is a positive correlation between the land index and the productivity of Arabica coffee plants ($r = 0.9$). It is means that the increasing land index along with the significantly increasing the Arabica coffee yield ($P < 0.05$) where a simple regression equation is $y = 0.012x + 0.045$. Through this equation, it is known that land suitability index in land unit can be tested on the results of the Arabica coffee obtained (predicted yield). According to [3], if the land in an S3 class (marginal) then the estimated yield of Arabica coffee in that land ranges from 0.48 to 0.72 tons/ha. Judging by the actual results that have been achieved at this time, the average coffee yield of 0.5 tons/ha is clear with the existing potential. The correlation between coffee production and land suitability index is presented in Figure 3.

Table 5. The land suitability index and Arabica coffee productivity for each land unit in the study area.

| Land Unit | Land suitability index (X) | Productivity (Y) |
|-----------|---------------------------|------------------|
| 1         | 37.5                      | 0.5              |
| 2         | 23.1                      | 0.3              |
| 3         | 30                        | 0.4              |
| 4         | 25                        | 0.4              |
| 5         | 23                        | 0.3              |
| 6         | 19                        | 0.2              |
| 7         | 32                        | 0.4              |
| 8         | 36                        | 0.5              |
| 9         | 15                        | 0.3              |
| 10        | 35.7                      | 0.5              |
4. Conclusions
The climate suitability class of Tompobulu district for developing Arabica coffee plantation is classified as S3 (marginal land) with a limiting factor is annual rainfall that exceeds the average optimal rainfall for Arabica coffee. Land suitability classes of Arabica coffee plants are classified as S3 (marginal land) and N1 (currently not suitable) with the dominant limiting factors of rainfall, soil depth, slope, coarse fragments, CaCO$_3$, and salinity. Strongly correlated land suitability index with Arabica coffee yield in Tompobulu district, Bantaeng Regency is shown with a correlation coefficient $r => 0.9$ where the regression equation is $y = 0.012x + 0.045$.

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