Land suitability evaluation for sweet corn in third cropping period at Wonosari Village, Karanganyar, Indonesia

Sumani¹, Muijiyo¹, J Winarno¹, H Widijanto¹ and K Hasanah²
¹Dept. of Soil Science, Faculty of Agriculture, Universitas Sebelas Maret Surakarta, Jalan Ir. Sutami No. 36 Kentingan, Surakarta, Indonesia, 57126
²Undergraduate Student, Dept. of Agrotechnology, Faculty of Agriculture, Universitas Sebelas Maret Surakarta, Jalan Ir. Sutami No. 36 Kentingan, Surakarta, Indonesia, 57126

Corresponding Author: khalyfahhasanah@gmail.com

Abstract. Climate change causes irregularity of rainfall, affecting the availability of groundwater and decrease crop production. This research aimed to investigate land suitability class for sweet corn in the third cropping period which takes place in the dry season (during June-September) at Wonosari Village. This research used survey method with purposive sampling. Wonosari Village classified into 4 Land Map Units (LMU). The actual land suitability was N class (not suitable) divided into 2 sub-classes: N1 class (currently not suitable) at LMU 1, 3, and 4 with rainfall as the limiting factor, and N2 class (permanently not suitable) at LMU 2 with crude material as the limiting factor. Improvement efforts were conducted on the LMUs with N1 class and marginally suitable class (S3) by providing organic materials, fertilizing, liming, and flooding the rain-fed fields. The improvement efforts resulted in an upgrade into moderately suitable class (S2) at LMU 1, 3 and 4 with limiting factors of crude material, soil depth, base saturation and erosion hazard, and not suitable class (N) at LMU 2 with limiting factors of crude material content. Sweet corn cultivation in Wonosari would be more profitable if conducted in the cropping periods I and II to overcome the low rainfall constraint.

1. Introduction
Climate change is a natural phenomenon caused by changes in the distribution patterns of climatic elements that occur in the long term. Climate change causes anomalies that have negative impacts on the agricultural sector. According to [1], the impact of climate change can be seen from the shifts in cropping pattern, cropping period, agricultural production and agricultural products. One element of climate that directly affects the agricultural sector is rainfall. Fluctuating rainfall is a direct impact of the climate change that will also result in the decline in yields which indirectly lead to a decrease in farmer’s income [2].

Wonosari is one of the villages in Karanganyar Regency where most of the area is rain-fed fields. During the first cropping period in October-January, the farming activities are dominated by rice paddy cultivation because this season is the rainy season. Whereas in the second cropping period from February to May, and the third Cropping period, from June to September, the land is left in a fallow condition or only planted with secondary crops [3]. Mustafa et al. [4] argued that land suitability evaluation can be a method in the effort to increase land productivity to achieve the optimal level.
Wirosoedarmo et al. [5] added that land suitability evaluation is needed in the planning of productive and sustainable land use that in accordance with the conditions required for plant growth.

Sweet corn is a commodity that considered in the effort to optimize the land in Wonosari Village because it has a short production age so that it can improve land use capacity. Land suitability evaluation is needed as a technical consideration for the development of sweet corn commodity, especially in the third cropping season in Wonosari Village. Based on this background, this study aims to determine the actual land suitability class, limiting factors and improvement efforts, as well as the potential land suitability class for sweet corn in the third cropping period in Wonosari Village, Karanganyar, Indonesia.

2. Materials and method
The research was conducted from July to December 2016 in Wonosari Village, Gondangrejo District, Karanganyar Regency, and for laboratory research at Laboratory of Chemistry and Soil Fertility, Faculty of Agriculture, Universitas Sebelas Maret Surakarta. This research is a survey research using the descriptive exploratory method. Determination of soil sampling locations was conducted using purposive sampling that represented each Land Map Unit (LMU). LMU was obtained by overlaying Wonosari Village Administration Map, Soil Type Map, Slope Map and Land Use Type Map using ArcView GIS Software 3.3. The soil characteristics observed included slope, drainage, soil depth, erosion hazard, flood hazard, texture, organic C, cation exchange capacity, base saturation, pH, K2O and P2O5. The stage of result presentation was conducted in the form of data tables and land suitability class maps for sweet corn crops derived from a matching system between the corn plant growth requirements and the data on the quality/characteristics of the land from each LMU [6].

