The land suitability evaluation of upland rice in the low dryland of Bengkulu Province

Nurmegawati, Yartiwi, I C Siagian, Yesmawati, S Yuliasari and Y Sastro

Bengkulu Assessment Institute for Agricultural Technology Bengkulu, Jl. Irian Km 6,5 Bengkulu, 38119, Indonesia

E-mail: nurmegawati400@gmail.com

Abstract. The problem with dry land is that it has a low fertility rate which causes low land productivity, so that production is low. This study aims to determine the suitability of upland rice land and soil fertility status in 3 sub-districts, namely Air Periukan, Pondok Kelapa, and Kerkap. The parameters observed were land characteristics which included climate data and soil physical and chemical properties. Data analysis was carried out by matching each land characteristic with the conditions for upland rice growth. The conclusion was based on the smallest value (minimum law) as a land suitability decision. The results showed that the suitability of the upland rice field in Air Periukan District, Pondok Kelapa district, and Kerkap district are included in S3 classes. Furthermore, the limiting factors for those districts are different. In the Air Periukan District, water availability and nutrient retention as limiting factors. However, only water availability is a limiting factor in Pondok Kelapa district. The land suitability in the Kerkap district for upland rice land has a limiting factor regarding nutrient retention and nutrient availability. The suggested alternative for soil cultivation in the research area is increasing C-organic and CEC, improving other nutrient content by providing manure, straw compost, and giving balanced inorganic fertilizers.

1. Introduction

The population of Indonesia from year to year continues to increase. Indonesia's population is 268 million with a growth of 1.31% per year [1]. In line with the increasing population growth rate in Indonesia, food demand is also getting more significant. Indonesia's per capita consumption rate is 139 kg/year [2]. It is predicted that rice needs in 2045 will reach 46,787 million tons of rice [3]. To supply the rice needs, it is necessary to increase the area of paddy fields. On the other hand, the availability continues to decrease due to land conversion. [4] stated that the paddy field's conversion rate to non-rice fields is estimated to be around 96,512 ha/year. This caused the rice harvested area to decrease from 53% in 1980 to 46% in 2014 with production from 62% to 52% [5], so it is necessary to optimize the expansion of dryland rice cultivation [6]. However, in its development, it is faced with more complex problems than in paddy fields.

Dry land productivity is low so that production is low [7]. [8] added that dry land generally has low fertility and low organic matter content, especially on dry land that has been used intensively. So that technological innovation is needed, [9] state that innovation must develop according to the times and needs and be adjusted to typology and land characteristics.
Bengkulu Province has the potential as an upland rice development area. Based on agricultural land statistics, the land area of Bengkulu Province is 67,685 ha [10]. To develop an agricultural commodity, it is necessary to know the land's biophysical conditions as a condition for its growth, including climate and soil conditions. Both of these factors will affect the resulting production later.

Land suitability is the suitability of land for specific uses [11]. Land suitability can be assessed in the present and future state after being repaired [12]. The actual land suitability can guide land management efforts to achieve average productivity [13]. Because of the importance of upland rice land suitability data and dryland soil fertility status, a study was conducted to know the suitability of upland, dryland and lowland soil fertility status in Bengkulu Province. With this information, it is hoped that appropriate alternative cultivation techniques can be carried out in upland rice cultivation in Bengkulu Province.

2. Research methods
The research was conducted in 3 sub-districts, namely Air Periuk, Pondok Kelapa and Kerkap Districts, in 2019 and 2020. The study used primary data and secondary data covering land characteristics, climate and upland rice growing requirements. Primary data is in the form of data obtained directly from field surveys, while secondary data is in the form of climate data (rainfall and humidity).

Land characteristics are land properties that can be measured or estimated, including air temperature, rainfall, humidity, drainage, soil texture, coarse material, soil depth and slopes obtained from field survey results, while soil chemical properties are obtained from sample analysis of soil in the laboratory.

The evaluation of land suitability was carried out by matching the land characteristics of the land with the requirements for upland rice plant growth (Table 1) to obtain land suitability classes. The results of land suitability are then based on the smallest value (minimum law), divided into 4 classes, namely S1 (very suitable), S2 (moderately suitable), S3 (according to marginal) and N (not suitable).

