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Ecological Spatial Model of Maize (Zea Mays L.) In Wanggarasi Sub-District, Pohuwato Regency – Gorontalo Province, Indonesia

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Abstract

This research was conducted in Wanggarasi Sub-district, Pohuwato Regency, Gorontalo Province, specifically in Bohusami Village and Bukit Harapan Village. The objectives of this study were (1). To analyze the biophysical land conditions (land capability, land suitability, land carrying capacity, production), as well as the social conditions of the community, particularly population pressure, which can support a sustainable maize land-use system. (2). To develop an appropriate model for optimizing sustainable maize cultivation in Wanggarasi Sub-district, Pohuwato Regency, Gorontalo Province. The method used was land evaluation with a land unit approach. Sampling locations were determined using stratified random sampling, considering land units at the study sites—namely, slope, landform, and land use. The preparation of land capability maps, land suitability maps, and land optimization maps was carried out through interpretation of RBI maps, administrative maps, land unit maps, and LCLP analysis results. Meanwhile, maps of land carrying capacity, population pressure, and production were developed based on RBI maps, administrative maps, and secondary data. Data analysis was conducted using ecological spatial analysis with Geographic Information System (GIS) and supporting socio-economic data were analyzed descriptively. The research results showed that the study area is dominated by land with low optimization categories (R), expressed through the functional formula: ***OPT (R) = ƒ (KL (III, IV) + KS (S3, N1) + DDL(R) + P(R) + TP(R))****. The models and strategies for optimizing land in the low category (R) can be implemented through: (1) Identifying land units combining dry fields and rainfed areas that ensure the availability of land with high (T) or moderate (S) optimization categories, with a minimum area approximately equal to that of land units categorized as moderate or low in the sub-district. (2) Identifying land-use combinations that can yield production categorized as high (T) or moderate (S) land optimization by converting part of the coconut*

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plantation area—particularly those needing replanting—into dryland maize cultivation. Additionally, seeking land-use combinations that ensure the availability of land areas with moderate optimization category (S), such as mixed gardens and dry fields.

Keyword: Optimization, Ecological Spatial Model, Pohuwato Regency, Gorontalo Province, Indonesia

INTRODUCTION

Wanggarasi Sub-district in Pohuwato Regency is one of the key centers for maize development in Gorontalo Province. This is based on the characteristic that the third largest area for maize cultivation in the province is located in this sub-district. In addition, it also holds the position as the third highest maize-producing area in the region. According to BPS (Central Bureau of Statistics) data from 2010, the area planted with maize in Pohuwato Regency reached 82,432 hectares (63.36%). Furthermore, from the total area cultivated with maize in 2010 (82,432 ha or 63.36%), there remained 47,661 hectares or 36.64% of land that had not yet been optimized for maize cultivation.

Background

Wanggarasi Sub-district is a region in Pohuwato Regency, Gorontalo Province, with a maize cultivation area of 5,251 hectares out of the total 82,432 hectares in the regency. Land use change in this area has accelerated significantly over the past seven years, shifting from agricultural land to residential areas. Efforts to preserve the potential maize production, which continues to diminish due to land conversion into residential use, are an important and relevant subject of study.

Distinctiveness of This Research

The primary distinction of this research compared to the studies presented in Table 1 lies in its use of more complex parameters, encompassing both biophysical parameters (land capability, land suitability, land carrying capacity, and production) and social parameters, specifically population pressure.

In light of the above, there is a pressing need for an ecologically-oriented strategy to optimize the use of maize agricultural land. Therefore, a comprehensive study is required—integrating land capability, land suitability, land carrying capacity, population pressure, and maize production potential—to effectively manage and optimize maize cropping patterns.

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Research Problems

1. The distribution of land with land capability classes I to IV in Wanggarasi Sub-district, which should be suitable for seasonal crops, has not been fully optimized for maize cultivation.
2. The area of land utilized for maize cultivation in Wanggarasi Sub-district in 2010 was 5,251 hectares. Thus, there remains a significant portion of land that has not been optimized compared to the available potential land area of 130,093 hectares.

Research Questions

1. What are the land capability, land suitability, land carrying capacity, maize production, and population pressure conditions that can support the optimization of maize agricultural land in Wanggarasi Sub-district?
2. What models and strategies can be implemented to ensure the sustainable optimization of maize cultivation land in Wanggarasi Sub-district?

