Mapping Agricultural Land Potential Based on the Geographic Information System (GIS) in Muna Regency, Southeast Sulawesi Province

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Abstract: This research aims to determine the potential of agricultural land in Muna Regency based on parameters, namely level of slope, lithology, soil type, rainfall, and level of flood vulnerability. This research was carried out in Muna Regency, Southeast Sulawesi Province, for four months, from February to May 2023. The data collected consisted of secondary data obtained from agencies related to this research and primary data obtained through surveys and direct observation by taking coordinate points for each parameter observed with the help of GPS. The data analysis technique uses overlay analysis, namely overlapping land potential index parameter maps using ArcMap software. The research results show that the area of agricultural land in Muna Regency is 205,769 hectares, distributed over three land potential index classes, namely, the medium land potential class with 50,538 hectares, or 24.6%. second: low land potential class covering 149,345 hectares, or 72.6%; and third: very low land potential class covering 5,886 hectares, or 2.9%. Based on this percentage data, the potential for land for agricultural development in Muna Regency is in the medium potential category. Thus, the actions or solutions needed to increase agricultural productivity are (a) spatial planning of conservation farming systems; (b) development of crop and livestock integration; and (c) location-specific commodity selection.

Key-Words: Agriculture, Land potential, GIS

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1 Introduction

Land, a place for humans, is the basis for developing various activities that must be managed and directed toward their best use [1]. Land includes all natural resources used for human activities and to meet their basic needs [2,3]. Geographically, land can mean a part of the earth's surface with certain characteristics, which include soil, geological layers, hydrology, biosphere, atmosphere, and plant and animal populations resulting from human activities in the past, currently, to a certain level [4,5]. The land is a physical environment that includes climate, land relief, hydrology, and vegetation which to a certain extent will influence land use capabilities [6]. The land has many functions, including production function, biotic environmental function, climate control function, surface water function, storage function, waste, and pollution control function, living space function, heritage and storage function, and spatial connecting function [7,8,9]. The land use plan is one of the new reconstruction tools [10]. Law Number 41 of 2009 concerning the protection of sustainable agricultural land, explains that the protection of food agricultural land is an inseparable part of regional spatial planning. Protection of food agricultural land must be carried out in several ways, such as by establishing food agricultural areas. According to [11] Sustainable Food Agricultural Land is a field of agricultural land that is determined to be protected and developed consistently to produce staple food for national food self-reliance, security, and sovereignty.

The community needs information regarding the land's potential to carry out the process of assessing and managing the land as closely as possible according to the condition and capabilities of the land. One way that can be done to support this is by using a land potential index. Determining a land potential index can help determine the distribution of land potential based on land potential index classes. Using the land potential index on land can describe the ideal condition and is suitable for agricultural land needs so that it can produce quality crops and have high economic value.

Muna Regency has quite a large area of agricultural land, namely 128,363 ha of the total area of Muna Regency [12]. However, Muna Regency is not free from land problems, such as converting agricultural land to non-agricultural land resulting from population growth and expanding investment. The existing population growth factor significantly contributes to land problems in the Muna Regency area. Every year, population growth in Muna Regency continues to increase. Of the 22 sub-districts in Muna Regency, only 5 sub-districts use the land for agricultural purposes [13].

Mapping land potential becomes more efficient if presented spatially (spatial variability). With mapping, the boundaries of each potential land and its distribution pattern can be known with certainty. Land Potential Mapping, if carried out manually, requires more time, energy, and costs [14]. Therefore, we need the most efficient method, namely using the help of a geographic information system (GIS). [15] explained that GIS can create models that provide descriptions, explanations, and estimates of factual conditions.

2 Problem Formulation

The tools used in this research activity are a camera, GPS, computer/laptop, ArcGIS 10.4 and the materials used in this research activity are a slope map of Muna Regency, a lithology map (rock type) of Muna Regency, a map of soil types in Muna Regency, Muna Regency rainfall map, Muna Regency disaster (flood) vulnerability map, Muna Regency administrative map to find out the location of the research area.