3. Results and discussion

3.1. The general condition of research location
This study focused on rain-fed fields in Wonosari Village which covers 147 ha. Wonosari Village has an average altitude of 117 meters above sea level with 25.6°C of air temperature. The research location divided into 4 LMUs covering 12 hamlets. The physiographic state of Wonosari Village divided into several types, namely: flat with a slope of <2%, ramps to slightly sloping <2-8% and slightly sloping <8-15%. The types of soil found in Wonosari Village included in the Inceptisols order.

3.2. Actual and potential land suitability for sweet corn
Actual suitability classes indicate the land suitability at the time of land evaluation, without any significant level of improvement and management that can be conducted to overcome the constraints or limiting factors that exist in the land [7]. The data of land characteristics and the results of the actual land suitability classification presented in Table 1.

Figure 1 (a) is the map of actual land suitability classifications for sweet corn in Wonosari Village. In general, the entire LMU has included in Class N (Not Suitable) criteria with the limiting factors of rainfall and high crude material content. According to Safuan et al. [7], N class is a class with a very heavy limiting factor which is difficult to overcome. FAO [8] in Nugroho and Savitri [9] added that N class divided into 2, namely N1 (currently not suitable with a limiting factor that still possible to overcome) and N2 (permanently not suitable with a limiting factor that impossible to overcome).

In determining the actual land suitability in Wonosari Village, rainfall is the main limiting factor that classified in N1 class because in cropping period III, the amount of rainfall is limited and insufficient for sweet corn cultivation. However, the characteristics of the land which was classified as marginally suitable (S3) could not be ruled out to obtain the optimal potential class. Potential land suitability is land suitability condition that will be achieved after improvements have made to the limiting factors that exist in each land unit [7]. The land characteristics classified as S3 include a large amount of crude material content, low base saturation and low potassium available in LMU 1, 3, and 4.
Table 1. Results of land characteristics and actual land suitability classes for sweet corn

| Use Requirements/Land Characteristics | Land Map Unit (LMU) |
|---------------------------------------|---------------------|
|                                       | 1               | 2       | 3       | 4       |
| Water Availability (wa)               |                 |         |         |         |
| Rainfall (mm)                         | 189.3 (N)        | 189.3 (N) | 189.3 (N) | 189.3 (N) |
| Rooting Conditions (rc)               |                 |         |         |         |
| Texture                               | Moderate (S1)    | Slightly Rough (S3) | Moderate (S1) | Moderate (S1) |
| Crude material (%)                    | 43.6 (S3)        | 60.8 (N)  | 30.7 (S2) | 38.8 (S3)  |
| Soil depth (cm)                       | 50-100 (S1)      | 50-100 (S1) | 30-50 (S2) | 50-100 (S1) |
| Nutrient Retention (nr)               |                 |         |         |         |
| Base saturation (%)                   | 29.3 (S3)        | 27.8 (S3) | 42.9 (S2) | 31.9 (S3)  |
| Nutrient Availability (na)            |                 |         |         |         |
| K₂O (mg 100g⁻¹)                       | Very low (S3)    | Very low (S3) | Very low (S3) | Low (S3)   |
| Erosion hazard (eh)                   |                 |         |         |         |
| Slope (%)                             | 3-8 (S2)         | < 3 (S1)  | < 3 (S1)  | < 3 (S1)  |
| Erosion hazard                        | Very light (S2)  | - (S1)    | - (S1)    | - (S1)    |
| Actual land suitability class         | N-wa1            | N-wa1, rc2 | N-wa1    | N-wa1    |

Information: S1=HighlySuitable; S2=Moderately Suitable; S3=Marginally Suitable; N=Not Suitable

Based on the conducted improvement efforts in Class S3, the potential land suitability class of Wonosari Village is divided into 2, namely moderately suitable class (S2) and not suitable (N). The potential land suitability class for sweet corn can be seen in Figure 1 (b). Rainfall as a limiting factor can be solved by changing or shifting the cropping period, considering that sweet corn requires enough water for its growth phase to produce optimally. Thus, if sweet corn planted in the third cropping season where water is limited, its growth will be inhibited.