Research Objectives

1. To analyze land capability, land suitability, land carrying capacity, maize production, and population pressure that can support the optimization of maize agricultural land in Wanggarasi Sub-district.
2. To develop appropriate models and strategies for optimizing maize land use and to implement those strategies in alignment with sustainable agricultural land-use systems.

LITERATURE REVIEW

Theoretical Framework

The following section outlines the theories applied in this study:

1. Theory of Land Evaluation
   According to Ramlan et al. (2023), land evaluation integrates soil survey approaches, spatial analysis, and agroecological criteria to determine the degree of land suitability for specific commodities both quantitatively and qualitatively.
2. Theory of Land Capability and Suitability for Maize (Zea mays L.)
   Arfiansyah (2024) states, *"Land suitability analysis is a multi-criteria assessment process to determine land feasibility for particular purposes—agriculture, settlement, conservation, or infrastructure."*

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3. Theory of Land Carrying Capacity
   Kondong et al. (2025) define *land-carrying capacity* as the ability of a region to support human life and economic activities without causing environmental degradation. According to Miswar et al. (2023), land carrying capacity is the ability of agricultural land to support human livelihoods, particularly in fulfilling regional food needs.
4. Theory of the Spatial–Ecological Approach
   Fu et al. (2025) explain that this paradigm focuses on the reciprocal relationship between spatial patterns and ecological processes, as well as how both influence ecosystem services and landscape sustainability. This approach also emphasizes the integration of spatial and temporal data in ecosystem analysis, supported by technologies such as Geographic Information Systems (GIS) to aid in evidence-based decision-making.
5. Theory of Population Pressure
   Khatun et al. (2023) discuss strategies for managing population pressure to achieve sustainable development, emphasizing the importance of inclusive policies and the integration of technology to address demographic challenges. Henderson et al. (2024) developed methods to assess the impacts of population growth and climate change on global economic output. Their study indicates that population growth may lead to a greater decline in income than scenarios of extreme climate change.
6. Geographic Information Systems (GIS) Approach
   This study employs a Geographic Information System (GIS) approach. Lukman et al. (2025) emphasize that *"GIS facilitates the matching of land suitability levels with maize growth requirements through spatial data analysis, manipulation, and presentation."* Nainggolan et al. (2025) highlight that *"GIS enables visualization and predictive modeling of actual regional conditions, thus supporting data-driven decision-making for land optimization."*
7. Maize Land Optimization
   To optimize land use in Pohuwato Regency, particularly in Wanggarasi Sub-district, a land management optimization model must be formulated based on the biogeophysical conditions of the research area.
8. Conceptual Framework
   All variables that serve as indicators in the ecological spatial model for land optimization are processed using a Geographic Information Systems approach. In this study, the conceptual framework is illustrated in a flowchart diagram presented in Figure 1.

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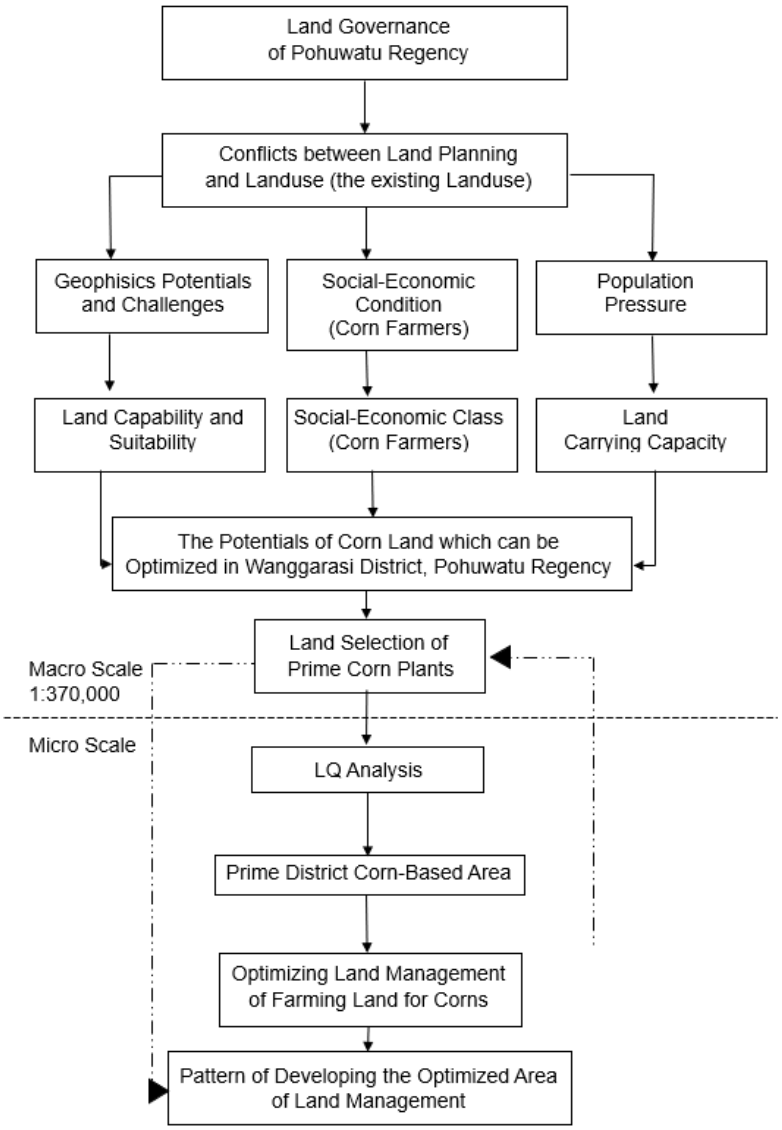


