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Evaluation of land suitability for sorghum crops in Lampasio District, Tolitoli Regency

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Abstract: Sorghum is an alternative food ingredient that contains high levels of carbohydrates and calories so it can be a solution to food security problems. This research aims to evaluate the suitability of land for sorghum (Sorghum bicolor L.) in Tolitoli Regency, Indonesia. This research was conducted in Lampasio District, Tolitoli Regency using purposive sampling and survey methods on five land map units (SPL). The results of the research show that the area is classified as quite suitable land class (S2) with limiting factors for drainage and nutrient retention (oa, nr) with a land area of 3,652.7 ha spread over 5 SPL, namely SPL 1,2,3 and 5 while class The land (S3) is SPL 4. However, this can be overcome by adding fertilizer and adding organic material. So that it can improve the status of each land to be very suitable (S1) and quite suitable (S2).

Key words: drainage; land evaluation; land suitability; nutrient retention; sorghum

INTRODUCTION

Sorghum (Sorghum bicolor L. Moench) is a cereal plant that is a source of carbohydrates. The nutritional value of sorg2hum is quite adequate as a food ingredient, namely containing around 83% carbohydrates, 3.50% fat, and 10% protein (dry weight). Sorghum plants can be produced even though they are cultivated on less fertile land, with limited water and low input, even on sandy land sorghum can be cultivated. Sorghum has high productivity, is resistant to plant pests and diseases, and is more resistant to marginal conditions such as drought (Harahap et al., 2021). According to research results from the Soil Research Institute (2012), land that is suitable for optimum growth for sorghum planting has the optimum temperature of 23-270C, relative humidity of less than 75%, altitude ≤ 200 m above sea level, rainfall of 400-900 mm/year. The physical criteria assessed are based on soil formation factors, namely climate factors, topographic factors, parent material factors, vegetation or land use factors, and time factors. In this research, physical factors were determined from the nutrient content of the soil, namely pH, CEC, KB, soil texture, soil depth, slope, and average rainfall.

One of the obstacles in developing sorghum cultivation is the lack of information about land suitability and the actions required on each land. Therefore, an assessment is needed to see the potential, characteristics, and capabilities of land in an area. Within the framework of this assessment, land survey and evaluation activities are needed. Land evaluation is the process of assessing the potential of land for certain land uses (Han et al., 2021) and evaluating a diversity of factors (Freire & Rocha, 2021). Land evaluation has an important role in the potential for agricultural efficiency and sustainable land use (Rendana et al., 2022). Inappropriate land use, apart from causing land damage, can also cause socio-economic problems, and can even destroy a previously existing culture. On the other hand, appropriate land use is the first step to support sustainable land conservation programs,

MATERIALS AND METHODS

Methodology

The data collection method is carried out in 2 ways, namely the interview method and sampling using the purposive sampling method, which is based on the needs and objectives of making maps and land suitability analysis which is used to obtain representative elements of data on each land unit (Djaenudin & Hidayat, 2011)

Data retrieval

To collect primary and secondary data, several data collection techniques were used, namely:

1. preparation and creation of work maps
2. Field survey
3. Carry out an inventory of potential resource data and information.
4. Analyze soil samples in the laboratory
5. Prepare a map of potential resources, opportunities, and regional development areas.
6. Data management and report preparation

Activities carried out at this preparation stage are arranging for field surveys, collecting secondary data (both numerical data and spatial data or base maps) related to the implementation of the study, providing tools, materials, and plans for placing observation plots, and collecting soil samples and area coverage. The base map is used as a guide in determining the boundaries of the mapping planning area and as a guide for determining observation points and taking soil samples because the map produced from this study is classified as a detailed scale.

The next stage of this activity is a preliminary survey in the form of a visit to the entire survey area to obtain a glimpse of the general physical condition of the study area, then accessibility, and social conditions and to obtain an overview of the location placement. Next, the placement of observation points as determined on the work map is carried out with the help of a Global Positioning System (GPS) tool. With this tool, the main survey can be carried out efficiently with a reliable level of accuracy. The reference sources for collecting data are:

Administrative maps, land cover maps, soil maps, slope maps, rainfall maps, and climate maps. Other data needed for land suitability analysis is in the form of physical field data to obtain the results of soil chemical analysis, both intact soil and incomplete soil, using a hoe, soil drill, and sample ring.