Figure 1. (a) Actual land suitability map for sweet corn (b) Potential land suitability map for sweet corn

3.3. Analysis of limiting factors and improvement efforts

The efforts to improve land characteristics which were classified as S3 in Wonosari Village are included as high management level because of large number of required costs. Marginally suitable class (S3) is a land with very dominant limiting factors that can reduce its productivity so that it needs to be given enhancement to the soil.
3.3.1. Limiting factor of high crude material content. Soil with high crude material content will be difficult to hold water and nutrients. Adding organic matter is expected to improve the soil aggregation process and improve the soil capacity to hold water. According to Intara et al. [10], the decomposed organic matter will produce humus which is a hydrophilic colloid, so the soil can hold more water and does not get dry easily. Humus formation will also improve clay texture. Soil with clay texture has more micropores and not porous. Hasibuan [11] explained that micropores are pores that are used to hold water. The more micropores formed, the higher the water retention capacity.

3.3.2. Limiting factor of low base saturation. Base saturation is closely related to the presence of base cations such as Ca²⁺, Mg²⁺, and K⁺ [12]. Lower base cation content in a land area means lower base saturation level. Low base saturation can be improved by fertilizing and giving lime to the soil [13]. Organic fertilizer can increase soil CEC because the organic matter has a surface with a negative charge that can absorb base cations. By increasing soil CEC, base saturation will also increase [14]. Giving limestone can also be considered because it contains Ca and Mg which can neutralize acidic cations that meet the cation exchange area, thus increasing base saturation [15].

3.3.3. Limiting factor of low K₂O available. The available potassium in the soil is in the form of a soil solution that has a balance with K in the absorption complex [16]. If the K in the absorption complex release continuously, there will be an impoverishment of the K element in the soil. According to Kaya [17], to increase the availability of potassium in the soil, fertilization measures are needed. Inorganic fertilizer in the form of NPK fertilizer accounts for 15% of available potassium. The provision of organic material in the form of manure can supply various nutrients as a result of decomposition. In addition to manure, returning paddy straw to the soil can provide some of the nutrients needed by plants [18]. In the dry season the rainfed field experience K element deficit caused by a lack of K element supply from irrigation water. The process of flooding in the paddy field will increase the availability of K soil because flooding will produce Fe²⁺ and Mn³⁺ which can replace K in the absorption complex and K release into the soil solution.

3.4. Limiting factor of low rainfall.
Yibarek et al. [19] argue that water shortages during the growth period can be overcome by irrigation so the water needs are met. In Wonosari Village irrigation is carried out by pumping water from shallow wells owned by farmers every 5-7 days during the cultivation of sweet corn. To be able to meet the needs of sweet corn water consumption in the third planting season, a large-scale irrigation system is needed because the rainfall is only around 189.3 mm per month. The rainfall is considered minimal and will cause problems with of production costs that will swell for the irrigation system. In the other side, one of the conditions for growing sweet corn is rainfall that is quite high during the planting months of 309 mm and 501 mm (an average of 427 mm per month).

Figure 2 (b) shows a graph of monthly rainfall during the third cropping period, calculated from 2007-2016, it can be seen that the monthly rainfall from June to September is not more than 80 mm/month. This condition is obviously lacking to meet the water needs of sweet corn and can cause drought stress on the plants. Lack of water during growth can cause small humps, seeds do not form, and leaves continue to turn yellow. Drought can be a sign of uncertain rainfall due to extreme climate change. The uncertain rainfall will affect the established cropping patterns in the rain-fed field system because it affects the availability of groundwater [20]. Figure 2 (a) shows the monthly rainfall graph for 2007-2016, November-March has high rainfall. The peak in November and March reaches a rainfall level of more than 300 mm/month. November-March is included in planting season I or II which coincides with the rainy season so that the water supply is abundant. If sweetcorn is planted in those months the water needs will be met. Selection of the right planting period will minimize the risk of plants experiencing drought stress in the critical phase of growth [21].
4. Conclusion
From the results, it found that the actual land suitability class classified as Not Suitable, with minimal rainfall and high crude material content as limiting factors. The minimal rainfall can be overcome by rearranging the cropping period of sweet corn from the planting season III to planting seasons I and II. That is an effort to adapt to the climate change. Climate change has impacts on the weather patterns, one of which is rainfall. The rainy season that can come later and end faster will affect groundwater availability. If the availability of water does not meet the needs of plants, the plants will be vulnerable to drought stress. Improvements were also conducted to the marginally suitable class (S3). Improvements were made by providing organic materials, fertilizing, liming, and flooding the rain-fed fields. Based on the conducted improvement efforts the potential land suitability class are classified as a Moderately Suitable class (S2) and Not Suitable (N).

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