Evaluation of soil fertility status was based on CEC and base saturation levels (NH₄OAc, pH 7.0); C-organic (Walkley & Black); P₂O₅ and K₂O (HCl 25%). Soil fertility status is determined based on the classification of the chemical properties combination values in table 2. Soil physical properties such as the texture of three fractions (pipette method) and other chemical properties such as soil pH, total N (Kjeldahl), available P₂O₅ (Bray I and Olsen), exchangeable cations (NH₄OAc, pH 7.0) is additional data in the assessment of soil fertility status and is still taken into account in the management of soil fertility.

3. Results and discussion

3.1. Land suitability
The suitability of upland rice land in several sub-districts in Bengkulu Province can be seen in table 3. In the table above, it can be seen that the land suitability for upland rice in Air Periukan sub-district, including S3, is marginal according to the limiting factors of water availability and nutrient retention, namely soil CEC and soil pH. The suitability of upland rice fields in pondok kelapa sub-district, including S3, is marginal with the limiting factor of water availability. According to the marginal factors of nutrient retention limiting, upland rice suitability in the kerkap sub-district includes S3, namely alkaline saturation and P availability.

In upland rice cultivation on dry land requires special attention because the source of irrigation only comes from rainfall, which is very erratic. According to [12] dryland agriculture is very dependent on the availability of rain which is already limited so it is very vulnerable to crop failure. [17] added that drought is an essential classic factor and significantly affects upland rice cultivation.

Limiting factors derived from land characteristics include nutrient retention and nutrient availability which can be improved to increase potential land suitability classes. The addition of organic matter can increase soil CEC. The addition of this material and improving soil chemical properties can also improve soil physical and biological properties. For instance, the climate limiting factors, temperature, rainfall and humidity are permanent limiting factors that cannot be repaired. It is necessary to adapt to these
factors based on the Oldeman and Schmith-Ferguson linkages for 30 years 1981-2010 [18]. Bengkulu has tropical rain by planting rice continuously using a good early planting season planning, except for parts of Bengkulu Tengah and Bengkulu Utara planting rice can be done once with crops twice with temperatures between 19 to 26 °C.

Table 1. Criteria for upland rice land suitability (Oryza sativa) [14].

| Requirements for land use/characteristics | S1 | S2 | S3 | N |
|------------------------------------------|----|----|----|----|
| Temperature (tc)                          |    |    |    |    |
| Average temperature (°C)                 | 24 - 29 | 22 – 24 | 18 - 22 | < 18 |
|                                           | 29 - 32 | 32 – 35 | < 18 |
| Availability of water (wa)               | C2,C3,D2,D3 | A2,B2,B3 | A1,B1,C1,D1,E | E4 |
| Humidity (%)                             | 33 - 90 | 30 - 33 | < 30 |
| Root media (rc)                          |    |    |    |    |
| Drainage                                 | good, moderate smooth | rather fast, a little stuck | hindered, very hindered, | fast |
| Texture                                  | mildly smooth, medium | smooth | Rather rough | Rough |
| Rough material (%)                       |    |    |    |    |
| Soil depth (cm)                          |    |    |    |    |
| Peat                                     |    |    |    |    |
| Thickness (cm)                           |    |    |    |    |
| Maturity                                 |    |    |    |    |
| Nutrient retention (nr)                  |    |    |    |    |
| Soil CEC (cmol)                          | > 16 | 5 - 16 | < 5 |
| Base saturation (%)                      | > 35 | 20-35 | < 20 |
| pH H2O                                   | 5.5–7.5 | 5.0–5.5 | < 5.0 |
|                                          | 7.5–7.9 | > 7.9 |
| C-organic (%)                            |    |    |    |    |
| Nutrien is available (na)                |    |    |    |    |
| K total                                  |    |    |    |    |
| P2O5 (mg/100 g)                          |    |    |    |    |
| K2O (mg/100 g)                           |    |    |    |    |
| Toxicity (xc)                            |    |    |    |    |
| Salinity (dS / m)                        |    |    |    |    |
| Sodicity (xn)                            |    |    |    |    |
| Alkalinity / ESP (%)                     |    |    |    |    |
| Sulfidic hazard (xs)                     |    |    |    |    |
| Sulfidic depth (cm)                      |    |    |    |    |
| Erosion hazard (eh)                      |    |    |    |    |
| Slope (%)                                |    |    |    |    |
| Erosion hazard                           |    |    |    |    |
| Danger of flooding/inundation during planting (fh) |    |    |    |    |
| Height (cm)                              |    |    |    |    |
| Length (days)                            |    |    |    |    |
| Land preparation (lp) Surface rock (%)   |    |    |    |    |
| Rock outcrop (%)                         |    |    |    |    |
### Table 2. Combination of soil chemical properties and soil fertility status (T = High, S = Medium, R = Low, SR = Very low) [15][16].