Apart from that, other primary data is also needed regarding social and economic aspects using questionnaires distributed directly to farmers or communities in the research area.

Data analysis

Analysis of Soil Physical and Chemical Properties

Analysis of soil samples/samples was carried out at the Soil Laboratory, Faculty of Agriculture, Tadulako University, Palu, namely to determine the texture (clay, sand, and dust), while soil chemistry consisted of macro and micronutrients: Nitrogen (N Total), Phosphorus (P2O5), Potassium (K2O), soil acidity (pH), Cation Exchange Capacity (CEC) and Organic C.

GIS analysis

GIS analysis is using various types of maps to see or match the field or area that will be the object of research according to certain objectives. Several map attributes are overlaid to make it easier to determine land map units or land units because each land unit has its characteristics (Andri Supriadi & Teddy Oswari, 2020), (Goodchild & Longley, 1999).

Land Suitability Evaluation

The method used in evaluating land suitability is the limiting factor method, namely, each land quality is arranged sequentially from the best (lightest limiting factor) to the worst (the most severe limiting factor), (Goodchild & Longley, 1999), (Anselin, 1992) each land quality is arranged in a criteria table:

Parameters in Land Evaluation

Temperature

Temperature or temperature is the degree of hot or cold which is measured based on a certain scale using a thermometer. Land characteristics from the Soil Temperature (tc) variable used in assessing land suitability classes are determined from the characteristics of the average soil temperature (Wirosoedarmo et al., 2011); (Djaenudin & Hidayat, 2011).

Rainfall

Rainfall is the height of rainwater (in millimeters) that is received on the surface before experiencing surface flow and infiltration or seepage into the ground.

Humidity

Humidity is the amount of water vapor in the air. Humidity can be seen from the climate classification of a place. According to Schmidt and Ferguson, the type of rain in an area is determined based on the Q value, namely by considering the number of dry months and wet months in one year multiplied by 100% (Sukarman et al., 2020)

Soil Drainage

Soil drainage assessment consists of Fast, Somewhat Fast, Good, Somewhat Good, Somewhat Inhibited, Inhibited, and Very Inhibited. (Djaenudin & Hidayat, 2011)

Soil Texture

It is the relative ratio of grains of sand, dust, and clay.

Nutrient Availability

What is measured in nutrient availability are C (%), N (%), C/N, P2O5 HCl 25% (mg/100 gr), K2O (Morgan) (ppm), P2O5 Bray (ppm), CEC (col (+)/kg clay), C-organic. (Djaenudin & Hidayat, 2011).

RESULT AND DISCUSSION

Result

In determining the research location, the GIS (Geographic Information System) method was used based on climate, soil, topography, and surface water resources (Han et al., 2021); (Elsheikh et al., 2013), as well as slope and soil type (Freire & Rocha, 2021), some of these parameters are limiting factors in sorghum cultivation (Aissata et al., 2022); (Komariah et al., 2021).

The results of the analysis of actual and potential land suitability maps in land map units (SPL) 1 - 5 for the area of sorghum development can be seen in the map image below:

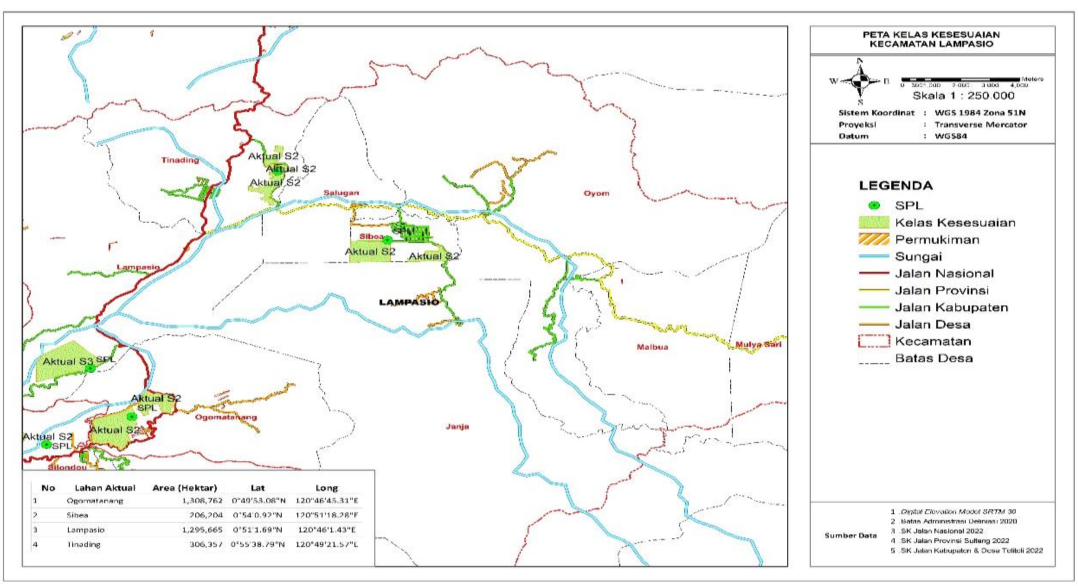

Figure 1. Map of actual land suitability and potential development of sorghum plants in Lampasio District

Furthermore, the area distribution for the development of sorghum plants is according to the table below.

Discussion

In principle, land suitability assessment is carried out by matching soil and physical environmental data with a land suitability rating table which has been prepared based on land use requirements including growing/living requirements for agricultural commodities including management and conservation (Pasang Sirappa et al., 2010). The minimum law matching process is used to determine factors. In assessing land suitability, it is necessary to determine the actual state (actual land suitability) or the potential state (potential land suitability). The potential state is achieved after carrying out improvement efforts (Improvement = I) toward each limiting factor to achieve the potential state (Sevani et al., 2010).

Climate Suitability Evaluation

Climate greatly influences almost all aspects of agricultural activities, both in long-term and short-term processes, the need for climate information will directly influence planting patterns, types, and even government policy strategies.

Table 1. Area of sorghum development in Lampasio District

No.	Village	Area (Ha)
1	Ogomatanang	1.308,8
2	Sibea	206,2
3	Salugan	534,6
4	Lampasio	1.296,7
5	Tinading	306, 4

Temperature

Temperature is an environmental factor that influences plant growth and development because every plant needs an appropriate temperature to grow and develop well. If plants are planted outside their climatic regions, their productivity is often not as expected. The plant growth environment is maintained at or close to optimum conditions. The suitable temperature for sorghum plants is between 24-29 °C. The higher the air temperature, the greater the evapotranspiration process fast. Evapotranspiration is a combination of evaporation and transpiration or the evaporation of water into steam that occurs in soil and plants.

If these temperature conditions are adjusted to the suitability class for sorghum plants, they are included in class S1, which is very suitable because the temperature at the research location is 26.50C, meaning this figure is between 24-29oC. The suitable temperature for sorghum plants is 25-27 degrees Celsius. (Cisitu et al., 2012).

Rainfall

Rainfall is one of the climate elements that plays a very big role in supporting the availability of water on land. Rainfall greatly influences plant growth and development. Rainfall (mm) is the height of rainwater that falls on a flat place assuming it does not evaporate, does not seep and

Table 2. Limiting factors for the development of sorghum plants in Lampasio District

SPL	Land Suitability Class	Limiting Factors	Additions/improvements
SPL 1	S2	Drainage	
SPL 2	S2	Drainage	
SPL 3		Drainage Nutrient retention Kelerengan	N-Total, K_2O
SPL 4	**S3**	Drainage Nutrient retention	KTK liat (cmol), N-Total, K_2O dan C Organik
SPL 5	S2	Drainage Nutrient retention	N-Total, P_2O_5
	Actual S3		Potential S2

does not flow. 1 (one) mm of rainfall is 1 (one) mm of rainwater that falls (is collected) on a flat area of 1 m2 with the assumption that nothing evaporates, flows or seeps (Jonizar & Utari, 2019). Climate change will have a negative impact on the agricultural sector, such as increasing water demand in the dry season and flooding in the rainy season (Rizwan & Prasetianto, 2023).

