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Potential Land Suitability For Spatial Planning of Wheat Commodity (Triticum Aestivum) In Tanah Datar Regency

Eggy Arya Giofandi[1*], Anissa Zuhrita[1], Assyaroh Meidini Putriana[1], Dhanu Sekarjati[1], Fitrah Andika Riyadhno[1], Ade Mashuri[1], Opi Sepriani[1], Muhammad Rifqi[1], Triyatno[1], Ahyuni[1], Cipta Estri Sekarrini[2]

[1] Department of Geography, Universitas Negeri Padang, Padang, 25132, Indonesia
[2]Department of Geography Education, Universitas Negeri Malang, Malang, 65145, Indonesia

***E-mail: aryaeggy15@gmail.com**

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ABSTRAK

Indonesia termasuk salah satu negara agraris tersebesar di dunia, kemampuan Indonesia dalam melakukan pertanian diimbangi dengan kondisi tanah yang sebagian besar lahannya subur. Pertanian ini di tanam berbagai komoditas pangan, sayur, hingga perkebunan. Dalam sektor pertanian sering kali memiliki beberapa kendala mulai dari tinggi nya permintaan pasar yang tidak diimbangi produksi dalam negeri, salah satunya permintaan gandum. Penelitian ini membahas perencanaan spasial untuk komoditas gandum di Kabupaten Tanah Datar, dengan menggunakan metode matching lalu pendekatan Fuzzy Logic untuk mengetahui kemampuan fisik di lahan tersebut. Hasil dari penelitian diperoleh kesesuaian lahan 111.132ha untuk kategori sesuai, 20.239ha untuk kategor cukup sesuai, dan 137m^2 untuk kategori tidak sesuai. Kemudian setelah kesesuaian lahan diperoleh dilakukan arahan pengembangan untuk perencaan pertanian komoditas gandum dengan pendekatan Boolean, hasil dari arahan pengembangan mencapai 42.873ha yang tersebar diseluruh kecamatan dengan potensi pengembangan paling tinggi di Kecamatan Lintau Buo Utara 9.657ha dan Kecamatan Lintau Buo 7.348ha. Potensi pengembangan ini dapat digunakan untuk referensi awal dalam bercocok tanam komoditas gandum (Triticum aestivum) di Kabupaten Tanah.

Kata Kunci: *Pertanian, Komoditas Gandum, Logika Fuzzy*

ABSTRACT

One of hindrances faced by Indonesia agriculture sector is domestic agriculture production that does not cover the market demand such as wheat commodity. The aim of this research is to calculate the spatial planning for wheat commodity in Tanah Datar Regency by using matching calculation with Fuzzy set method to find out the land physical ability. The method used in this research using fuzzy set equations and Boolean approach. The research results obtain land suitability 111.132 ha for suitable category, 20.239 ha for quite suitable, and 137 m^2 for unsuitable category. Then after the land suitability is obtained, development instruction is given for the agriculture planning of wheat commodity with Boolean approach. The result of development instruction reaches 42.873 ha spread in all over sub districts with the highest development potency is at North Lintau Buo Sub District 9.657 ha and Lintau Buo Sub District 7.348 ha. This development

potency can be used as the initial reference for planting wheat commodity (Triticum aestivum) in Tanah Datar Regency.

Keywords: Agriculture, Wheat Commodity, Fuzzy Set.

INTRODUCTION

Wheat has become the main food ingredient in Indonesia. Most Indonesians have consumed bread and noodles made from wheat flour as the second staple after rice (Wicaksono et al., 2016). Wheat flour is a product of wheat seeds that contain carbohydrates as much as 60-80%, protein 10-20%, fat 2-2,5, minerals 4-4,5%, and several vitamins. This food commodity also has gluten which is expandable and sticky in various food products, especially bread, noodles, and cakes (Praptana & Hermanto, 2016).

