Evaluation of land suitability on arabica coffee plantation by parametric method in Lintongnihuta District

P Marbun1*, Z Nasution1, H Hanum1 and A Karim2

1Faculty of Agriculture, Universitas Sumatera Utara, Indonesia
2Faculty of Agriculture, University of Syiah Kuala, Indonesia

E-mail: *posma.marbun@usu.ac.id

Abstract. This study aims to establish the land suitability class and improvement efforts that need to be done in each of the Soil Map Unit (SMU) on arabica coffee fields in Lintongnihuta district. Results of overlaying the map of soil type, the map of altitude and slope map with a scale of 1: 50,000 produced 13 SMU. Evaluation of several soil characteristics (texture, coarse fragment, CaCO3 and salinity) must consider the appropriate soil depth, where the normal root depth of the Arabica coffee plant is 150 cm, so that it uses 6 (six) parts of the depth of the soil with a depth of 25 cm for each section. Correction indexes used in succession are: 2.00 - 1.5 - 1.00 - 0.75 - 0.5 - 0.25. The results showed that all SMU in Arabica coffee land in Lintongnihuta District has the actual land suitability class S3 (f) (marginally suitable, limiting factor: soil fertility). Improvement efforts that can be done are: giving lime, organic material, fertilization and reclamation. All SMU has the potential land suitability class S2 (c,s)(moderately suitable, limiting factor: climate and natural soil).

1. Introduction

Land evaluation is a way to assess the potential of land resources. The main activity in land evaluation related to land use is the determination of the type/type of land use and the determination of the growing requirements of the type of land use. After the land use type is set, then the land use requirements are followed [1]. Land use requirements are then matched with land characteristics or quality to determine the land suitability of an area for a crop commodity [2].

One approach that can be done in a land suitability evaluation is a parametric approach. The parametric approach is a system of classification and division of land by the influence or characteristic value of a particular land which is then combined to obtain its suitability [3]. In parametric systems, diagnostic criteria are assessed numerically and mathematical calculations obtain land suitability classification. The advantage of this parametric system not only calculates land suitability classes based on soil properties but also takes into account all climate factors and maps them in one land suitability map.

Coffee is the second most important export commodity in global trade after petroleum. Coffee is a vital plantation commodity that has a significant contribution in the Indonesian economy, namely as a foreign exchange earner, a source of income for farmers, industrial raw material producers, job creation and regional development [4].

The Arabica coffee plant of the SigararUtang variety from LintongNihuta District has been known internationally as one of the best varieties of Arabica coffee that received grade A, because it has...
comparative advantages compared to other coffees in Indonesia, which have a superior taste like excellent aroma and taste and higher quality. Lintong Arabica Coffee has been recognized as a specialty coffee by the Specialty Coffee Association of America (SCAA) parallel to Gayo coffee, Takengon coffee, Toraja coffee and Javanese coffee [5].

However, according to the North Sumatra Plantation Statistics Data, the productivity level of Arabica coffee in LintongNihuta District is still low at 867.35 kg / ha/year. This production is still deficient compared to the potential production of similar Arabica coffee which can reach 1.50 - 2.0 tons/ha/year [6]. The low Arabica coffee production is mainly due to the lack of planting Arabica coffee in the right land suitability class, planted on land that has a slope of more than 15% without being followed by soil and water conservation, low soil fertility and poorly managed shade [7].

The purpose of this study was to obtain land suitability classes and improvement efforts that could be carried out for each SMU on Arabica coffee plantation in LintongNihuta District.

2. Materials and Methods

This research was conducted on Arabica coffee plantation in District of Lintong Nihuta, Humbang Hasundutan Regency (2°13’ - 2°20’NL and 98°47’ - 98°57’EL), with a height of 1,200 to 1,500 meters above sea level. Soil analysis was conducted at the Faculty of Agriculture’s Research and Technology Laboratory, University of Sumatera Utara.