The technique used to map land potential in Muna Regency is the overlay technique. This is a duplication technique for two or more maps that uses geographic information system technology to retrieve new information. [16] explained that GIS analysis uses an overlay of parameters including slope, lithology, soil type, rainfall, and disaster areas (floods). The land potential is expressed by a value called the Land Potential Index (IPL), the amount of which is determined by evaluating 5 rational formula calculation factors as presented in Equation 1 [17,18]:

Formula: IPL = (R+L+T+H).B ...……….(1)

Information:
IPL = Land Potential Index
R = slope factor value
L = lithology factor value
T = soil type factor value
H = hydrological factor value
B = disaster vulnerability factor value or barrier

The Land Potential Index class is divided into 5 classes, namely: very low, low, medium, high, and very high. Land Potential Index Classes can be classified after all total values are known. Classifying IPL classes is [19]:

$$\text{IPL} = \frac{\text{The Highest Score} - \text{The Lowest Score}}{5}$$

The following is a table for assessing the value of each map parameter needed to create a land potential index map:

Table 1. Parameters and Indicators for Measuring the Agricultural Land Potential Index, in Muna Regency, Southeast Sulawesi Province

No	Parameters/Indicators	Value
A.	**Slope (%)**	
1	Flat– slope (0 – 5)	5
2	Wavy (5 – 15)	4
3	Low hills (15 – 25)	3
4	Hilly (25 – 45)	2
5	Mountainous (> 45)	1
B.	**Lithologi Type**	
1.	Alluvium/colluvium	10
2.	Pyroclastic rocks	8
3.	Limestone	5
4.	Massive igneous rock	5
5.	Coarse-grained clastic sediments	5
6.	Calcareous and metamorphic sediments	3
7.	Fine-grained calstic sediments	2
C.	**Soil Type**	
1	Brown Alluvial, Mediterranean	5
2	Andosol, Podsolik	4
3	Gley Humus, Renzina,	3

No	Parameters/Indicators	Value
4	Grumusol, Latosol, Alluvial Gray	2
5	Regosol, Litosol,Organosol	1
D.	**Rainfall (mm/year)**	
1	>4.000	4
2	3.000-4.000	3
3	2.000-3.000	2
4	1.000-2.000	1
E.	**Flood Vulnerability**	
1	Free flooded	1,0
2	Rarely flooded	0,8
3	Sometimes flooded	0,7
4	Often flooded	0,6

Source: [17,19,20,21]

Based on the value of each parameter in each indicator of agricultural land potential, the class of land potential index values for agricultural land use can be determined based on the magnitude of the index value as presented in Table 2 below:

Table 2. Class and Land Potential Index Value, in Muna Regency, Southeast Sulawesi Province

No	Land Potential Index Class (IPL)	Value Range IPL
1	Very high	32 - 40
2	High	24 - 31,9
3	Moderate	16 - 23,9
4	Low	8 - 15,9
5	Very low	0 - 7,9

Source: [17,19,20]

3 Problem Solution

3.1 Land Potential

3.1.1 Hillside

Based on the analysis of land potential index parameters, most of the Muna Regency area is on a slope of 0-5% of the 22 (twenty-two) sub-districts, the area with the largest area on this slope is Tongkuno District, namely 26.119 hectares and the lowest is in Duruka District, 653 hectares with a total slope area of 123.900 hectares. The most extensive slope of 5 – 15% is in Tongkuno District at 8.557 hectares and the lowest is in the southern Tongkuno District area at 288 hectares with a total slope area of 61.391 hectares. The area with a slope of 15 – 25% is the largest in Pasir Putih District with 2.842 hectares and the lowest is in Kabangka District with 0,12 hectares with a total slope area of 13.570 hectares. Slope slopes of 25 – 45% are only found in 14 sub-districts and the one with the widest slope is in Pasir Putih District at 1.220 hectares and the lowest is in Towea District at 0,09 hectares with a total slope area of 6.810 hectares. The slope of Muna Regency can be seen in Table 3.