Wheat flour is the main commodity that tends to be strategic from year to year in Indonesia. The domestic industry has invested in very large amounts, especially to manage fluctuations in the domestic price of wheat flour from year to year (Erenstein *et al*., 2021). Therefore, it is undeniable that the domestic industry has an important role in the sustainability of the production and trade of wheat/wheat flour. The current productive agricultural land (paddy fields, dry fields, plantations, etc.) has an area of 70.2 million ha and is capable of producing most of the strategic commodities, especially rice, corn, and sugar for the next few years (Widowati *et al*., 2016). However, for other important commodities such as soybeans and wheat, most and even all of them are still imported from outside Indonesia (Sembiring *et al.*, 2016). The volume of Indonesian wheat imports has increased from year to year with a trend calculation from 1992-2011 that there will be an increase in imports of around 11,793 tons (Pradeksa *et al*., 2016).

Currently, the government is actively developing domestic wheat through research programs. One of the studies in this field is research on the level of land production. The potential of land for wheat development in Indonesia is still wide, considering that the plant can be cultivated in dryland and highlands with an altitude of > 800 m above sea level and a temperature of 15- 25ºC which reaches 1,453,800 ha (Simmons *et al*., 2020). The agroecosystem is currently planted with vegetables and potatoes. In the highlands, wheat can be cultivated because the results from the cultivation of other gramine plants such as rice are not optimal, especially on land with an altitude of 1,200 meters above sea level (Konduri *et al*., 2020). In addition, wheat cultivation can break the pest and disease cycle and provide biomass for the cultivation of vegetables and potatoes. The potential that is optimally utilized will provide opportunities for the development of domestic wheat to be quite broad (Clarke *et al*., 2021). The information obtained from this study discusses areas that have the potential to produce wheat. However, the information is still limited, more precisely on the distribution of the potential of the island of Sumatra which reaches 7,748,000 ha for dry land and 278,146 ha for upland dry land with a dry climate, which is spread over the Provinces of West Sumatra, Jambi Province, and Bengkulu Province (Center for Agricultural Land Resources, 2008 in Sembiring *et al*., 2016).

This information is very useful for planning the development of the agricultural sector so that the direction of regional development based on the suitability of the existing land for wheat crops can be recommended.

METHODS

Potential land suitability for spatial planning of wheat commodity food crops

in this study was carried out for Tanah Datar Regency. The matching calculation with the fuzzy set method was used to calculate potential land planning wheat commodity. Where the tolerance for the indicators used was given with the help of a geographic information system (Baja et al., 2002a). The next step taken was to direct agricultural development using the Boolean method which is overlaid from land use. The data used at this stage are described on **Table 1**.

Table 1. Research Data

No.	Variable	Indicators
1	Climate	Temperature Rainfall
2	Topography	Height Slope
3	Soil and Its Characteristics	Texture Drainage Soil Depth Base Saturation pH Soil KTK

Fuzzy Set

Fuzzy sets are developed and applied in various problems, including in environmental applications and spatial planning. The main purpose of using the fuzzy set classification technique is to provide solutions to serious problems, especially related to accuracy through the application of Boolean binary classification logic where it is only true or false, namely one or zero (Baja *et al*., 2006). One of the important considerations is that the spatial attributes of the environment in nature vary widely. Therefore, the presentation of continuous functions with fuzzy sets, both in the assessment procedure and the presentation of outputs, is considered to be much more representative than the method of grouping attribute values into a categorical system. The criteria and indicators of land evaluation used are the characteristics of land evaluation. These characteristics are the main determinants based on research and development of agricultural land resources from the Center for Agricultural Research and Development, Ministry of Agriculture of the Republic of Indonesia compiled as presented in **Table 2**.