Land suitability evaluation research uses a survey method, where the assessment of climate characteristics and land characteristics using parametric methods. To calculate the climate index used the Rabia method [8], with the equation:

\[
CI = W_{\text{max}} \times \prod_{i=1}^{n-1} 0.01 \times R_i
\]

Where,
- \( CI \) = Climate index
- \( W_{\text{max}} \) = The rating value of the climate characteristics that have the maximum weight
- \( R_i \) = Rating values of other parameters
- \( \prod \) = Mathematical symbols for multiplication 0.01 to make the whole value in percent

The index obtained is then converted into all climate ratings with empirical equation [9] namely CR = 13.999 + 0.897 CI. This CR value is used for land evaluation by combining this CR value into the land index.

Calculation of land values starts from the maximum (100) for soil characteristics that do not have a limiting factor for agricultural production, to a minimum (0) for soil characteristics that are not suitable for agriculture.

Finally, the land index is calculated based on the rating of all factors using the Rabiamethod[9], where the equation is as follows:

\[
IL = W_{\text{max}} \times \prod_{i=1}^{n-1} 0.01 \times R_i
\]

Where,
- \( IL \) = Land index
- \( W_{\text{max}} \) = The rating value of the land characteristics that has maximum weight (including the overall climate value)
- \( R_i \) = Rating values of other parameters
- \( \prod \) = Mathematical symbols for multiplication 0.01 to make the whole value in percent
To obtain land suitability classes for Arabica coffee plants, the land index obtained is matched with the conditions for growing Arabica coffee [10]. The land suitability class using the parametric method is then determined based on the land index value obtained, as shown in Table 1.

**Table 1. Land index for different land suitability classes**

| Land Index | Land Suitability Class |
|------------|------------------------|
| 100 – 76   | S1 = very suitable      |
| 75 – 51    | S2 = moderately suitable|
| 50 – 26    | S3 = marginally suitable|
| 25 – 0     | N = unsuitable          |

The climate and land characteristics calculated by the parametric method in the land suitability evaluation are: annual precipitation, temperature, air humidity, the length of the sun, altitude, slope, soil texture, drainage, flooding hazard, coarse fragment, soil depth, CaCO$_3$, CEC clay, base saturation, C-organic, the sum of basic cations, pH H$_2$O and salinity [9].

**Table 2. Village’s name and SMU area on arabica coffee plantation in Lintongnihuta District**

| SMU | Soil, Altitude (m asl), Slope (%) | Village’s Name | Area (ha) |
|-----|----------------------------------|----------------|----------|
| SMU 1 | Humitropepts; 1,200-1,300; 0-4% | Lobuta         | 417.41   |
| SMU 2 | Humitropepts; 1,200-1,300; 8-16% | Lumban Ina-in, Naga Saribu I | 186.66  |
| SMU 3 | Humitropepts; 1,300-1,400; 0-4% | Naga Saribu I, Naga Saribu II | 2,468.53 |
| SMU 4 | Humitropepts; 1,300-1,400; 4-8% | Sipultak, Pargaulan | 59.65   |
| SMU 5 | Humitropepts; 1,300-1,400; 8-16% | Naga Saribu I, Pargaulan, LobuTua | 1,225.27 |
| SMU 6 | Humitropepts; 1,400-1,500; 0-4% | Hutaso, Siponjot, DolokMardugu, TapianNauli, SitoluBhal, Sibuntuon, SibuntuonParpea, Sibarjulo, Naga Saribu I, Naga Saribu II | 6,041.31 |
| SMU 7 | Humitropepts; 1,400-1,500; 4-8% | Sibarjulo, Pargaulan, SibuntuonParpea, Siponjot, SitoluBhal, TapianNauli, DolokMardugu | 1,347.11 |
| SMU 8 | Humitropepts; 1,400-1,500; 8-16% | Pargaulan, SibuntuonParpea, SitoluBhal | 730.67   |
| SMU 9 | Tropothents; 1,200-1,300; 0-4% | Hutaso, LobuTua | 434.29   |
| SMU 10 | Tropothent; 1,200-1,300; 4-8% | LobuTua, Pargaulan, Naga Saribu I, Hutaso | 338.55   |
| SMU 11 | Tropothents; 1,300-1,400; 0-4% | Hutaso, DolokMardugu, Siponjot, TapianNauli, LobuTua | 1,602.41 |
| SMU 12 | Tropothent; 1,400-1,500; 0-4% | Hutaso, DolokMardugu, Siponjot, TapianNauli | 718.06   |
| SMU 13 | Tropothents; 1,400-1,500; 4-8% | DolokMardugu, Siponjot | 520.09   |

