Characteristics and land potential for sugarcane development in Blitar Regency, East Java Province

M M Pratamaningsih and A Mulyani
Indonesian Center for Agricultural Land Resources Research and Development, Bogor, Indonesia
E-mail: miramedia@pertanian.go.id

Abstract. The expansion of the sugarcane planting area needs to be supported by land resource data, such as characteristics and land suitability maps to optimize sugarcane growth and production. The study aimed to evaluate the land suitability, the dominant limiting factor, and the land availability for sugarcane development in Blitar Regency. Land suitability assessment was conducted by matching between land characteristics and sugarcane growth requirements. The study showed that the dominant soil in Blitar Regency was Kambisol Eutrik, having moderate to very deep soil depth, well-drained, and medium to a fine texture. The suitability classes of the land in the Blitar Regency were mostly marginally suitable (S3) covering of 87,529 ha (97.11%). This type of land has limiting factors, i.e., rooting condition (poorly drained and slightly coarse texture), nutrient retention (CEC <5 cmol, kg⁻¹, pH >8.0), nutrient availability (very low K₂O), and erosion hazard (slope 8 to 15%). The rest were classified as moderately suitable (S2) covering 2,604 ha (2.89%). The study implies that the extensification areas of sugarcane area in Blitar Regency around 21,876 ha could be expected to increase sugarcane productivity and sugar production.

1. Introduction
Sugarcane is one of the national strategic commodities that play essential role in the agricultural sector, particularly in the plantation subsector. Sugar consumption will continue to increase along with the enhancement of the population that has reached 265 million people [1] and the development of a downstream industry made from sugar. Sugar is a food for consumption and industrial raw material. In 2018, the area of sugarcane land reached 415,663 ha so that the sugarcane industry was a source of income for sugarcane farmers and workers in the sugar industry [2]. Sugar is also one of the necessities for most people and a relatively affordable source of calories.

In 2018, the national sugar production was 2.17 million tons [2], while the demand reached 5.1 million tons [3]. The gap in national sugar demand and its yield is likely to continue. In 2021, the total national sugar demand is projected to reach 5.3 million tons, with a total production of 2.5 million tons [3].

East Java Province had the most considerable contribution to sugar production, namely 51.15% of the total national sugar production with a total yield of 1,110,841 tons and the area of 196,897 ha in 2018 [2]. To achieve the target of self-sufficiency in sugar by 2029, the government through the Ministry of Agriculture has issued a Decree of the Minister of Agriculture No. 472 of 2018 concerning the Location of National Agricultural Areas, established Blitar Regency as one of the Locations of Priority Plantation Commodities for sugarcane [4].
Soil and climate are critical as environmental factors that affect the growth and yield of sugarcane [5]. Sugarcane plants grow optimally at <700 m above sea level (asl) altitude [6,7], and rainfall of 1,200 to 1,300 mm year\(^{-1}\) [8]. The growth and substance in sugarcane stalks are affected by soil properties and conditions [9]. According to Johnson and Richard [10], sugarcane can grow optimally in fertile soil with good permeability. Based on the land suitability criteria [11], the most suitable land for sugarcane is a land with 24 to 30\(^{\circ}\)C daily average temperature, medium to fine texture with a soil depth of >75 cm, soil pH 5.5 to 7.5, and flat slope (<3\%). Rainfall and slope are the main requirements for the growth of sugarcane.

The expansion of the sugarcane planting area needs to be supported by land resource data, such as land characteristics and suitability maps to optimize sugarcane growth and production. Sugarcane can grow both in paddy land and on dry land. Land use planning needs to consider limiting factors for growth and increased production. The study aimed to evaluate the land suitability, the dominant limiting factor, and the land availability for sugarcane development in Blitar Regency.

2. Materials and methods
The secondary data used for sugarcane land suitability analysis consist of (1) Land characteristics of Blitar Regency [12], (2) Map of Rupa Bumi Indonesia (RBI) Scale 1:25,000 [13], (3) Digital Elevation Model Nasional (DEMNAS) 8 m resolution [14], (4) Administrative Boundary Map [15], (5) Land Cover Map Scale 1:25,000 [16], (6) Forest Area Status Map [17], (7) Land Suitability Criteria for Sugarcane [11], dan (8) The Regency Spatial Planning Map (RTRW Map) of Blitar Regency [18].

