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Evaluation of land potential for organic farming development and implications for achieving Sustainable Development Goals (SDGs) in Sleman District, Yogyakarta, Indonesia

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Abstract. *Romadhona S, Soedarmo SPK, Mussadun. 2025. Evaluation of land potential for organic farming development and implications for achieving Sustainable Development Goals (SDGs) in Sleman District, Yogyakarta, Indonesia. Asian J Agric 9: 69-83.* The land potential is a critical factor in managing and utilizing land for agriculture. Land with high potential can support quality crop growth, increase production yields, and contribute to food security. Identifying and mapping land potential helps farmers and policymakers make informed decisions to optimize land use, increase production efficiency, and minimize negative environmental impacts. This research highlights the importance of land potential analysis in land use optimization for the agricultural sector in Sleman District, which has a strategic role in the regional economy and community welfare. Using quantitative descriptive analysis and scoring techniques, this research identifies high-potential land for agriculture capable of producing quality crops and high productivity. An overlay approach of multiple maps was used to generate comprehensive new information on land potential, providing essential insights for more efficient and sustainable agricultural decision-making and planning. The novelty of this research lies in integrating scoring and map overlay methods in the analysis of land potential, which has yet to be widely applied in the local context, thus making a new contribution to the literature on agricultural land management in the region. The results of this study identified land potential in Sleman based on the Land Potential Index (IPL) classification. The highest land potential class (IPL) covers 45,741 hectares or 79.77% of the total land area and is spread across all sub-districts. The very high IPL class covers 7,239 hectares or 12.62%, spread across Moyudan, Minggir, Seyegan, Godean, Gamping, Mlati, Depok, Berbah, Prambanan, Kalasan, Ngemplak, Ngaglik, Candi, and Pakem. The medium IPL class covers 3,772 hectares (6.57%), while the low class is only 583 hectares (1.01%). This data shows that most areas have high land potential, essential for planning sustainable agricultural development.

Keywords: Agricultural development, geographic information system, index potential land, organic farming, sustainable development goals

INTRODUCTION

Indonesia is an agricultural country with the agricultural sector as one of its leading sectors. The sustainability of the agricultural sector, especially food crop farming, is under serious threat, namely the shrinking of agricultural land in Indonesia due to the massive conversion of productive agricultural land to non-agricultural use (Romadhona et al. 2023). The increasing need for land, the scarcity of fertile and potential agricultural land, and the competition for land use between the agricultural and non-agricultural sectors, require appropriate technology in an effort to optimize land use in a sustainable manner (Horrillo et al. 2020). To be able to utilize land resources in a directed and efficient manner, it is necessary to have complete data and information regarding the condition of climate, soil and other physical environmental characteristics, as well as the growing requirements for the plants being cultivated, especially plants that have good market opportunities and economic significance (Tscharntke et al. 2021). Sustainable development has become a global concern realized through the Sustainable Development Goals (SDGs), an international agenda that includes 17 key goals to achieve a balance between social, economic and environmental needs by 2030 (MacPherson et al. 2020). The SDGs have an important role in driving the transformation of development practices, especially in the agricultural sector which plays a central role in supporting food security and reducing global poverty. In the local context, the implementation of the SDGs in the agriculture sector is a challenge, especially in terms of efficient and sustainable land resource management. Various studies emphasize the importance of implementing environmentally friendly agricultural practices (Dwiartama et al. 2024).

Sleman District, located in the Special Region of Yogyakarta, is one of the regions that has great potential in the agricultural sector. Its strategic geographical location, with fertile soil and favourable climate, makes Sleman a leading region in agriculture. Sleman is famous for its quality agricultural products, such as salak pondoh, organic rice, and various vegetables and fruits (Widiati et al. 2017). Agricultural sector in Sleman District is a strategic sector and plays an important role in the regional economy and community survival, especially in its contribution to the Regional Revenue and Expenditure Budget, providing employment opportunities and providing food in Sleman District (Devi et al. 2021). Therefore, the concept of spatial planning in Sleman District refers to the model of growth centers which emphasizes services for the agricultural product processing industry (Romadhona et al. 2020). A use of land in a suitable location will be very profitable, not only in the agricultural sector, but also in industry, trade, education and so on. Agricultural areas located in areas with high potential fertility will produce larger harvests compared to agricultural areas with low soil fertility.

The research area faces significant challenges due to rapid urbanization and land-use changes from 2013 to 2023. These changes have led to an increase in agricultural land but also added pressure on the sustainability of agricultural practices. Rapid urbanization can result in land fragmentation, conversion of agricultural land to non-agricultural uses, and increased pollution and environmental degradation (Widayani et al. 2022). These conditions make the spatial assessment of land potential crucial. Proper spatial analysis can help identify the most suitable areas for the development of organic and horticultural agriculture, thereby optimizing sustainable land use and reducing negative environmental impacts.