| Cation Exchange Capacity (CEC) | Base saturation | P₂O₅, K₂O dan C-organic | Fertility Status |
|-------------------------------|-----------------|---------------------------|-----------------|
| T                             | T               | ≥ 2T without R            | High            |
| T                             | T               | ≥ 2T with R               | Medium          |
| T                             | T               | ≥ 2S without R            | High            |
| T                             | T               | ≥ 2S with R               | Medium          |
| T                             | T               | T S R                     | Medium          |
| T                             | T               | ≥ 2R with T               | Medium          |
| T                             | S               | ≥ 2T without R            | High            |
| T                             | S               | ≥ 2T with R               | Medium          |
| T                             | S               | ≥ 2R without T            | Low             |
| T                             | S               | ≥ 2R with T               | Low             |
| T                             | R               | ≥ 2S without R            | Medium          |
| T                             | R               | ≥ 2T with R               | Low             |
| T                             | R               | Another combination       | Low             |
| S                             | T               | ≥ 2T without R            | Medium          |
| S                             | T               | ≥ 2S without R            | Medium          |
| S                             | T               | Another combination       | Low             |
| S                             | S               | ≥ 2T without R            | Medium          |
| S                             | S               | ≥ 2S with R               | Medium          |
| S                             | S               | Another combination       | Low             |
| S                             | R               | 3T                        | Medium          |
| S                             | R               | Another combination       | Low             |
| R                             | T               | ≥ 2T without R            | Medium          |
| R                             | T               | ≥ 2S with R               | Low             |
| R                             | T               | Kombinasi lain            | Low             |
| R                             | S               | ≥ 2T without R            | Medium          |
| R                             | S               | Another combination       | Low             |
| R                             | R               | All combinations          | Low             |
| SR                            | TRS             | All combinations          | Very low        |

#### 3.2. Soil fertility status

The land suitability evaluation process is carried out through an interpretation approach to soil data and physical environment. Soil chemical properties are needed in evaluating land suitability, namely nutrient retention and nutrient availability. Both land qualities are closely related to soil fertility conditions.

Soil fertility conditions and soil nutrient status result from various soil-forming factors, namely parent material, climate (rainfall and temperature), topography, vegetation and human intervention. The interaction of several of the factors mentioned above results in different levels of fertility and soil nutrient status. Assessment of soil fertility status is shown in table 4.

The cation exchange capacity is the maximum value of the soil's ability to absorb alkaline and acidic cations. In contrast, is the percentage of the number of base cations absorbed in 100 g of soil. Lands that have low CEC and base saturation tend to be poorer than lands that have high CEC and base saturation. In the table above, it can be seen that the CEC of the three sub-districts is very low to moderate, so the soil does not respond to fertilization. Soil CEC’s value can indicate soil response to fertilization. Soils with low CEC are generally unresponsive and efficient to fertilization [16].
Table 3. Suitability of upland rice fields in several districts in Bengkulu Province.