Figure 1. Conceptual Framework of the Research

Based on the flow diagram, the object of this study at the micro scale is the agricultural land owned by farmers in Wanggarasi Sub-district, specifically in Bohusami Village and Bukit Harapan Village. Wanggarasi Sub-district consists of several villages, and through a maize-based selection process, Bohusami and Bukit Harapan were chosen as the research locations. The selection of base areas was conducted using the benchmark of maize production levels in the respective regions.

Moreover, the selection focused on land areas with land-use compositions that are

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assumed *not* to be convertible into agricultural land for maize, such as forests, mangroves, settlements, and swamps/fishponds. In other words, these land-use types were excluded from the analysis. In contrast, land-use types such as dry fields, mixed gardens, *alang-alang* grasslands, shrubs, coconut plantations, rice fields, and thickets were included in the analysis.

METHOD

Location and Time of Research

This research was conducted in Wanggarasi Sub-district, focusing on Bohusami Village and Bukit Harapan Village, Pohuwato Regency. This area was selected as the research site for the following reasons: (1). **Geographical Importance**: Wanggarasi is the third-largest maize-producing sub-district in Pohuwato Regency. The regency itself is one of the 13 main maize production centers, contributing 25,492.32 tons of maize from the total regency production of 397,237.56 tons in 2010. This figure accounts for 44.93% of the total maize production in Gorontalo Province, which reached 753,598 tons. (2). **Regional Typology**: The typology of Wanggarasi Sub-district is quite diverse in terms of geography, natural resources, administrative boundaries, population, land ownership, income levels, and human resources (e.g., education levels). (3) **Strategic Development Zone**: The land in this sub-district lies within the strategic development zone for maize, officially designated as a maize base area in the spatial planning of Pohuwato Regency.(4). **Representative Village Selection**: The two selected villages—Bukit Harapan and Bohusami—represent areas with relatively low maize production that can be optimized. These villages reflect variations in landform, slope, and land use, making them ideal for representing the diversity of land units within the sub-district. (5). **Land Suitability**: Wanggarasi Sub-district possesses land characteristics that meet the minimum requirements for maize cultivation.

Table 1. Maize Base Areas Based on Production Potential

Sub-district	Production (tons)	Production Leve
Wangarasi	25492,32	Low
Patilangio	57574,5	Medium
Randangan	50993,72	Medium

Source: Department of Agriculture, Pohuwato Regency, 2010

Based on Table 1, the maize base area with low production is Wanggarasi Sub-district. In determining the research location, in addition to considering the production aspect, the

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population size was also taken into account. Therefore, a **Location Quotient (LQ)** analysis was employed. The results of the LQ analysis are presented in Table 3.2.

Table 2. The selection of corn-based regency based on LQ analysis

No.	Districts	Corn Production	Population	*LQ*	Ranking
1	Dengilo	26259.84	5,353	1.58	IV
2	Paguat	23212.8	15,389	0.48	-
3	Marisa	11019.61	16,962	0.20	-
4	Duhiadaa	5643.17	10,960	0.16	-
5	Buntulia	11160.82	10,424	0.35	-
6	Patilanggio	89441.18	8,736	3.30	I
7	Randangan	57574.5	13,752	1.34	V
8	Taluditi	50993.72	6,836	2.40	II
9	Wanggarasi	25492.32	4,720	1.74	III *)
10	Lemito	24549.12	11,164	0.70	-
11	Popayato	27002.88	9,485	0.91	-
12	East Popayato	20615.48	7,586	0.87	-
13	West Popayato	24272.12	6,682	1.17	VI

Source: Analysis Result, (2020). Note: *) is the research location

Based on Table 2, the district that is corn based according to the LQ analysis is: LQ>1 included Patilangio, Taluditi, Wanggarasi, Dengilo, Randangan and West Popayato. According to 6 districts which are corn-based area. The chosen district for this research is the one in rank LQ III (low).