The development of organic agriculture in Sleman District has gained significant momentum with the issuance of Sleman Regent Regulation (PERBUP) No. 62 of 2023 concerning the Development of Area-Based Organic Agriculture. This regulation provides a strong legal foundation and strategic direction for the sustainable and competitive development of organic agriculture in Sleman. Organic agriculture, which prioritizes environmentally friendly and sustainable practices, is considered a solution to various problems faced by the conventional agricultural sector, such as soil degradation, declining water quality, and loss of biodiversity. On the other hand, organic agriculture also promises added economic value for farmers through products that have higher market value and wider market access, both domestically and internationally (Triyono et al. 2023). Mapping recommendations for organic agricultural land in Sleman District is an effort to implement sustainable agriculture and improve the quality of regional products through organic farming. The mapping of organic agricultural land recommendations needs to consider the potential and suitability of the land (Wacano et al. 2012). Evaluating land suitability potential is a crucial step to identify environmental limits in sustainable land use planning. This relates to the assessment of land performance for specific uses, namely crop production.

Another important focus is the absence of specific maps indicating locations with the potential for organic farming development in Sleman District. Without detailed and accurate maps, it is difficult for stakeholders to effectively plan and direct land development. Comprehensive mapping is needed to identify areas with soil and climate conditions suitable for organic farming and to determine sustainable land development strategies (El Baroudy 2016). With such maps, local governments, research institutions, and farmers can collaborate more efficiently in developing more planned and focused organic farming. Therefore, this research aims to fill this gap by mapping potential and providing land development directions in Sleman to support the enhancement of more sustainable and profitable organic farming implementation.

MATERIALS AND METHODS

Study area

Sleman District, Yogyakarta, Indonesia (Figure 1) has an area of 57,482 Ha or 574.82 km^2 covering 17 sub-districts, 86 villages, and 1,212 hamlets. Most of the area is fertile agricultural land with technical irrigation in the west and south, and the land varies between paddy fields, tegal, yards, and forests. The topography is divided into four elevation classes: <100 m (10.79%), 100-499 m (75.32%), 500-999 m (11.38%), and >1000 m (2.60%). The land potential index is used to assess the feasibility of agricultural development, taking into account altitude and soil fertility for various commodities, especially in sub-districts with altitude <100 m such as Moyudan, Minggir, Godean, Prambanan, Gamping, and Berbah, to >1000 m in sub-districts such as Turi, Pakem, and Cangkringan.

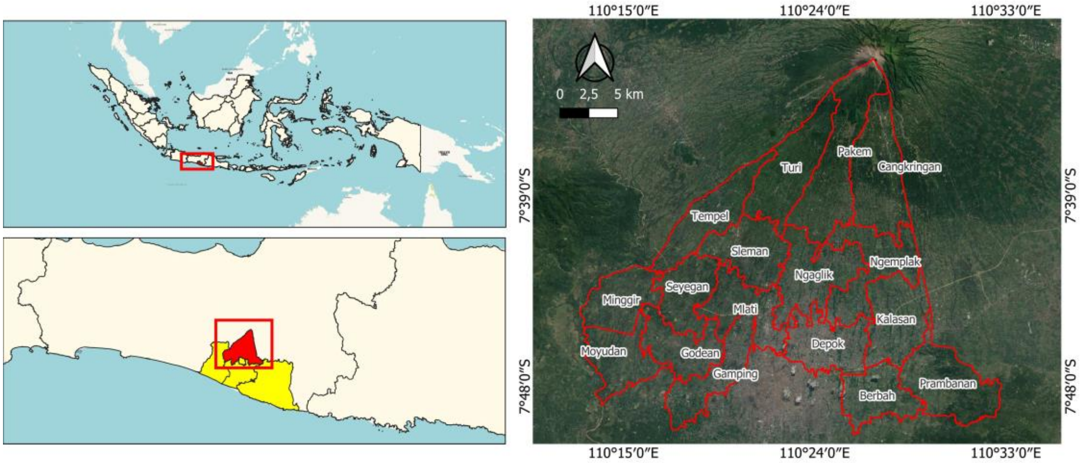

Figure 1. Map of research location in Sleman District, Yogyakarta, Indonesia

Procedures

In Figure 2, the flowchart for determining the Land Potential Index (IPL) for agriculture is a crucial process involving the thorough collection and analysis of data to support sustainable agriculture. This process begins with the collection of mosaic data, which includes spatial and non-spatial data such as topography, soil types, climate, and current land use. This data is then intricately overlaid using geographic information systems (GIS) to produce a land potential map. The next step is the assessment and weighting of each parameter based on its influence on agricultural productivity. The result of this analysis is a land potential index map that identifies the most suitable areas for the development of organic and non-organic agriculture. This analysis is essential as it provides accurate and detailed information to decision-makers to optimize land use, minimize environmental impact, and enhance agricultural production efficiency, all of which contribute to sustainable farming practices.