| Requirements for land use / characteristics | Air Periukan District | Kec. Pondok Kelapa District | Kec. Kerkap District |
|--------------------------------------------|------------------------|-----------------------------|----------------------|
|                                            | Eksisting Land         | Eksisting Land              | Eksisting Land       |
|                                            | Suitability            | Suitability                 | Suitability          |
| Temperature (tc)                           | 24.5                   | S2                          | 23                   | S2                   |
| Average Temperature (°C)                   |                        |                             |                      |
| Water Availability (wa)                     |                        |                             |                      |
| Agroclimate Zone                           | B1                     | S3                          | B1                   | S3                   |
| (Oldeman) Humidity (%)                     | 83                     | S1                          | 82                   | S1                   |
| Root Media (rc)                            |                        |                             |                      |
| Drainage                                   | Good                   | S1                          | Good                 | S1                   |
| Texture                                    | Smooth                 | S1                          | Smooth              | S1                   |
| Crude Material (%)                         | 15-35                  | S1                          | 15-35               | S1                   |
| Soil Depth (cm)                            | > 100                  | S1                          | > 100               | S1                   |
| Nutrient Retention (nr)                    |                        |                             |                      |
| Soil CEC (cmol)                            | 4.80                   | S3                          | 7.84                | S2                   |
| Base Saturation (%)                        | 40                     | S1                          | 30                  | S2                   |
| pH H2O                                     | 4.68                   | S3                          | 5.07                | S2                   |
| Organic- C (%)                             | 2.35                   | S1                          | 0.95                | S2                   |
| Nutrient Availability (na)                 |                        |                             |                      |
| N total                                    | Moderate               | S1                          | Moderate            | S1                   |
| P2O5 (mg/100 g)                            | Moderate               | S2                          | Moderate            | S2                   |
| K2O (mg/100 g)                             | High                   | S1                          | High                | S1                   |
| Erosion hazard (eh)                        | 3 - 8                  | S1                          | 3 - 8               | S1                   |

The total P content in the study area was considered moderate except for Kerkap District which was very low and the total K content including very high to high but for Kerkap District it was low. Phosphorus (P) deficiency is one of the main limiting factors for plant growth and production. Plants need P of 0.3% to 0.5% of their dry weight for optimal growth [19]. The content of C-organic is an element that can determine the level of soil fertility. In general, the C-organic content in the study area was very low to very high. The percentage of organic matter indicates the fertility level of a soil type. Organic matter greatly determines the CEC, if the organic material is high then the CEC will also be high. The study area's of low organic matter content is because the soils are dominated by inceptisols, which are newly developed soils.

Table 4. Soil fertility status in 3 districts in Bengkulu Province.

| Assessment Components | Air Periukan District | Pondok Kelapa District | Kerkap District |
|-----------------------|-----------------------|------------------------|----------------|
|                       | Value                 | Class                  | Value         | Class | Value | Class |
| ECE (me/100 g tanah)  | 4.80                  | Very low               | 7.84          | Low   | 19.03 | Medium |
| Base saturation (BS)  | 39.74                 | Low                    | 29.97         | Low   | 8.25  | Very low |
| Total P2O5 (mg/100 g) | 25.68                 | Medium                 | 31.84         | Medium | 8.65 | Very low |
| Total K2O (mg/100 g)  | 61.35                 | Very high              | 55.24         | High  | 20.03 | Medium |
| C-organic (%)         | 2.35                  | Medium                 | 0.95          | very low | 6.53 | Very high |

Soil fertility status

|                       | Very low      | Low          | Low         |
|-----------------------|---------------|--------------|-------------|

It appears that the results of the assessment of the fertility status of the study area are very low to low. Each nutrient status class provides specific information about the expected outcome response. According to [20], the low nutrient status (R) indicates that plants are very responsive to fertilizer application without fertilizer. The production will decrease and the plants will show scaling symptoms, plant growth without fertilizers is not average, the possibility of dying is small even though it does not change.
Some essential the physical and chemical properties directly or indirectly involved in assessing soil fertility status can be seen in Table 5. The soil texture in the study area is generally clayey. The texture is the ratio between the content of sand, dust and clay soil. The fine soil fraction is directly related to the supply of plant nutrients. The texture is closely related to soil CEC. Chemically, the clay fraction that dominates causes the CEC of the soil to be high. According to [21] that clay colloids have the primary control over cation exchange in the soil because they have a negative charge to be drawn electrostatically.