Table 2. Main Determination of Land Suitability for Wheat Plants

Usage requirements/Land characteristics	S1 (Very suitable)	S2 (Suitable)	S3 (Very marginal)	N (Unsuitable)
Temperature (tc)	12 – 23	10 - 12	10 - 12	< 10
Average temperature (ºC)		23 - 25	23 - 25	> 25
Place height (mdpl)	< 1.200	1.200 - 1.500	1.500 - 2.000	> 2.000
Water availability (wa)				
Rainfall (mm)	350 - 1.250	250 - 350	200 - 250	< 200
		1.250 -1.500	1.500 - 1.750	> 1.750
Oxygen availability (oa)				
Drainage	good, a bit inhibited	a bit quick, medium	Inhibited	a bit inhibited, quick
Root media (rc)				
Texture	smooth, rather	smooth, a bit smooth	a bit rough	rough
Soil Depth (cm)	> 50	20 - 50	10 - 20	< 10
Nutrient potential (nr)				
Soil KTK (cmol)	> 16	5 - 16	< 5	
Base saturation (%)	> 50	35 - 50	< 35	
pH H_2O	6,0 - 8,2	5,6 - 6,0	<5,6	
		8,2 - 8,5	>8,5	
Erotion Danger				
Slope (%)	< 3	3 - 8	8 - 15	> 15

Source: (Ritung et al., 2011)

Land quality and characteristics are divided into three criteria which are used as land evaluation indicators. The three categories are climate, topography, and soil characteristics/quality (Hardjowigeno & Widiatmaka, 2007). Furthermore, each indicator is grouped based on the level of importance, the difficulty of repairing, and repair costs. According to (Aji & Ahyuni, 2019) Land, characteristic parameters are grouped into. Group A: Very difficult to repair and requires high costs, namely temperature, rainfall, elevation, slope, and texture. Group B: Difficult to repair and requires high cost of drainage and soil depth. Group C: Easy to repair and does not require high costs, namely base saturation, soil CEC, and soil acidity or pH.

The indicators that have been selected in the suitability of wheatland are assessed using the membership function (MF) formula. The fuzzy membership function value based on the S curve model (sigmoid) consists of four symmetrical function models, namely symmetric function (model 1), symmetric function (model 2), left asymmetric function (model 3), and right asymmetric function (model 4). Each of these models has a different fuzzy set membership function value. Determination of the model and degree of membership of each land indicator refers to one of the S curve models (sigmoid) in the Semantic Import Model (SIM) approach, including symmetric, right asymmetric, or left asymmetrical. The model S curve used in the fuzzy set function equation is presented in **Figure 1**.

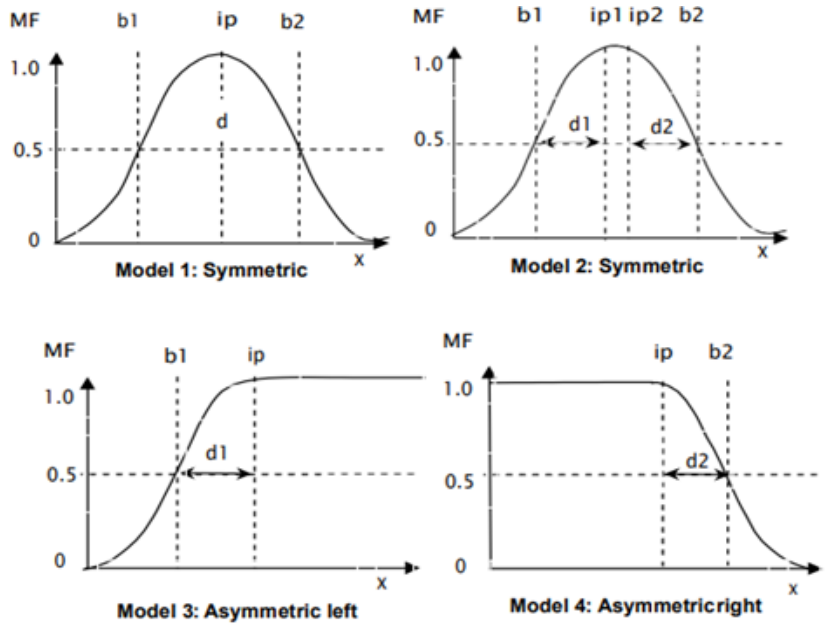

Figure 1. The Membership Function of the Fuzzy Set (Borrough & McDonnell, 1998)

The fuzzy set membership function model formula used in the land suitability rating (Peter A Burrough & McDonnell, 1998) is as follows:

1) Fungsi simetris (model 1)

$$MF(xi) = \frac{1}{1+[\frac{x-b1}{d}]^2} \text{ jika } 0 < xi < 1 \quad (1)$$

2) Fungsi simetris (model 2)