Table 3. Downhill Slope in Muna Regency

No.	Classification	Slope (%)	Wide (hectares)	Percentage (%)
1	Flat– slope	0 - 5	123.900	60,21
2	Wavy	5 -15	61.391	29,83
3	Low hills	15 - 25	13.570	6,59
4	Hilly	25 - 45	6.810	3,31
5	Mountainous	>45	99	0,05
	Total		**205.769**	**100,00**

Source: Muna Regency Slope Analysis Results, 2024.

3.1.2 Lithological Factors

If you look at these lithological parameters, Muna Regency has 5 types of rock out of 7 grades that belong to this parameter, namely alluvium, limestone, coarse-grained clastic sediment, metamorphic calcareous sediment, and fine-grained clastic sediment. Based on the analysis results obtained, they are in Table 4.

Table 4. Muna Regency Lithology Data

No	The Rock Type	Wide (hectares)	Percentage (%)
1	Alluvium/colluvium	15.207	7,39
2	Pyroclastic rocks	0	0
3	Limestone	148.303	72,07
4	Massive igneous rock	0	0
5	Coarse-grained clastic sediments	39.806	19,35
6	Calcareous and metamorphic sediments	125	0,06
7	Fine-grained calstic sediments	2.328	1,13
Total		**205.769**	**100,00**

Source: Results of Rock Type Analysis for Muna Regency, 2024

Based on Table 4, it is known that of the total area of Muna Regency, 205,797 hectares, the most dominant rock type is limestone with the highest value, namely 5, which is the most extensive rock with an area of 148.303 hectares (72%). The largest area is in Tongkuno District with an area of 35.736 hectares and the smallest area is in Batukara District with an area of 44 hectares. Muna Regency also has alluvium rock types, covering an area of 15.207 hectares (7%) of the total area of Muna Regency. The subdistrict that has the most extensive type of alluvium rock is in Parigi District covering an area of 3.093 hectares and the smallest is in Batalaiworu District covering an area of 2 hectares. Coarse-grained clastic sediment with a grade of 5 and a total area of 39.806 hectares (19%) Muna Regency. The area with the largest area of this type of rock is in Maligano District, 6.631 hectares, and the one with the smallest area of coarse-grained clastic sedimentary rock is in Pasikolaga District, covering an area of 301 hectares. The calcareous and metamorphic sediments with grade 3 in the Muna Regency area are in the Kanpatoreh Ultrabasic Complex covering an area of 125 hectares (0.06%). The only area that has calcareous and metamorphic sedimentary rock types is in Maligano District covering an area of 125 hectares. Fine-grained, clastic sedimentary rock type with grade 2, area of 2.328 hectares (0.1%) located in Towea District.

3.1.3 Soil Type Factors

Classification of soil types to determine land potential based on the land potential index shows that of the 5 (five) distribution of soil types in Muna Regency, only 3 of them are classified, namely Mediterranean soil type 5, organosol and lithosol 1 and cambisol and brown podzolic. (based on the naming of soil classifications according to the 1978/1982 modification) grade 4. The results of this analysis are in Table 5 which shows the distribution of rock types after being classified in the soil type parameters of the land potential index. This considers the kinds of rock formations available and then identifies them based on texture class. The classifications included in the Muna Regency land potential index assessment are in Table 5.

Table 5. Muna Regency Land Classification Based on Land Potential Index

No	Soil Type	Texture Class	Wide (hectares)	Percentage (%)
1	Regosol, Litosol,Organosol	Rough	35.340	17
2	Andosol,Podsolik	Quite rough	120.533	59
3	Brown Alluvial, Mediterranean	Medium	49.896	24
4	Gley Hummus, Renzina	Quite delicate	0	0
5	Grumusol, Latosol, Alluvial Gray	Delicate	0	0
Total			**205.769**	**100**