### Table 5. Physical and chemical properties of soil in three districts in Bengkulu Province.

| Physical and chemical properties of soil          | Air Periukan District | Pondok Kelapa District | Kerkap District |
|--------------------------------------------------|------------------------|-------------------------|-----------------|
| Texture                                          | Clay                   | Clay                    | Silty clay loam |
| pH (H₂O)                                         | 4.68                   | 5.07                    | 6.2             |
| P is available (ppm)                             | 2.25                   | 21.01                   | 1.66            |
| K is exchangeable (me/100g)                      | 0.74                   | 0.01                    | 0.74            |
| Na is exchangeable (me/100g)                     | 0.18                   | 0.39                    | 0.18            |
| Ca is exchangeable (me/100g)                     | 0.51                   | 0.54                    | 0.51            |
| Mg is exchangeable (me/100g)                     | 0.48                   | 1.41                    | 0.48            |

Soil reactions are an indication of the availability of nutrient elements for plants. The soil’s pH value at the study location was acidic (4.5 – 5.5) and slightly acidic (5.5 – 6.5), but in general it was somewhat acidic. In the reaction of acidic to very acidic soils, the availability of macronutrients such as P, K, Ca and Mg is small to cause nutrient deficiency for plants. Increasing the soil pH to be slightly acidic to neutral is essential because at this pH, nutrient’s elements solubility is in an optimum state. According to [22] that the cause of lack of nutrients can be caused by too high or low soil pH. Soil is categorized as acidic if its pH is less than 5.5, this value limit is used as a general tolerance limit for plants to soil pH in influencing plant growth.

The P content available in the research area, namely Air Periukan and Kerkap Districts, is very deficient, while in Pondok Kubang District, it is high. Deficient soil P conditions available to plants are also affected by pH. The pH analysis result at the research location was in the range of 4.68 – 6.2 indicating that the soil’s acidity was acidic. According to [23], phosphorus is available in high quantities for plants in soil conditions with a pH ranging from 6.5 – 7.5. The addition of organic matter can also increase Phosphorus's availability of Phosphorus in the soil because organic acids resulting from the decomposition of organic matter can bind cations such as Al and Fe through chelation bonds to phosphorus (P) can be available. [24] stated that the addition of organic matter and P fertilizer to the treatment had more effect in increasing the pH and P-available.

#### 3.3. Management of soil fertility status

A high soil fertility status will be achieved if all the factors used as the basis for the assessment are also in the high class. The lowest factor affecting the low fertility status is now referred to as the limiting factor for soil fertility status. The limiting factors for soil fertility status in the study area can be grouped into five CEC, base saturation, total P₂O₅, total K₂O and C-organic. The results of the inventory of fertility limiting factors are shown in Table 6. It can be seen that each study area has different fertility limiting factors. To overcome these factors, soil management can be carried out by looking for alternative improvements.
Overall, in the research area the limiting factors were CEC, base saturation, C-organic, total P$_2$O$_5$ and total K$_2$O. CEC can be increased by considering the factors influencing the soil's CEC, namely the number of organic colloids and mineral colloids (clay). The addition of organic matter in addition to increasing soil CEC can also increase C-organic. According to [25], organic matter is the key to the success and sustainability of agriculture in the wet tropics. The causes of organic matter degradation include fertilization, erosion, burning of crop residues, and over-cultivation.

Alkaline cations can increase base saturation's limiting factor through the addition of lime, both calcite and dolomite, in addition to increasing base saturation it can also increase soil pH. Increasing soil K and P levels can be done by applying K-rich organic matter such as straw compost and P-rich organic matter such as guano and poultry manure or applying inorganic fertilizers SP36 and KCl according to plant needs.

4. Conclusions
The suitability of upland rice fields in Air Periukan District includes S3 limiting water availability and nutrient retention. The suitability of upland rice fields in Pondok Kelapa sub-district including S3 with limiting factors for water availability. In contrast, upland rice land in the sub-district is often included as S3, limiting nutrient retention and availability factors. The status of soil fertility is very low - low. The suggested alternative for soil cultivation is to increase C-organic and CEC, increasing other nutrient content by providing manure, straw compost and balanced inorganic fertilizers.

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