$MF(xi) = 1$ jika $(b1 + d1) \leq xi \leq (b2 - d2)$

3) Fungsi asimetris kiri (model 3)

$$MF(xi) = \frac{1}{1+[\frac{x-b1-d1}{d1}]^2} \text{ jika } x < b_1+d_1 \quad (3)$$

4) Fungsi asimetris kanan (model 4)

$$MF(xi) = \frac{1}{1+[\frac{x-b2-d2}{d2}]^2} \text{ jika } x < b_1+d_1 \quad (4)$$

Information:
$MF(x_i)$ = individual membership value for land characteristics x
d = width of the transition zone
xi = characteristic value of x land
b = value of x land characteristic value at the ideal point or standard index
ip = optimal point

The next step is to determine the JMF value which can be obtained by multiplying each membership function or membership function (MF) of each indicator with the group weight value based on the level of importance of these characteristics in the calculation (P. A. Burrough, 1989).

After the suitability of the land for wheat commodities is known, then to find out the direction of the development of wheat crops is based on the suitability of the land by considering the use of the land. The method used to determine the direction of the development of the suitability of wheat crops is the Boolean logic method. This is the simplest with easy-to-understand concepts, making this logic most often applied in research for decision making. The application of boolean logic, in this case, uses the number 0 and the number 1, with the principle of true or false. The use of boolean logic is in parameters. Land use and land suitability maps for wheat that can be developed will be assigned a score of 1, while those that cannot be developed will be assigned a number 0 with the principle of true or false. The results of this boolean calculation will produce information on directions for the development of wheat commodity agriculture (By *et al*., 2001).

RESULT AND DISCUSSION

The productivity of food crops is largely determined by the quality of the land used. If there is no allowance for unproductive areas during land selection at the beginning of land development, then quite large (financial) losses are likely to occur. Determination of the type of cultivation of food crops that are suitable for planting on a certain land is still done manually, namely comparing the data in the field with the criteria for land use requirements for certain food crops. Thus, this kind of process will require a lot of time, effort, and money. This is following the condition of land units that have different land characteristics for each horizon in the soil profile which in turn may affect land use.

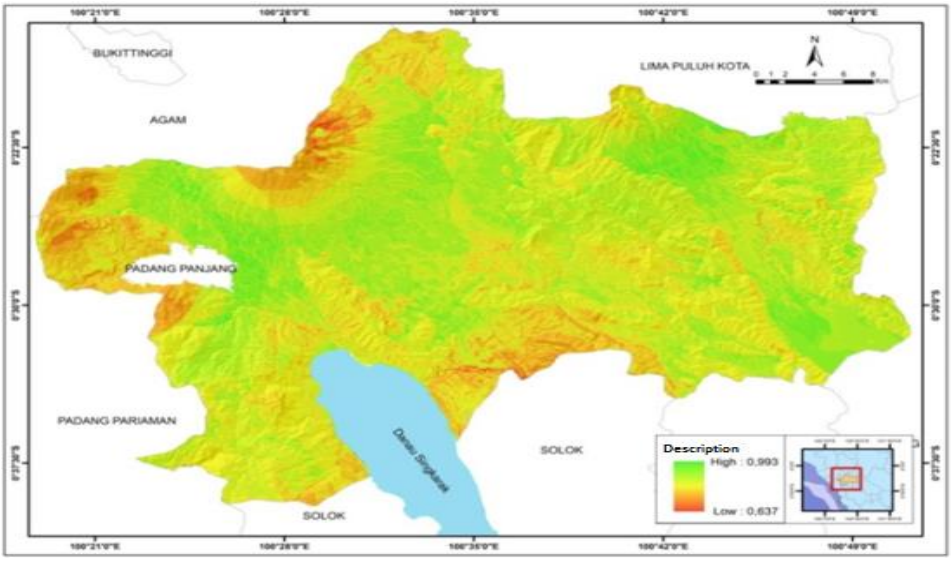

Figure 2. Map of Wheat Defuzzification in Tanah Datar Regency

Figure 2 describes the level of land suitability from the defuzzification results of 10 parameters based on temperature, rainfall, drainage, texture, soil depth, soil cation exchange capacity, base saturation, soil pH, altitude, and slope which was carried out in a raster format so that the results were 0 to 1 The value close to 1 indicates that the land is suitable for wheat commodity agriculture. Conversely, if the value is close to 0, it indicates that the area is not suitable for wheat farming.