Source: Muna Regency Soil Type Analysis Results, 2024

The analysis results in Table 5 show that the highest score with a value of 5 is owned by the medium soil texture class which is in the Mediterranean soil type area covering an area of 49.896 hectares (24%) of the total area of Muna Regency of 205.769 hectares. Muna Regency has 16 sub-districts that have this type of land. Among these sub-districts, the area that has a dignity value classification of 5 is the largest in Tongkuno District, covering an area of 9.228 hectares and the smallest is in Kontukowuna District, covering an area of 532 hectares. The type of land that covers most of the Muna Regency area is land with a valuable classification of 4 according to Table 5 with a total land type area of 120.533 hectares. This classification includes cambisol (brown podzolic) soil types covering an area of 111.574 hectares and podzolic soil covering an area of 8.959 hectares. Of the total sub-districts in Muna Regency, the area that has the largest value of 4 is in Tongkuno District covering an area of 21.145 hectares and the smallest is in Duruka District covering an area of 17 hectares. The largest area of Muna Regency, which has a value of 1 (litosol and organosol soil types), is in Tongkuno District covering an area of 5.361 hectares and the smallest is in Marobo District covering an area of 20 hectares.

3.1.4 Rainfall Factors

The results of the Muna Regency rainfall analysis show that from the hydrological parameters of rainfall, Muna Regency is only included in two classes, namely rainfall with an intensity of 1.000–2.000 mm/year, which has a value of 1 covering an area of 136.966 hectares with a percentage of 67%. Rainfall with an intensity of 2000–3000 mm/year which has level 2 covers an area of 68.803 hectares or 33% of the total area of Muna Regency. Details of the analysis results can be seen in Table 6.

Table 6. Muna Regency Rainfall 2024

No.	Rainfall (mm/Year)	Wide (hectares)	Percentage (%)
1	> 4.000	0	0
2	3.000 – 4.000	0	0
3	2.000 – 3.000	68.803	33
4	1.000 – 2.000	136.966	67
	Total	**205.769**	**100**

Source: Muna Regency Rainfall Analysis Results, 2024

3.1.5 Flood Disaster Vulnerability Factors

Mapping land with the potential for flooding is an important part of agricultural development. Parts of land that are classified as slightly flood-prone or even prone to flooding cannot be developed as agricultural land. Based on the results of the analysis of the classification of flood disaster vulnerability in Muna Regency, it can be seen in Table 7.

Table 7. Muna Regency Flood Disaster Vulnerability

No	Flood Disaster Classification	Flood Vulnerability Class	Wide (hectares)	Percentage (%)	Value
1	Free flooded	Not prone to flooding Prone to flooding	154.603	75	1,0
2	Rarely flooded	Slightly prone to flooding	0	0	0,8
3	Sometimes flooded	Somewhat prone to flooding	43.586	21	0,7
4	Often flooded	Prone to Flooding	7.581	4	0,6

Source: Results of Flood Vulnerability Analysis for Muna Regency, 2024

Analysis of Table 7 shows that the level of flood vulnerability is dominated by areas that are not prone to flooding. Based on data on the distribution of areas not prone to flooding, which has a value of 1,0, it covers an area of 154.604 hectares (75%) of the total area of Muna Regency which is 205.769 hectares. The sub-district that has a level that is not prone to flooding is in Tongkuno District covering an area of 35.732 hectares and the smallest sub-district that has a level that is not prone to flooding is in Napabalano District covering an area of 32 hectares. Areas with a slightly flood-prone level which has a rating of 0,7 based on the analysis results, are spread across 12 sub-districts in Muna Regency with a total area of 43.586 hectares (21%) of the entire area of Muna Regency. The area with largest area classified as somewhat prone to flooding is in Pasir Putih District with an area of 11.347 hectares and the lowest is in Lasalepa District with an area of 1.052 hectares. The level of flood-prone areas with a value of 0,6 in Muna Regency is not very large, only 7.581 hectares (4%) of the entire area of Muna Regency. Areas prone to flooding are in two sub-districts, namely Lasalepa District and Napabalano District. The sub-district with the highest flood area level is Lasalepa District covering an area of 6.936 hectares and the smallest is Napabalano District covering an area of 1.052 hectares.

3.2 Land Potential Index Class (IPL)

The land potential index class (IPL) in Muna Regency is divided into 3 classes, namely medium, low, and very low land potential. These results are obtained by scoring each value of the supporting and limiting parameters of the land potential index. Muna Regency land potential index classes are presented in Table 8.