Data Collection Method

The research sample was collected by using a survey method to obtain inputs and information about the parameter of land capability, land suitability, lad carrying capability, population pressure, and the potentials of corn production which were needed to support the data analysis of this research in optimizing the land of corn plants.

The stages of Analysis and SIG Data Synthesis

The stages are:

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1. On-scree digitalization. It conversed the analogue data to digital data of maps from the interpretation result as well as the available thematic maps (parts of the data were input to GIS).
2. Did an overlay of the tentative maps obtained from the interpretation process to create a map of land unit.
3. The data analysis for land capability and land suitability was carried out using **LCLP software (Land Classification and Land Use Planning)** to determine the distribution of land capability classes and appropriate land-use recommendations. Integration with **GIS software** enables effective and efficient spatial data processing (Tangge, 2025). Kondong et al. (2025), in their study in **South Sorong Regency**, also adopted a similar approach and integrated it with **Geographic Information Systems (GIS)**, allowing for spatial visualization of carrying capacity status and providing guidance for optimizing land use. Carrying capacity analysis using this method is crucial for formulating sustainable development policies, especially in areas with **high population pressure and extensive land conversion**.

Database Compilation

1. **Preparation of thematic maps**
2. **Land unit maps** were generated through the overlay of landform maps, slope maps, and land use maps.
3. **Land capability and suitability maps** were developed based on the 1999 RBI (Basic Map), the 2010 administrative map of Pohuwato Regency, the 2010 land unit map of Pohuwato Regency, and the 2011 LCLP (Land Classification and Land Use Planning) analysis results.
4. **Land carrying capacity maps, population pressure maps, and maize productivity maps** were developed using the 1999 RBI map, the 2010 administrative map, and the 2010 edition of “Pohuwato Regency in Figures.”
5. **Maize land optimization maps and cropping pattern optimization maps** were prepared based on the 1999 RBI map, the 2010 administrative map, and the land unit map of Wanggarasi Sub-district.

RESULTS AND DISCUSSION

Land Optimization of Corn Plants in Wanggarasi District

Optimization in managing land of corn plants which can be developed in Wanggarasi District, Pohuwatu Regency, was based on an integral approach of several paramaters, i.e.:

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1) The potential of the availability of *biogeophysical* resources: a) land capability, b) land suitability, c) carrying capacity, and d) potentials in corn production
2) Social and economic potentials of the population in terms of population pressure

The analysis result showed that after integrating the function of land capability, land suitability, land carrying capacity, population pressure and potential production in the location of the research, Wanggarasi District is categorized as a low optimized land after applying this formula:

OPT ® = f (KL(III,IV) + KS (S3,N1) + DDL ® + P® +TP ®

Note: OPT ® map = category of low land optimization; KL = Land capability; KL (I,II,III,IV) = classes of land capacity I,II,III,IV; KS = land suitability, KS (S2, S3, N1) = moderately suitable, marginally suitable and currently not suitable; DDL = land carrying capacity, DDL (T) = high land carrying capacity, DDL® = low land carrying capacity, P = production, P (T,S,R) = high, moderate, and low production, TP = population pressure, TP® = low population pressure.

Based on the laboratory analysis result and direct observation in the field, there were 18 land unit in Wanggarasi District. Based on the result of laboratory analysis on 18 land units, they have several characteristics and quality as follows: the slope is approximately 0-2% and 2-8%. The depth of the effective soil is approximately 50-25 cm, 90-50 cm and >90 cm. The level of erosion hazard was categorized low and there was another part that was heavy. The types of soils in the region are brown alluvial, mediterranean, humic gleysol, Rendzina, Podzolic soil, Grumusol, Latosol, and Grey alluvial soils. The annual ground erosion was around 17.64 ton/ha/year until 395 ton/ha/year. There was a factor in managing the soil such as planting the cacao, sugarcane, and CGPRT crops (coarse grains, pulses, roots and tuber crops) as the mixture of plants besides the main plants that is corn. The factor of length and slope was approximately reaching 0.3 and 0.4. the erodibility or the parameter on how the soils response towards the erosion was around 0.13 to 0.29. Besides, the rainfall was between 1000-1500 mm per year and 1500-2500 mm/year.