For the purposes of assessing land suitability, it is usually expressed in terms of the amount of annual rainfall, the number of dry months and the number of wet months. Ritung et al. (2007) groups regions based on the number of wet months and dry months respectively (Wredaningrum & Sudibiyakto., 2013). Wet months are months that have rainfall >200 mm, while dry months have rainfall of 100 mm) and dry months. (The trend of rising and falling temperatures is an indication that the possibility of rainfall in the last 10 years could reach greater amounts. Suitable rainfall (S1) for sorghum plants is <200 mm on average/year.

Humidity

Humidity is the amount of water vapor in the air. In evaluating land suitability, humidity is the annual average air humidity expressed in %. Air humidity affects the water content in the air and the air in the soil. The higher the humidity value, the higher the water content in the air. If the humidity is too high, it will reduce the evapotranspiration process and the absorption capacity of plant roots to obtain nutrients, whereas if it is too low, evapotranspiration will occur very quickly so that it is not balanced by the provision of water by the roots and causes the plants to wilt.

The best humidity for sorghum plants is 33-90%, the results of climate suitability analysis at the research location include actual very suitable humidity (S1) with an average humidity of 83%.

Texture

Texture is the composition of fine soil partic easily flows on the surface and causes erosion, while sandy soil seeps more easily and cannot store water. Soil texture is said to be good if the composition of sand, dust, and clay is almost balanced. This kind of soil is called clay soil. The finer the grains of sand, the stronger the soil holds water and nutrients.

The results of the actual suitability analysis at the research location regarding the growing requirements for sorghum plants are at a fine, rather fine level so they are classified as very suitable (S1) and suitable (S2), except for those found in SPL 4 Lampsio Village which are in the somewhat rough category (S3), so the texture in this area is one of the limiting factors.

Drainage

Soil drainage is the speed at which water absorbs from the soil or the condition of the soil which indicates the duration and frequency of water saturation. Poor drainage makes it difficult for water to seep into the soil or it absorbs very easily so the water disappears quickly. The relationship between this parameter and other physical parameters is quite large. Drainage conditions on land with limestone parent rock will be different from volcanic rock because limestone can allow water to pass through, while volcanic parent rock is generally dominated by a smooth texture that is difficult for water to pass through.

The suitability of soil drainage for sorghum cultivation in Lampasio District and Basi Dondo District is included in the S2 suitability class, namely quite suitable. Soil drainage is a limiting factor in land for sorghum cultivation but it can still be improved.

Cation Exchange Capacity

Cation exchange capacity (CEC) is defined as the capacity of the soil to absorb and exchange cations which is usually expressed in milliequivalents per 100 grams of soil. Soil colloids can absorb and exchange several cations, including Ca, Mg, K, Na, NH4, Al, Fe, and H. Bases that can be exchanged include Potassium (K), Sodium (Na), Calcium (Ca), and Magnesium (Mg) (Nursyamsi et al., 2007) Cation exchange capacity (CEC) is a chemical property of soil that is very closely related to soil fertility. Soil with a high CEC can absorb and provide nutrients better than soil with a low CEC because these nutrients are not easily washed away by water (Wantasen, 2001). The average CEC at the research location is classified as quite suitable (S2) to very suitable (S1). In Lampasio District, of the 5 SPLs, there is only 1 SPL in the category (S2), namely SPL 4 (Lampasio Village). To improve this limiting factor, it is necessary to limit and add organic fertilizer. The CEC value in soil can be influenced by the level of soil weathering, soil organic matter content, and the amount of basic cations in the soil solution. Soil with a high organic matter content has a higher CEC, likewise, young soil with a new level of weathering starting from soil with an advanced level of weathering has a low CEC value (Simanjuntak & Budi Hendrawan, 2022).

Soil Acidity (pH H2O)

pH is the level of soil acidity that regulates the absorption and distribution of cations by soil particles. High soil pH of less than 6 causes the elements Forfor, Calcium, Sulfur, Calcium, Magnesium, and Molybdenum to decrease rapidly, while soil pH higher than 8 will cause the elements Nitrogen, Iron, Manganese, Boron, Copper, and Zinc availability is relatively small (Tioner Purba, et al., 2021). The pH for sorghum plants is 5.5 – 7.0, while at the research location, it is 4.8 – 6.5, which is classified as sour to slightly acidic. The highest pH (4.99) is found in SPL 2 Kayu Lompa Village, Ogodeide District, and this is a limiting factor. For sorghum plants, the way to overcome this is by liming and adding organic material.