Table 8. Land Potential Index (IPL) Class of Land Potential for Muna Regency in 2024

No.	Class of Land Potential	IPL Value	Wide (hectares)	Percentage (%)
1	Very high	32 - 40	0	0
2	High	24 - 32	0	0
3	Medium	16 - 24	50.538	24,6
4	Low	8 - 16	149.345	72,6
5	Very low	0 - 8	5.886	2,9
Total			**205.769**	**100,0**

Source: Potential Analysis, 2024.

The Muna Regency area which has the largest area in the medium land potential class with a class interval of 16–23,9 is in Tongkuno District covering an area of 18.338 hectares and the smallest is in the Kabangka District area covering an area of 174 hectares. The area of Muna Regency which is in the medium potential class is 50.538 hectares (24%) of the entire area of Muna Regency. In general, areas in the medium land potential class have supporting factors such as flat slopes with a score of 5 and flood vulnerability with a classification of not prone to flooding with a score of 1, which means that the inhibiting factors in this parameter do not affect other supporting parameters. The Muna Regency area which is in the low potential class covers an area of 149.345 hectares (72,6%) the area with the largest land area in the low potential class is in Tongkuno District covering an area of 25.760 hectares and the smallest is in Duruka District covering an area of 753 hectares with a scoring interval of 8 – 15,9.

Land potential assessment based on the land potential index which is in the very low land potential class only covers several areas of Muna Regency. Measurement or assessment by knowing the land potential index value can provide an idea of which areas have high or low potential. The higher the potential value of the land obtained, the higher the potential of the land [22,18]. The total area in this class is 5,886 hectares (2.9%) of the entire area of Muna Regency. The largest land potential index class with very low potential is in Pasir Putih District with an area of 2094 hectares and the lowest is in Marobo District. Most of the areas classified as very low land potential class have a value of 0.6, which means they are prone to flooding and have a slope value of 15%–45%, from hilly to mountainous. The following is a land potential index map for Muna Regency, which can be seen in Figure 1 below.