Calculation of the land suitability index from the results of defuzzification is carried out after knowing the level of land suitability. This stage aims to determine the limits included in the appropriate to the inappropriate class. The calculation of this land suitability index uses categories according to (Hapsari *et al*., 2014). The category according to Hapsari consists of a class that does not match values ranging from 0 to 0.59, a fairly appropriate class from 0.59 to 0.79, and an appropriate class if the value obtained is in the range of 0.79 to 1. Land suitability classes that are not suitable generally have a marginally suitable parameter class where the value is very far from the potential conditions of life for wheat commodities. Meanwhile, the suitability class in the quite appropriate category has a fuzzy value range of 0.59 to 0.79. If calculated, the presence of this value is categorized as suitable to marginal land suitability with the limitations of several parameters, such as air temperature, rainfall, altitude, soil depth, and slopes which are therefore categorized as quite suitable.

The range of 0.79 to 1 is a range of values as a condition of very suitable and suitable land characteristics where the defuzzification value of very suitable land characteristics has a higher value. If the fuzzy value of the land characteristics required for each parameter has a high value, then the sum of the fuzzy values for each parameter reaches 1 so that it can be identified as a potential area for wheat farming (Baja *et al*., 2002b).

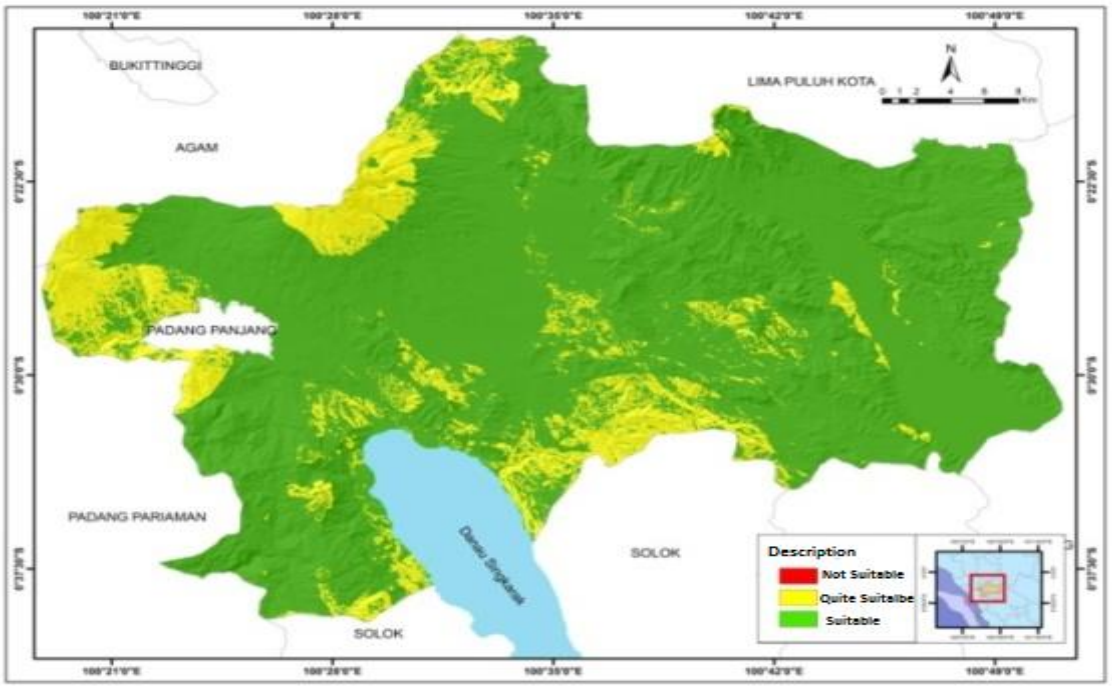

Figure 3. Wheatland Suitability Map

Figure 3 describes the land suitability index which is divided into three classes where each class has a different area where the land area with the appropriate class category is 111,131,886 m²/111,132 ha, the moderately suitable class is 20,239,468 m²/20,239 ha, and the unsuitable class is 137 m². Generally, the appropriate classes are on slopes < 8 with flat to undulating areas. This area is suitable for wheat farming because of the availability of water in the soil which can accelerate the root growth process. In the quite appropriate class, the land is usually on a slope of 8-15 to a bit steep. This kind of area will affect the growth and production of plants. Climate and altitude parameters are some of the parameters that cannot be improved, which if engineered will require a high cost to do so. Soil parameters and characteristics determine the availability of land for wheat commodity agriculture. One of the characteristics of the land that is difficult to improve is soil depth and soil texture. Soil depth in a land that is less than the appropriate land suitability requirement of <50 cm requires more costs to stockpile humus soil with a soil texture that is also very difficult to repair so it requires expensive costs to change the soil texture from coarse to fine. This explains that water also plays a major role in determining the opening or closing of stomata on leaves, so the availability of sufficient water will greatly determine the amount of assimilating gain of a plant (Thomas, 2013).