Land suitability evaluation was conducted by matching land characteristics and sugarcane growth requirements [19,11], i.e., highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N). Based on the land suitability map of sugarcane, the field verification was done to see the accuracy between land suitability classes and plant performance. The suitability map of the land was verified byoverlaying with the land use. The results were then mapped using the SPOT 6 image interpretation, the forest area status map, and the RTRW map of the Blitar Regency. Finally, a map of potential and land availability for sugarcane development in Blitar Regency was generated. The suitable lands were assumed to be available for sugarcane cultivation following the use of the land in the form of the annual crops, mixed gardens, shrubs, bare land, and grassland, which were in other land uses (APL). However, paddy land suitable for sugarcane was not included in the land available for sugarcane cultivation. This is following the policy of the local government that rice fields are designated for rice production and maintaining food sufficiency.

3. Results and discussion

Based on the SPOT 6 satellite imagery interpretation, the Blitar Regency has an area of 175,281 ha, most of the land has been used for agriculture, namely rice fields, dry fields, and mixed garden, including sugar cane plantations. The rest are in the form of settlements, offices and forest areas.

3.1. Land characteristic

Blitar Regency is found at the foot of Mount Kelud within the southern part of which consists of lowland and upland. Blitar Regency is split by the Brantas River and to the south are crossed by the South Karst Mountains. The northern part of Blitar is dominated by Volcanic landform, while the southern part is dominated by Karst. This can affect the potency of land for agriculture.

Blitar Regency has various relief, predominantly steep (25 to 40\%) covering 48,652 ha (27.76\%) (table 1). Generally, land with flat and undulating relief, which spread over Aluvial, Marine, Karst, partly Tectonic, and partly Volcanic, is potential for agriculture. However, it is necessary to pay attention to the limiting factors of plant growth, such as low soil fertility. Sugarcane was not suitable for planting on slopes >15\% because of the high risk of erosion.
Table 1. Relief/slope distribution lands in the Blitar Regency.

| Symbol | Relief/Slope | Slope | Area |
|--------|--------------|-------|------|
| f/A    | Flat         | <1    | 43,958 | 25.08% |
| N      | Nearly flat  | 1-3   | 3,492  | 1.99%  |
| u/B    | Undulating/Gentle sloping | 3-8 | 20,923 | 11.94% |
| r/C    | Rolling/Sloping | 8-15 | 16,513 | 9.42%  |
| c/D    | Hillocky/Moderately steep | 15-25 | 39,563 | 22.57% |
| h/E    | Hilly/Steep  | 25-40 | 48,652 | 27.76% |
| G      | Extremely steep and abrupt | >60 | 3,801  | 2.17%  |
|        | Total        |       | 175,281 | 100.00% |

Source: BBSDLP, 2017.

The soil types of the Blitar Regency were Litosol, Regosol, Andosol, Latosol, Molisol, Kambisol, Gleisol, and Mediteran [12]. Kambisol dominates 58.59% of the area of the Blitar Regency (table 2). The soil has a moderate to very deep depth, well drainage, medium to fine texture, slightly acidic to slightly alkaline pH, low to very high cation exchange capacity (CEC), and has a high to very high base saturation. The organic C content varies from low to high, and the total N is very low to moderate. Total P₂O₅ was moderate to very high and the total K₂O ranged from a very low to very high. Kambisol has a moderate to very high fertility levels [12].

Table 2. Soil types in Blitar Regency.

| Nasional of classification [20] | Soil Taxonomy [21] | Area |
|--------------------------------|-------------------|------|
| Soil Type                      | Soil Kind         | ha   | %    |
| Litosol                        | Litosol           | 46   | 0.03 |
| Regosol                        | Regosol Eutrik    | 5,056 | 2.93 |
| Andosol                        | Andosol Eutrik    | 25,832 | 14.98 |
| Latosol                        | Latosol Haplik    | 2,609  | 1.51 |
| Molisol                        | Molisol Haplik    | 1,659  | 0.96 |
| Kambisol Eutrik                | Aquic Eutrudcepts | 101,073 | 58.59 |
| Kambisol Vertik                | Vertic Eutrudcepts |        |
| Kambisol Litik                 | Lithic Eutrudcepts, Lithic Dystrudepts | 32,169 | 18.65 |
| Kambisol Eutrik                | Fluventic Eutrudcepts, Typic Eutrudcepts, Vitrandic Eutrudcepts, Andic Eutrudcepts, Arenic Eutrudcepts | |
| Gleisol                        | Gleisol Fluvik    | 4,053 | 2.35 |
| Mediteran                      | Typic Hapludalfs  | 172,497 | 100.00 |

Source: BBSDLP, 2017.