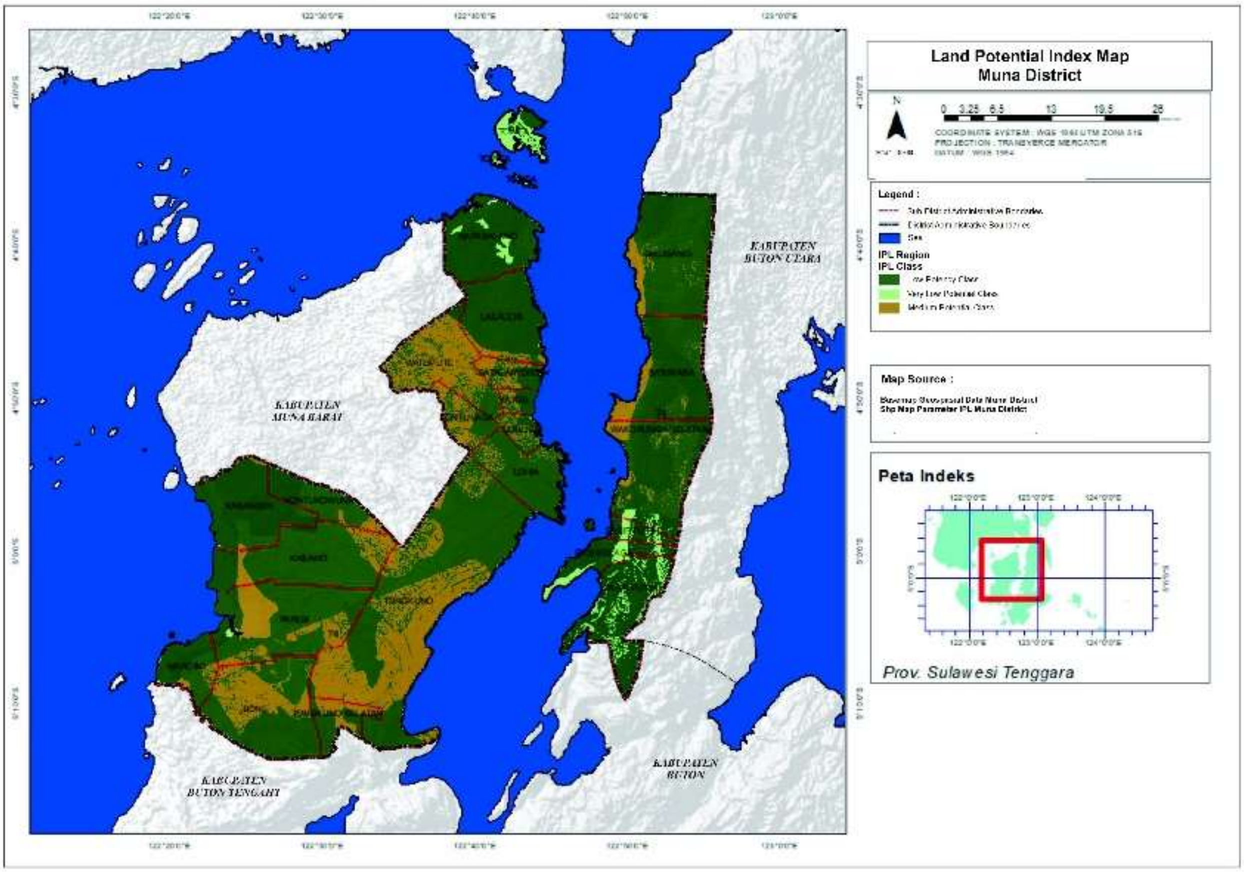

Figure-1 Muna Regency Agricultural Land Potential Map (Source: Muna Regency Geospatial Data Basemap, Muna Regency IPL Parameter Map SHP, 2024)

The distribution of agricultural land potential index classes per sub-district of Muna Regency is shown in table 9 as follows:

Table 9. Distribution of Agricultural Land Potential Index Classes per Su-District of Muna Regency

No	Sub-District	Land Potential Index (hectares)			Wide (hectares)
		Medium Potential Class	Low Potential Class	Very Low Potential Class	
1	Batalaiworu	1.004	1.267	0	2.271
2	Batukara	2.289	4.650	0	6.939
3	Bone	4.554	8.455	0	1.3009
4	Duruka	399	753	0	1.152
5	Kabangka	174	9588	0	9.762
6	Kabawo	2.780	17.714	0	20.494
7	Katobu	459	829	0	1.288
8	Kontu Kowuna	259	6.797	0	7.056
9	Kontunaga	2.603	2.485	0	5.088
10	Lasalepa	637	10.148	7	10.792
11	Lohia	646	4.335	0	4.981
12	Maligano	1.377	8.432	0	9.809
13	Marobo	376	3.746	15	4.137
14	Napabalano	0	10.251	296	10.547

No	Sub-District	Land Potential Index (hectares)			Wide (hectares)
		Medium Potential Class	Low Potential Class	Very Low Potential Class	
15	Parigi	3.546	8.730	100	12.376
16	Pasi Kolaga	0	3.805	1.072	4.877
17	Pasir Putih	0	6.859	2.094	8.953
18	Tongkuno	18.338	25.760	-	44.098
19	Tongkuno Selatan	2.523	3.203	0	5.726
20	Towea	0	9.70	1.932	2.902
21	Wakorumba Selatan	2.185	6.945	370	9.500
22	Watopute	6.389	3.623	-	10.012
	Total	**50.538**	**149.345**	**5.886**	**205.769**

Source: Data Analysis, 2024

3.3 Alternative Measures for Marginal Land Use

The marginal land referred to in this study consists of 3 (three) categories, namely: land with a medium, low, and very low land potential index with a total area of 205,769 hectares spread over several areas in Muna Regency, Southeast Sulawesi Province. Alternative actions or solutions are needed to increase agricultural productivity, namely:

3.3.1 Spatial Planning for Conservation Farming Systems

One strategy for optimizing the use of land resources is the spatial planning of conservation farming systems. Criteria to be considered include land slope, depth of solum, soil erodibility, and prospects for commodities to be cultivated. On land with a slope of <15%, the proportion of annual plants must be greater than annual plants. On land slopes of 15–30%, the ratio of annual and annual plants is relatively balanced, while on land with a slope of 30-45% the proportion of annual plants is greater than annual plants, and on land slopes >45%, all annual plants are planted in combination with legume plants.