Land characteristics indicators greatly affect the plants that grow on it. This indicator explains the need and availability of nutrients in the soil to make the farming system run smoothly. Any type of land characteristics can be grown by various types of plants, however, the level of productivity of the plants planted will be different from the plants grown on certain land characteristics (Harding *et al*., 2021). The factors that affect the characteristics of the level land are drainage and soil texture. Drainage will affect the availability of groundwater. If the drainage is bad, then the level of root productivity will also be bad, and vice versa. This problem can be overcome by making drainage barriers and making improvements to the drainage system, for example by making drainage channels (Mottaleb *et al*., 2019). The condition of the fine soil texture and large pores will affect the strength of the soil in passing water quickly where the absorption capacity of plants will be inferior to the absorption capacity of the soil (Hochman *et al*., 2013). Meanwhile, the coarse texture with small pores can regulate the absorption of water into the soil and water on the surface and which is used by plants for photosynthesis. However, the depth of the soil cannot be changed because the limiting factor is generally contained a thick layer that inhibits and cannot be penetrated (Mann & Warner, 2017).

Characteristics of land on the soil surface such as soil CEC, base saturation, and resistant pH are elements that store nutrients that affect the fertility of a plant. This is often a problem that can be overcome by applying silica fertilizer, compound fertilizer, area fertilizer, lime, organic fertilizer, or insecticide to the soil surface (Silahturrohmah *et al*., 2019). Silicon plays a role in increasing antioxidant activity in plants which causes chloroplasts to not be damaged by heat stress. Indicators of temperature and rainfall are natural indicators that cannot be changed. If you want to overcome it, this will require expensive costs. In terms of temperature indicators, the determination of a suitable location for wheat plants is 12 ^{o}C – 23 ^{o}C with a cool area and not too hot to make wheat crop productivity grow according to its growth phase. This also applies to rainfall indicators where the rainfall required for

wheat farming is moderate rainfall, not high or low rainfall intensity (Kath et *al*., 2019).

The direction of development, in this case, is in the form of an idea that aims to realize the results of the land suitability index with land use. In carrying out development, not all types of land use can be used as development areas. One example of such land is a forest which has the purpose and designation to maintain the ecosystem in it, where it cannot be disturbed to be used as agricultural land development (Elaalem, 2013). Categories of land use that can be used for development are shrubs, plantations, and fields/fields. From the land suitability index, the land used for development is the appropriate category.