Total: 16,090.01

Evaluation of several soil characteristics (texture, coarse fragment, CaCO$_3$ and salinity) must consider the appropriate soil depth, where the normal root depth of the Arabica coffee plant is 150 cm so that it uses 6 (six) parts of the depth of the soil with a depth of 25 cm for each section. Correction indexes used in succession are: 2.00 - 1.5 - 1.00 - 0.75 - 0.5 - 0.25. Evaluation of the CEC clay value is obtained from the CEC value at B horizon or at a depth of 50 cm from the ground surface, while evaluating the sum of basic cations (K-exchange, Na-exchange, Ca-exchange, and Mg-exchange), base saturation, pH H$_2$O and C-organic was carried out at a depth of 25 cm above the soil surface [11].
3. Results and Discussion
The results of overlaying the soil type map, altitude map and slope map produce 13 SMU, the area of each SMU can be seen in Table 2.

3.1. Climate
Climate data including annual rainfall, dry season length, relative humidity and irradiation length of 5 dryest months in all SMU are the same, namely: 2,024 mm; 1.72 months; 84.02% and 0.31 h. Mean maximum temperature, minimum temperature, and annual temperature can be seen in Table 3 below.

Table 3. Climate data for 18 years (1996 - 2013) in each of SMU on arabica coffee plantation in Lintongnihuta District

| SMU   | Mean Temperature (°C) | Maximum | Minimum | Annual |
|-------|------------------------|---------|---------|--------|
|       |                        |         |         |        |
| SMU 1 |                        | 20.51   | 19.49   | 19.98  |
| SMU 2 |                        | 20.51   | 19.49   | 19.98  |
| SMU 3 |                        | 19.91   | 18.89   | 19.38  |
| SMU 4 |                        | 19.91   | 18.89   | 19.38  |
| SMU 5 |                        | 19.31   | 18.29   | 18.78  |
| SMU 6 |                        | 19.31   | 18.29   | 18.78  |
| SMU 7 |                        | 19.31   | 18.29   | 18.78  |
| SMU 8 |                        | 19.31   | 18.29   | 18.78  |
| SMU 9 |                        | 20.51   | 19.49   | 19.98  |
| SMU 10|                        | 19.91   | 18.89   | 19.38  |
| SMU 11|                        | 19.31   | 18.29   | 18.78  |
| SMU 12|                        | 19.31   | 18.29   | 18.78  |
| SMU 13|                        | 20.51   | 19.49   | 19.98  |

3.2. Land characteristic
The physical and chemical characteristics of the soil in each SMU can be seen in Table 4 and Table 5.

Table 4. Physical soil characteristics (texture and coarse fragment) in each of SMU on Arabica coffee plantation in Lintongnihuta District

| SMU   | Sand (%) | Silty (%) | Clay (%) | Coarse Fragments (% v) |
|-------|----------|-----------|----------|------------------------|
|       |          |           |          |                        |
| SMU 1 | 81.92    | 10.47     | 7.61     | 1.23                   |
| SMU 2 | 81.17    | 9.51      | 9.32     | 0                      |
| SMU 3 | 79.36    | 12.08     | 8.56     | 3.6                    |
| SMU 4 | 83.41    | 8.54      | 8.05     | 1.48                   |
| SMU 5 | 75.54    | 14.07     | 10.39    | 6.48                   |
| SMU 6 | 73.21    | 18.99     | 7.80     | 0.63                   |
| SMU 7 | 62.37    | 16.61     | 21.02    | 1.13                   |
| SMU 8 | 67.12    | 23.57     | 9.31     | 1.05                   |
| SMU 9 | 87.32    | 5.20      | 7.48     | 3.6                    |
| SMU 10| 76.69    | 14.27     | 9.04     | 12.3                   |
| SMU 11| 76.48    | 16.39     | 7.13     | 0.13                   |
| SMU 12| 77.43    | 14.92     | 7.65     | 3.9                    |
| SMU 13| 87.72    | 4.45      | 7.83     | 1.48                   |
Table 5. CEC clay, the sum of basic cations, base saturation, pH H₂O, C-organic and EC data in each of SMU on Arabica coffee plantation in Lintongnihuta district