Low category of corn production is located in Wanggarasi District with planted area 5,251 ha, harvested area 4,4996 ha, and production attainment as big as 25,492.32 ton. Along with the increase of population that is elevating as well as the escalation of land use cruciality in fulfilling foods, it will create the land use which is production-oriented. As impacts, the productivity of land is decreasing which finally will lower the prosperity level among the farmers (Idjudin dan Marwanto, 2008). This means that the increase of production does not sustainably increase the prosperity of the farmers if the indicator of a good land use is overlooked.

The carrying capacity in Wanggarasi District is considered high. The status of the carrying capacity was obtained from the comparison of the availability of land (SL) and total needs of land (DL). If SL>DL, the carrying capacity is surplus. If SL<DL, the carrying capacity is deficit or exceeded.

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Basically, the carrying capacity depends on the percentage of land which can be used for farming activities and the total of the farming production is calculated per unit area and time. The bigger the percentage of land used for farming activities, the higher the carrying capacity of the region. The percentage of land is determined by the suitability of land for farming, the needs of land for other needs beyond the farming sector, and the existence of dangerous animal or human diseases. The total area of the land unit for land availability class of S2, S3, and N2 in Wanggarasi was 532,007 ha or 25.07%.

The analysis of optimization of land was conducted based on the use of a sustainable land. An aspect of the developing environmental damage should be counted when assessing the optimization of land to anticipate further damage in the future upon the environment. Although it is a short-term, the monoculture of corn is significantly beneficial.

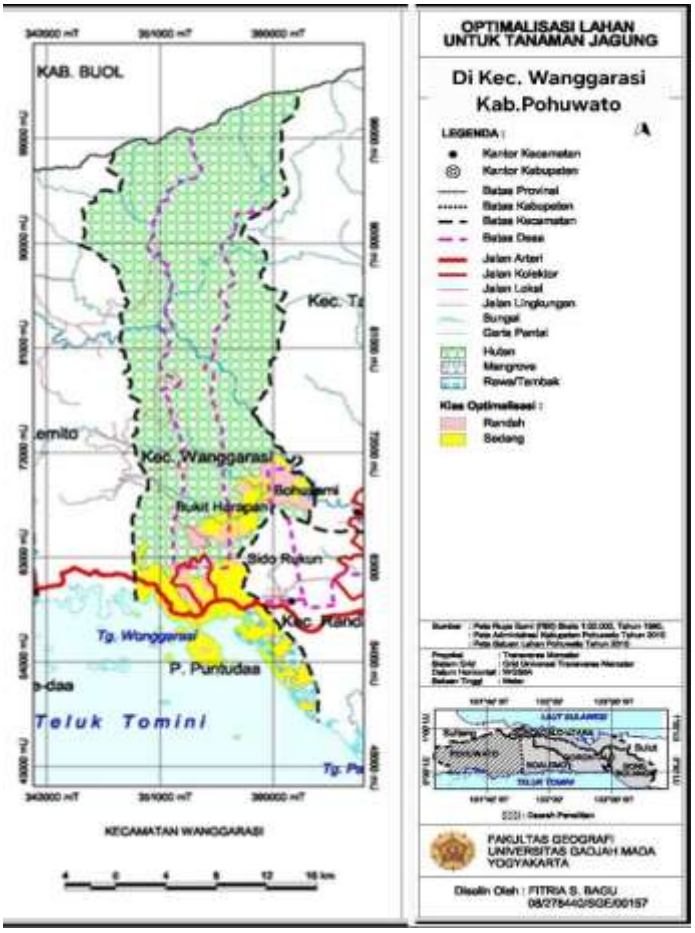


Figure 2. Map of Land Optimization in Wanggarasi District

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Table 3 Land Optimization for Corn Plants in Wanggarasi District