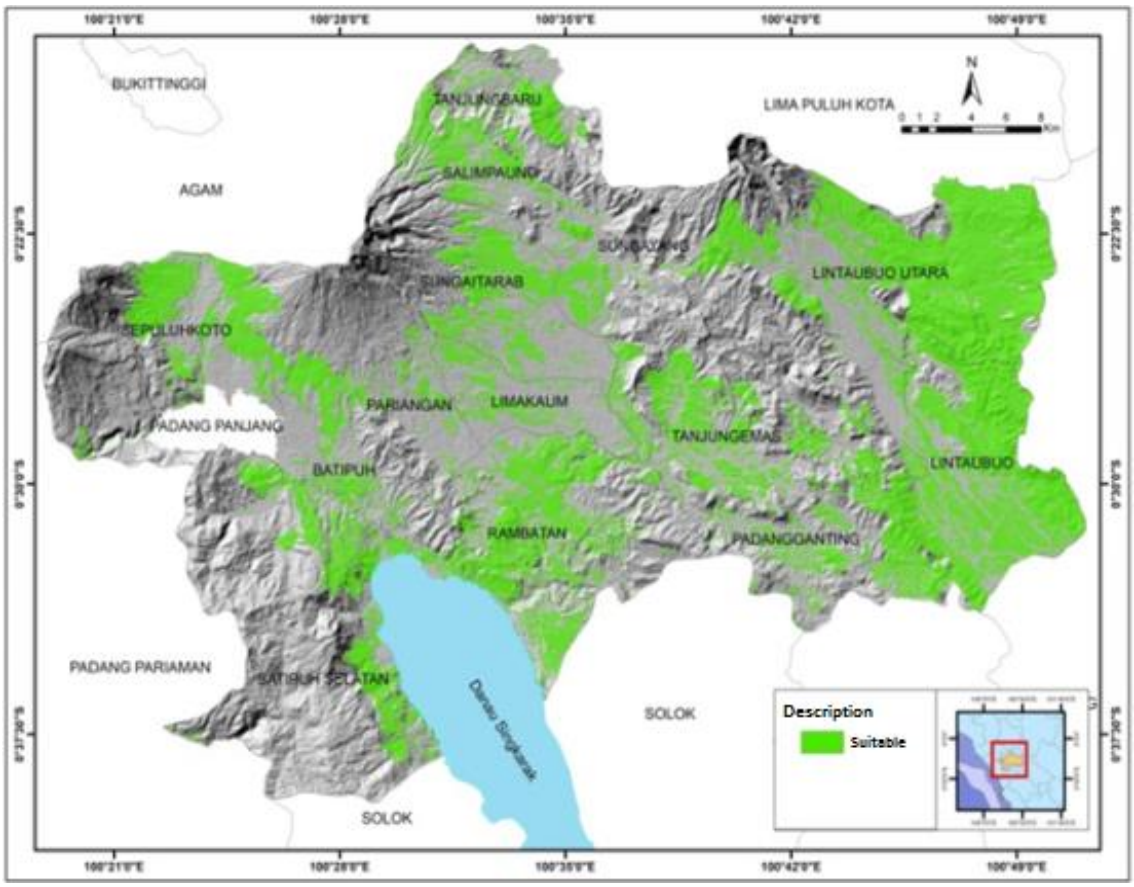

Figure 4. Directional Map for Wheat Farming Development

Commodity development directives are developed through consideration of commodity planning following the suitability of the land. In addition, the aspect of land availability will also be considered to determine whether the appropriate land status is available for commodity development.

Figure 4 explains that North Lintau Buo Sub-district has the widest potential for development area, while Pariangan District has the least development potential. Calculations related to a lot or a little development area cannot be separated from the use of land that is used as rice fields by the community because of previous habits where farming, some people choose to farm rather than do other livelihoods. This makes the type of use of paddy fields unable to be converted into wheat farming.