N- Total

Nitrogen is an essential nutrient for plants, nitrogen is used by plants in the form of Ammonium ions (NH4) and Nitrate ions (NO3) found in the soil solution and is mobile and bound by soil particles, the N element is easily leached and evaporates (Farah et al., 2018); (Patti et al., 2013), further stated that nitrogen elements are needed in the growth process of the main organs, namely roots, which will then accelerate the absorption of nutrients available in the soil and help the growth of vegetative and generative organs.

The total N needed by sorghum plants is around 0.2 – 0.75%. At the research location, N is one of the limiting factors, including SPL 4, SPL 5 in Basi Dondo District, and SPL 3, SPL, 4, and SPL 5 in Lampasio District. This limiting factor can be increased to become potential if fertilization contains Nitrogen elements.

Phosphorus (P2O5)

Phosphorus (P2O5) functions to stimulate root growth, especially in the roots of seeds and young plants, apart from that as an ingredient in forming several certain proteins, helping assimilation and respiration and accelerating fruit ripening (M. TUFAILA et al., 2014); (Agoesdy et al., 2019) Phosphorus used by sorghum plants is 15 - > 60%. phosphorus is a limiting factor at SPL 2, SPL 3, and SPL 4 in Basi Dondo District as well as SPL 4, SPL 5 in Lampasio District. This limiting factor can be overcome by adding fertilizer containing phosphorus.

Potassium (K2O)

Potassium plays a role in the formation of starch, activator of enzymes, opening of stomata, physiological processes in plants, metabolic processes in cells, influences the absorption of other elements, and forms strong stems. Potassium is a catalytic agent that plays a role in plant metabolic processes, such as: (1) increasing enzyme activation, (2) reducing transpiration water loss through stomatal regulation, (3) increasing the production of adenosine triphosphate (ATP), (4) helping the translocation of assimilate, and (5) increasing N uptake and protein synthesis. If soil potassium availability is low, plant growth will be disrupted and plants will show symptoms of nutrient deficiency (Agoesdy et al., 2019), (Sudaryono, 2016). Potassium at the research location is classified as good, potassium deficiency is only found in SPL 5, Lampasio District.

C-Organic

C-organic or organic material content is plant remains that act as a reservoir for plant nutrients. The amount of organic C content in the soil can also determine the amount of organic matter content in the soil (Pradana et al., 2013). Organic matter is generally found on the surface of the soil, the amount is very small, around 3-5% but its influence is quite large on soil properties. It can be seen that organic matter can function to improve soil structure, as a source of nutrients, the capacity to increase the CEC value of the soil, a source of energy for soil microorganisms and increase the soil's ability to hold water (Susila et al., 2015).

C-organic at the research location is in the low, medium, and high categories. Low organic C is found in SPL 4 Basi Dondo District and SPL 4 Lampasio District. To correct the deficiency of organic C is by adding organic materials.

Efforts to Improve Limiting Factors

Based on the analysis carried out, the limiting factors include Cation Exchange Capacity, pH, and C-Organic, then the characteristics of available nutrients, namely N-total, P2O5, and K-dd, while the erosion hazard characteristics are slope and actual erosion hazard. Improvement of limiting factors for drainage is by improving the irrigation system. Improving the limiting factors for nutrient retention, including cation exchange capacity, pH, and organic C, can be done by liming and adding soil organic matter. Improving the limiting factors for available nutrients which include N-total, P2O5, and K-dd can be done by fertilizing in a balanced manner with the right dose and at the right time. Improving the limiting factors for erosion hazards which include slopes and actual erosion hazards can be done by terracing, planting parallel to contours, cultivating land according to contours, and planting ground covers.

CONCLUSIONS

Of the 5 land map units located in Lampasio District, land suitability analysis has been carried out, each has different limiting factors, but only mild limiting factors, namely in the S2 category, Based on research results, the suitability of land for developing sorghum plants in Lampasio District, Tolitoli Regency is as follows:

a. Class S2 – oa, nr (land sufficient to meet the limiting factors for drainage and nutrient retention with a land area of 3,652.7 ha. spread over 5 SPLs, namely SPL 1 to SPL 5.

b. This limiting factor can be done by adding organic materials, liming, and fertilizing.

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