Kambisol Eutrik and Gleisol Eutrik dominated the suitable lands. Kambisol and Gleisol were suitable for crops, such as sugarcane, tubers, and maize [22]. Kambisol and Gleisol have medium to fine texture and high base saturation. Still, the slightly alkaline soil, very low CEC, and deficient K nutrient become limiting factors for sugarcane growth. According to Jamil et al. [23], sugarcane can tolerate the acidity...
level and alkalinity of soil. Therefore, sugarcane can grow on the slightly acid to slightly alkali soil at pH 6.5 to 8.5.

3.2. Climate characteristic
Blitar Regency has average annual temperature ranging from 23.9 to 25.2°C and average humidity of 55.5%. The distribution of annual rainfall is presented on figure 1. The annual rainfall ranges from 1,565 to 3,066 mm year$^{-1}$ with eight wet months and four dry months based on Schmidt and Ferguson classification. The highest rainfall occurs in January, and the lowest is in July.

Rainfall affects the growth and production of sugarcane, which then affects the amount of sugar production [24]. Sugarcane can grow well in areas with rainfall ranging from 1,000 to 1,300 mm year$^{-1}$ with at least three dry months [25]. If there is not enough rainfall, then additional irrigation water is needed.

![Figure 1. Distribution of annual rainfall in the Blitar Regency, East Java.](image)

3.3. Land suitability of sugarcane
The result of the land suitability evaluation showed the suitable land in Blitar Regency was 90,133 ha with land suitability classes consist of moderately suitable land (S2) and marginally suitable land (S3) (table 3). The land suitability map of sugarcane is presented on figure 2. The limiting factor for growth and crop production on S2 was lighter than on S3. The S3 was limited by poorly drained and slightly coarse texture, soil depth of 50 to 75 cm, very low CEC ($<5$ cmol, kg$^{-1}$), pH $>8.0$ (slightly alkaline), very low total K$_2$O, and slope of 8 to 15%.

| Symbol | Suitability Class          | Limiting Factor                                                                 | Area (ha) |
|--------|----------------------------|---------------------------------------------------------------------------------|-----------|
| S1     | Highly Suitable            | -                                                                               | -         |
| S2     | Moderately Suitable        | rooting condition, nutrient retention, nutrient availability, erosion hazard    | 2,604     |
| S3     | Marginally Suitable        | oxygen availability, rooting condition, nutrient retention, nutrient availability, erosion hazard | 87,529    |
|        | Total                      |                                                                                  | 90,133    |
Improvement efforts can be made to increase the productivity of S3 land. The availability of K nutrients in the soil can be improved with the addition of K fertilizers. K is a nutrient that determines the quality of plant production. The deficiency of K in sugarcane causes low sugar yields [9]. Also, the application of organic matter can improve soil structure and increase the ability of the soil to absorb nutrients and exchange cations.

Steep sloping land can cause the soil to be quickly eroded [26]. Therefore, the application of terracing and contour planting was recommended in slopes of 8 to 15%. The effect of slope steepness and soil erosion could be reduced by terracing, mulching, and contour planting applications [27]. Efforts to improve the drainage system could be made by making drainage channels to reduce excess water and improve soil aeration [11]. According to Jamil et al. [23], a good soil drainage system can prevent erosion so that soil and nutrient losses can be minimized.

![Figure 2. Land suitability map of sugarcane in the Blitar Regency.](image)

### 3.4. Analysis of land potential and availability

The results of the analysis of SPOT 6’s high-resolution satellite imagery and the forest area status map showed that the land use in the other land uses (APL) covering of 80,822 ha (89.67%), in production forest (HP) covering of 8,644 ha (9.59%), and in the protected forest (HL) was 667 ha (0.74%). Based on the result of overlay between the land suitability map with the land use map, the forest area status map, and the RTRW map of Blitar Regency, the potential and available land for sugarcane expansion were in APL covering 21,876 ha. Indonesian law states that plantation could only be carried out in other land uses (APL) [28].

Based on the results of the assessment of land potential and availability, the moderately suitable (S2) land was 1,271 ha, and marginally suitable land (S3) was 20,605 ha. The largest moderately suitable land (S2) land was in Kesamben Subdistrict, and marginally suitable land (S3) land was in Kademangan Subdistrict. The potential land for sugarcane development was in mixed gardens, shrubs, bare land, and annual crops. Potential land with an area of >2,000 ha was in the southern part of the Blitar Regency, namely in Wonotirto Subdistrict 2,009 ha, Wates Subdistrict 2,231 ha, Panggungrejo Subdistrict 2,841 ha, Binangun Subdistrict 3,316 ha, and Kademangan Subdistrict 3,723 ha (table 4). Figure 3 presents the potential and land availability of sugarcane in the Blitar Regency.
Table 4. Potential and land availability for sugarcane development in the Blitar Regency.