| SMU  | CEC clay (cmol/kg clay) | Σ Basic Cations (me/100g) | Base Saturation (%) | pH H₂O | C-organic (%) | EC (dS/m) |
|------|-------------------------|---------------------------|---------------------|--------|--------------|-----------|
| SMU 1| 18.54                   | 1.75                      | 6.42                | 5.72   | 2.33         | 0.81      |
| SMU 2| 25.31                   | 2.12                      | 9.32                | 4.81   | 1.75         | 0.59      |
| SMU 3| 8.77                    | 1.33                      | 6.80                | 5.08   | 2.58         | 0.73      |
| SMU 4| 25.97                   | 1.08                      | 3.67                | 6.00   | 1.56         | 0.44      |
| SMU 5| 11.66                   | 1.97                      | 7.14                | 5.46   | 2.59         | 0.93      |
| SMU 6| 21.42                   | 4.15                      | 21.99               | 5.98   | 3.56         | 0.71      |
| SMU 7| 12.88                   | 3.15                      | 24.46               | 5.17   | 1.95         | 0.42      |
| SMU 8| 16.21                   | 1.03                      | 6.32                | 3.84   | 1.65         | 0.40      |
| SMU 9| 33.41                   | 1.48                      | 4.34                | 5.12   | 3.39         | 0.75      |
| SMU 10| 30.34                   | 3.36                      | 5.84                | 5.86   | 1.43         | 0.45      |
| SMU 11| 39.51                   | 1.20                      | 2.83                | 7.23   | 5.56         | 0.83      |
| SMU 12| 34.22                   | 1.56                      | 1.66                | 5.69   | 2.55         | 0.80      |
| SMU 13| 13.88                   | 0.82                      | 10.12               | 5.65   | 0.86         | 0.42      |

3.3. Land suitability class

Climate and land characteristics data obtained were then matched with the criteria of the Arabica coffee land suitability class to obtain suitability on Arabica coffee plantation in LintongNihuta District, as seen in Table 6.

Table 6. Land suitability class (actual and potential) on arabica coffee plantation in Lintongnihuta District

| SMU  | Land Suitability Class (Actual) | Improvement effort | Land Suitability Class (Potential) | Limitation Factors                        |
|------|---------------------------------|--------------------|------------------------------------|------------------------------------------|
| SMU 1| S3 (f)                          | om, r              | S2 (c,s)                           | humidity> 80%; coarse texture             |
| SMU 2| S3 (f)                          | l, om, r           | S2 (c,s)                           | humidity> 80%; coarse texture             |
| SMU 3| S3 (f)                          | l, f, r            | S2 (c)                             | max. temp< 20°C; humidity> 80%;          |
| SMU 4| S3 (f)                          | om, f              | S2 (c,s)                           | max. temp< 20°C; humidity> 80%; coarse text |
| SMU 13| S3 (f)                           | l, om              | S2 (c,s)                           | max. temp< 20°C; humidity> 80%; coarse text |
| SMU 9| S3 (f)                          | l, r               | S2 (c,s)                           | max. temp< 20°C; humidity> 80%;          |
| SMU 5| S3 (f)                          | l, r               | S2 (c)                             | max. temp< 20°C; humidity> 80%           |
| SMU 8| S3 (f)                          | l, om              | S2 (c)                             | max. temp< 20°C; humidity> 80%           |
| SMU 6| S3 (f)                          | f, r               | S2 (c)                             | max. temp< 20°C; humidity> 80%;          |
| SMU 10| S3 (f)                           | om, f              | S2 (c)                             | max. temp< 20°C; humidity> 80%           |
| SMU 1| S3 (f)                          | l, f, r            | S2 (c)                             | max. temp< 20°C; humidity> 80%           |
| SMU 12| S3 (f)                          | f, r               | S2 (c)                             | max. temp< 20°C; humidity> 80%           |
| SMU 7| S3 (f)                          | l, om              | S2 (c)                             | max. temp< 20°C; humidity> 80%           |