Optimization	District	Village	Land Unit	Land Capability	Land Suitability	Limiting Factors	Land Reparation (Action)	Land Carrying Capacity	Class of Land Carrying Capacity	Production	Class of Production	Population Pressure	Class of Population Pressure	Area	
Medium	Wanggarasi	Bohusami	D1IIIT1BI	III	Marginally Suitable	Permeability; Fragile Soil; Slope; Gravel/Stone	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	15.0	0.77%
			D1IIIT3BI	III	Marginally Suitable	Permeability; Fragile Soil; Slope; Gravel/Stone	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	2.6	0.14%
			D1IIT1BI	III	Marginally Suitable	Fragile Soil;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	2.4	0.12%
			D1IIT4BI	III	Marginally Suitable	Fragile Soil;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	10.3	0.53%
			S1IIIT1BI	III	Marginally Suitable	Permeability; Fragile Soil; Slope; Gravel/Stone	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	0.2	0.01%
			S1IIIT3BI	III	Marginally Suitable	Permeability; Fragile Soil; Slope; Gravel/Stone	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	49.6	2.55%
			S1IIIT4BI	III	Marginally Suitable	Permeability; Fragile Soil; Slope; Gravel/Stone	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	0.1%	0.01%
			S1IIT3BI	III	Marginally Suitable	Fragile Soil; Gravel/Stone;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	56.5	2.90%
						Permeability; Fragile Soil;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	28.7	1.47%
			S1IIIT3Tg	III	Marginally Suitable	Fragile Soil;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	19.3	0.99%
						Fragile Soil; Gravel/Stone;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	28.5	1.46%
		Total												287.3	10.65%
		Bukit Harapan	S1IIT4BI	III	Marginally Suitable	Fragile Soil; Gravel/Stone;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	4.0	0.20%
						Permeability;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	130.4	6.70%
						Permeability; Fragile Soil;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	171.2	8.79%
			D1IIT1B1	III	Marginally Suitable	Fragile Soil;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	2.3	0.12%
			S1IIIT1B1	III	Marginally Suitable	Permeability;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	8.3	0.42%
			S1IIIT4B1	III	Marginally Suitable	Permeability;	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	7.1	0.36%
		Total												323.2	16.66%
		Bohusami	S1IIIT3Tg	III	Marginally Suitable	Permeability; Fragile Soil; Slope; Gravel/Stone	Medium Conservation	3.014	High	25,492.32	Medium	0.332	Low	1.2	0.06%

Strategy of Optimizing the Land for Sustainable Corn Plants

Strategies in optimizing land for sustainable corn plants in Wanggarasi District, Pohuwatu Regency, are delivered in Table 4.

Table 4. The optimization of Sustainable Corn Plants

Strategy in optimizing a Low Category Land
1) Changing the management of a limited land through intensification pattern (efficiency towards the use of land resources) to the extensive and sustainable land management
2) Changing the small scale and limited farming business to a medium/large scale of farming business
3) Improving human resources through trainings and direct example on the farming land
4) Increasing production through adaptation and appropriate use of technology for a sustainable land management
5) Limiting the number of local settler farmers nor the migrants from out of town
6) Undergoing a medium and heavy conservation

Land conservation aims to gain optimum production of a land sustainably while trying to make the erosion rate smaller or at least dissimilar to the rate of soil formation. Thus, steps or attempts to manage the land are needed.

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CONCLUSION

According to the result and discussions of the research, it can be concluded that:

1. The distribution of land capability on the most dominant class level located in the research site is land capability class III. Classes of land suitability for corn in the research site is N1 (currently not suitable. The limiting factors in the land unit in the research location is considered as the temporary limitation. Therefore, if land improvement was conducted, it was conducted through a medium conservation of N1 and further N1 can turn its status into a potential land of S3 (marginally suitable). The land that can be developed for corn plants is N1 (currently not suitable) which is as big as 66.3 ha (3.41%). The total area of the land availability for corn plants in the research site is as big as 2121,86 ha.
2. The carrying capacity of the land was considered medium. On the status of the carrying capacity of the land, it was shown surplus.
3. The optimization of corn plants had been spatially done in the form of land optimization map for a low category of corn plant (R).
   a. Land optimization for corn plants is an attempt of using a land unit which is not used/abandoned by combining the potential land with good suitability, carrying capacity, population pressure, and appropriate production that are in line with the goals of making a sustainable land management.
   b. Strategies which can be used to optimize the low category land (R) are:
      - exploring a land unit with a combination of moorland and intermittent land that guarantee the availability of land with medium (S) optimization which is closely similar to the area of land units of Wanggarasi district which are categorized low (R);
      - exploring the combination of a land which is capable in creating a production with medium (S) land optimization category by conversing parts of the land of coconut plants which needs to be revitalized to become a dry farm land for corns.
      - Exploring the combination of land use that guarantees the availability of land area which is categorized in a medium optimization (S) in the form of mixed garden or moorland.

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