Furthermore, [23] stated that the arrangement of annual plants (horticulture, plantations, wood) is planted parallel to the contour with a distance of +1 meter between the planting hole and the edge of the terrace, with the same type of plant in the contour row, while in the other contour rows, other types of annual plants are planted. The location of plants in one row with another must consider the width of the plant canopy so that it does not cover the land below, especially on terraces with narrow cultivation areas.

Plant spacing for annual plants depends on the slope of the land. The arrangement of plant rows can be started from the base of the terrace or +50 cm from the edge of the terrace. Plants strengthening the terrace, such as grass and ground cover legumes double as conservation plants and can also be used as animal feed or firewood. Grass is planted on the side of the terrace + 20 cm from the edge of the terrace, while legume trees are planted on the side of the terrace under the grass.

3.3.2 Development of the Crop-Livestock System (CLS)

According to [23], increasing productivity on marginal land requires an assembly of location-specific integrated management technologies, including (a) the existence of location-specific superior varieties that are acceptable to farmers and do not hurt nature conservation; (b) specific rational fertilization location, which refers to the nutrient content of the soil and plant needs; (c) the addition of organic fertilizer, due to the lower organic matter in the soil; and (d) integrated plant management.

Furthermore, according to [24,23], to meet the need for organic fertilizer on marginal land and provide additional income for farmers, farmers are encouraged to cultivate livestock (cattle and goats) to produce organic fertilizer at low cost through the application of the Crop-Livestock System (CLS). In the development of ruminant livestock (cattle and goats), the problems often faced by farmers on marginal land are related to the availability of forage sources, especially during the dry season. It is not uncommon for breeders to have to sell other livestock to cover the cost of purchasing forage. Another condition is that there are frequent disputes or quarrels between village residents because grazing livestock destroys their neighbors' crops. Apart from that, theft of grass and tree leaves during the dry season increases and often occurs in areas around plantations or forestry areas, so the presence of livestock is felt to be detrimental to environmental sustainability. Research results show that around 70% of livestock productivity is influenced by environmental factors, while genetic factors only influence around 30%. Among these environmental factors, the feed aspect has the greatest influence, namely around 60%. This shows that even though the genetic potential of livestock is high if the feed does not meet the quantity and quality requirements, high production will not be achieved. Apart from its large influence on livestock productivity, the feed factor is also the largest production cost in the livestock business. The cost of this feed can reach 60–80% of the total production costs. Thus, producing feed is not only required to achieve quality aspects, but what is more important is producing feed that is economical, cheap, and affordable to the farmer's capabilities [25].

3.3.3 Selection of Location-Specific Commodities

According to Ernawanto and Sudaryono (2005) [27], the criteria that need to be considered in selecting specific commodities that are suitable for development are: have a small risk; the cultivation technology is relatively easy and requires low input; have a good chance of being marketed; are suitable for intercropping with food and horticultural crops; products' The product is long-lasting so that it can provide a long marketing period, as well as fast production, and is by the interests and desires of farmers. Selecting the level of agroecological suitability of a commodity requires four types of input, namely: soil characteristics, topography, climate, and plant growing conditions.

4 Conclusion

Based on the results and discussion, the following conclusions can be drawn:

1. Based on the land potential index, Muna Regency is divided into 3 classes of land potential, namely the medium class of 50.538 hectares or 24,6%. The low land potential class is 149.345 hectares or 72,6%. The land potential class is very low, covering an area of 5.886 hectares or 2,9% of the total area of Muna district of 205.769 hectares.
2. Muna Regency's agricultural land potential is very limited if viewed from the land potential index class parameters, so only certain types of crops can be utilized with maximum management to support the productivity of these crops.
3. Alternative actions or solutions needed to increase agricultural productivity in Muna Regency, namely (a) spatial planning of conservation farming systems; (b) development of crop and livestock integration; and (c) location-specific commodity selection.

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