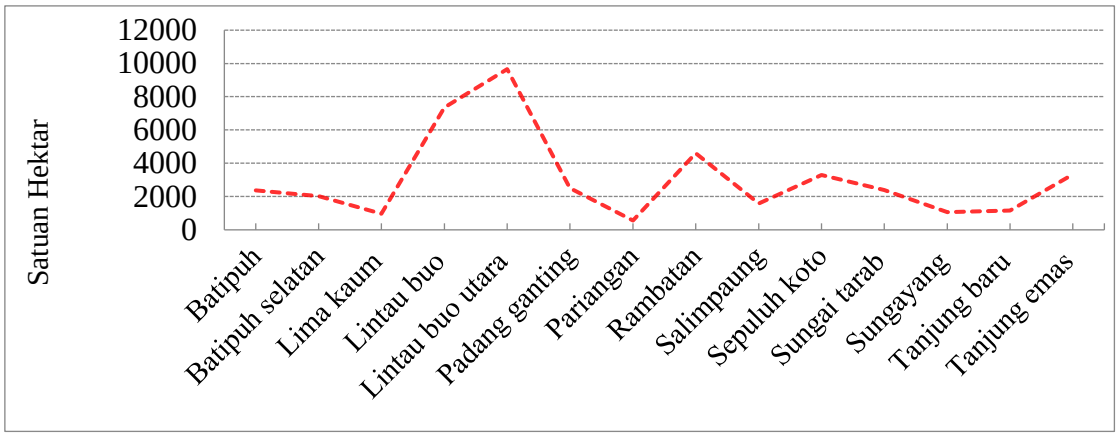

Figure 5. Graph of the Broad Direction of Wheat Development

Table 3. The Number of Suitable and Unsuitable in Each Sub District

Sub District	Suitable (ha)	Unsuitable (ha)
Batipuh	2.374	7.239
Batipuh Selatan	2.027	10.272
Lima Kaum	965	2.747
Lintau Buo	7.348	4.095
Lintau Buo Utara	9.657	9.392
Padang Ganting	2.513	5.273
Pariangan	561	4.701
Rambatan	4.599	5.387
Salimpaung	1.574	3.715
Sepuluh Koto	3.292	12.713
Sungai Tarab	2.392	5.935
Sungayang	1.062	6.164
Tanjung Baru	1.161	2.374
Tanjung Emas	3.333	8.218

Source: Secondary Data Analysis, 2020

Figure 5 describes the information on the Districts that have the potential for developing wheat agriculture. In Table 3, the land area in each of these sub-districts is described which reaches 42.873 ha and is spread over 13 sub-districts. The thirteen sub-districts consist of Batipuh sub-district with an area of 2,374 ha, South Batipuh sub-district covering an area of 2.027 ha, Lima Kaum sub-district covering an area of 965 ha, Lintau Buo sub-district covering an area of 7.348 ha, North Lintau Buo sub-district covering an area of 9.657 ha, Padang Ganting sub-district covering an area of 2.513 ha, Pariangan sub-district. covering an area of 561 ha, Rambatan sub-district covering an area of 4.599 ha, Salimpaung sub-district covering an area of 1.574 ha, Sepuluh Koto sub-district covering an area of 3.292 ha, Sungai Tarab sub-district covering an area of 2,392 ha, Sungayang sub-district covering an area of 1.062 ha, Tanjung Baru sub-district covering an area of 1.161 ha, and Tanjung Emas sub-district covering an area of 3.333 ha.

CONCLUSION

The results of the direction map for the development of wheat agriculture show that the results achieved in the potential development of wheat agriculture are 42.873 ha spread over 13 sub-districts with area of each sub Lintau Buo Utara sub-district covering an area of 9.657 ha, Lintau Buo sub-district covering an area of

7.348 ha, Rambatan sub-district covering an area of 4.599 ha, Tanjung Emas sub-district covering an area of 3.333 ha, Sepuluh Koto sub-district covering an area of 3.292 ha, Padang Ganting sub-district covering an area of 2.513 ha, Sungai Tarab sub-district covering an area of 2.392 ha, Batipuh sub-district has an area of 2.374 ha, South Batipuh sub-district is 2.027 ha, Salimpaung subdistrict is 1.574 ha, Tanjung Baru subdistrict is 1.161 ha, Sungayang subdistrict is 1.062 ha, and Lima Kaum subdistrict is 965 ha. The development of wheat-based agriculture has become a new commodity in Tanah Datar Regency, where it is hoped that large regional opportunities will be able to bring up potential that can reduce the number of wheat imports from outside. The results of the land suitability analysis and development directions can be the latest information for farmers in looking for opportunities for the commodities to be planted in order to keep up with market demand.

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