| Subdistrict      | Mixed Garden | Shrub | Bare Land | Annual Crops | Total |
|------------------|--------------|-------|-----------|--------------|-------|
|                  | S2 | S3 | S2 | S3 | S2 | S3 | S2 | S3 | S2 | S3 | S2 | S3 | S2 | S3 | S2 | S3 | Total |
| Bakung           | 6  | 597 | - | 2  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 312 | 918  |
| Binangun         | 7  | 692 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 2,615 | 3,316 |
| Doko             | 27 | 364 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 7  | 399  |
| Gandusari        | 8  | 31  | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 1  | 39   |
| Garum            | 32 | 144 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 32  | 83   |
| Kademangan       | 38 | 1,121 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 15  | 2,548 | 3,723 |
| Kanigoro         | 40 | 430 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 41  | 30   | 541  |
| Kesamben         | 218 | 313 | 5 | 1  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 2  | 23   | 562  |
| Nglegok          | 8  | 28  | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 1    | 37   |
| Panggungrejo     | -  | 343 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 2,498 | 2,841 |
| Ponggok          | 29 | 333 | - | -  | -  | -  | 1  | 23 | -  | -  | -  | -  | -  | -  | -  | -  | 23  | 392  | 779  |
| Sanan Kulon      | 92 | 133 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 20  | 58   | 304  |
| Selopuro         | 24 | 199 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 1   | -    | 224  |
| Selorejo         | 67 | 485 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 3   | 43   | 598  |
| Srengat          | 91 | 838 | - | 2  | 2  | 112 | 183 | -  | -  | -  | -  | -  | -  | -  | -  | -  | 1,229 |
| Sutojayan        | 41 | 141 | - | 1  | 22 | 32  | 353 | -  | -  | -  | -  | -  | -  | -  | -  | -  | 590  |
| Talun            | 105| 307 | - | -  | -  | -  | -  | -  | -  | 7  | 41 | -  | -  | -  | -  | -  | 1,248 | 460  |
| Udanawu          | 79 | 123 | - | -  | -  | -  | -  | -  | -  | 1  | 6  | 71 | -  | -  | -  | -  | 1,534 | 280  |
| Wates            | -  | 324 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 1,907 | 2,231 |
| Wlingi           | -  | 163 | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 2   | 166  |
| Wonodadi         | 45 | 203 | - | -  | -  | -  | -  | -  | -  | 1  | 6  | 82 | -  | -  | -  | -  | 88   | 337  |
| Wonotirto        | -  | 343 | - | -  | -  | -  | -  | -  | -  | 2  | -  | -  | -  | -  | -  | -  | 1,665 | 2,009 |
| **Total**        | 959 | 7,657 | 5 | 4  | 4  | 30 | 303 | 12,915 | 21,876 |

Note: S2 = moderately suitable, S3 = marginally suitable.

Figure 3. Potential and land availability map of sugarcane in the Blitar Regency.
Sugarcane productivity in Blitar Regency within five years (2014 to 2018) had been decreased from 79.5 t ha⁻¹ in 2014 to 63.9 t ha⁻¹ in 2018 [29]. Therefore, expanding the sugarcane planting area is expected to increase sugarcane productivity and sugar production. Besides, increasing production can also be done by cultivating high-yielding sugarcane varieties and improve agronomic management and postharvest technology [28].

4. Conclusions
The dominant soil in Blitar Regency is Kambisol Eutrik, which has a moderate to very deep soil depth, well-drained, and medium to fine texture. The land suitability classes for sugarcane in Blitar Regency are moderately suitable (S2) and marginally suitable (S3). The limiting factors for marginally suitable (S3) land are poorly drained or excessively drained, slightly coarse soil texture, soil depth of 50 to 75 cm, CEC <5 cmol, kg⁻¹, pH >8.0 (slightly alkaline), very low to low K nutrient, and slope of 8 to 15%. The potential and available land for sugarcane expansion is 21,876 ha. The available lands are mixed garden, shrub, bare land, and annual crops. The largest areas are in Kademangan Subdistrict 3,723 ha, Binangun Subdistrict 3,316 ha, Panggungrejo Subdistrict 2,841 ha, and Wonotirto Subdistrict 2,009 ha. Meanwhile, in other subdistricts the land spreading evenly with areas of less than 2,000 ha. The unsuitable land, especially the areas with slopes >15%, sand texture, or shallow soils, are not recommended for planting sugarcane.

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