Note: 1. Land suitability class 2. Land characteristic:
S1 = very suitable  f = soil fertility
S2 = moderately suitable s = physical soil characteristics
S3 = marginally suitable c = climate
3. Improvement effort: l = liming,  om = organic matter, r = reclamation,  f = fertilizer
From the results of the land suitability evaluation, it was obtained that all SMU in Arabica coffee land has the actual land suitability class S3 (marginally suitable) with the same limiting factor that is soil fertility characteristic (f): base saturation, the sum of basic cations and pH H$_2$O. Improvement efforts that can be done are: giving lime, organic material, fertilization or reclamation. The results showed that if the repair effort were carried out, then all existing SMU would have a potential land suitability class S2 (moderately suitable) with the main limiting factor is climate (c): maximum temperature and humidity; and physical soil (s): texture.

4. Conclusion
All SMU in Arabica coffee land in LintongNihuta District has the actual land suitability class S3 (marginally suitable) with the same limiting factor that is soil fertility characteristic (f): base saturation, the sum of basic cations and pH H$_2$O. Improvement efforts that can be done are: giving lime, organic material, fertilization or reclamation. All SMU have the potential land suitability class S2 (moderately suitable) with the main limiting factor is climate (c): maximum temperature and humidity; and physical soil (s): texture.

References
[1] Sys C, Van Ranst and Debaveye J 1991 Land evaluation part I. principles in land evaluation and crop production calculations (Brussels-Belgium: Agricultural No 7 General Administration for Development Cooperation)
[2] Davidson D A 1992 The evaluation of land resources longman scientific and technical (New York) p 198
[3] Udawatta R P, Henderson G S 2006 Root distribution relationships to soil properties in Missouri oak stands (Columbia: Center for Agroforestry, School of Natural Resources Univ. of Missouri)
[4] Amsalu, Aklilu and Ludi E 2010 The effect of global coffee price changes on rural livelihoods and natural resource management in Ethiopia: A case study from jimma area (Ethiopia, NCCR North-South Dialogue No 26)
[5] Badan Pusat Statistik Kabupaten Tapanuli Utara [Central Bureau of Statistics of North Tapanuli District] 2012 Kabupaten Tapanuli Utara dalam angka [North Tapanuli district in numbers] (Tapanuli Utara: Central Bureau of Statistic)
[6] Dinas Perkebunan Provinsi Sumatera Utara [Plantation Office of North Sumatera Province] 2016 Data statistik perkebunan Sumatera Utara tahun 2015 [North Sumatera plantation statistic data of 2015] (Indonesia: Plantation Office of North Sumatera Province)
[7] Karim A 2012 Pengelolaan lahan kopi arabika Gayo berbasis satuan lahan dan hubungannya dengan indikasi geografis [Management of Gayo arabica coffee land based on land units and relationship with geographical indications] (Medan, Paper at Balanced Nutrition and Sustainable Soil Fertility Management in Arabica Coffee Production in North Sumatera and Aceh)
[8] Rabia A H and Fabio T 2013 Introducing a new parametric concept for land suitability assessment International Journal of Environmental Science and Development 4 1
[9] Nasution Z 1989 Evaluate van Enkele Typische Bodems van de Aceh Provincie voor Rijst (Belgia, Rijks Universiteit Ghent)
[10] Sys C, Van Ranst, Debaveye J and Beernaert F 1993 Land evaluation part III crop requirement agricultural No. 7 (Brussels-Belgium, General Administration for Development Cooperation)
[11] Sys C, Van Ranst and Debaveye J 1991 Land evaluation part II methods in land evaluation agricultural No 7 (Brussels-Belgium, General Administration for Development Cooperation)