Determining the land potential index will be more efficient if presented spatially (spatial variability). The boundaries for each potential land area can be known with certainty, as the spatial pattern and the most important thing is the absolute position. Therefore, we need the most efficient method to process and analyze spatial and attribute data containing other information for making a Land Potential Index Map (Karimi et al. 2018). The land potential index is carried out by dividing classes, namely an evaluation carried out by grouping land into several categories based on five parameters: slope, soil type, lithology, rainfall, and disaster vulnerability. Land potential classification is the grouping of land into special units according to its ability to be used optimally and its treatment so that it can be used continuously.

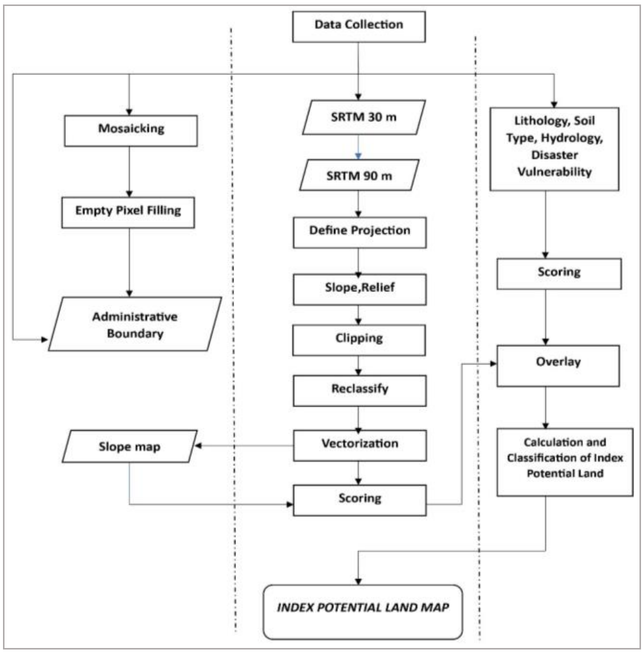

Figure 2. Research stages for land potential index assessment

Therefore, this classification system aims to group land that can be cultivated according to its potential and obstacles to sustainable production. The system is based on inhibiting factors and other potential hazards still acceptable in land classification (Castoldi and Bechini 2010).

Land potential index is carried out using a tiered quantitative method for each supporting variable except the erosion vulnerability parameter because it is a limiting variable. Erosion vulnerability is used as a multiplier in the summation of all supporting variable scores. Land potential is expressed by a numerical value called the Land Potential Index (IPL). The amount of land potential index is determined by evaluating 5 rational formula calculation factors, following the rational formula calculation formula, which describes the relationship between various environmental variables that influence each other in determining the level of sustainable agriculture (Marco et al. 2021; Devianti et al. 2022).

The data analysis technique used in this research is quantitative descriptive analysis, namely by scoring. This research also uses the overlay technique of several maps to generate new information, which is then analyzed. Each parameter map consisting of a slope map, lithology map, soil texture map, groundwater potential map, and landslide hazard map was assessed based on the reference table of land potential index parameter assessment and overlaid (Chiaka et al. 2024) . The Land Potential Index (IPL) states the relative potential of land for public use. The higher the IPL value, the higher the land's capability when used for land processing activities to provide optimal results. Land potential can be classified using a formula.

IPL formula = $(R + L + T + H) \times B$

Where:
IPL: Land Potential Index
R: Value of slope factor
L: Value of lithology factor
T: Value Soil type factor
H: Value of hydrological factors
B: Value of disaster vulnerability or barrier

Table 1 explains that the Land Class Characteristics Information provides a comprehensive overview of the Index of Land Potential (IPL), which is an important metric for determining the relative potential of land for public use. The HDI value is directly correlated with the ability of the land to deliver optimal crop yields when used for various land management activities. Higher IPL values indicate higher land capability, which indicates its suitability for agricultural and other land-intensive activities. Classification of land potential is done systematically using a specialized formula that takes into account factors such as soil quality, topography, climatic conditions and water availability. This classification helps in identifying the most suitable areas for development, ensuring sustainable land management practices.

Table 1. Characteristics of land class information

Class	Obstacle	Land Characteristics
Land class with very high capabilities	Land in this class has obstacles that limit its use, suitable for all kinds of agricultural uses (Hartati et al. 2018; Firmansyah et al. 2022)	This class is characterized by flat soil, little danger of erosion, deep solum, generally well-drained, easy to cultivate, can hold water well and is responsive to fertilization (Abdelrahman et al. 2016)
Land class with high land potential	Land in this class has several obstacles that narrow crop choices or require land preservation measures (Islam et al. 2018)	This class is characterized by rolling slopes, moderate erosion hazard, moderately shallow soil depth, and moderate drainage.
Land class with medium capabilities	Suitable for all agricultural businesses where the threat of damage is greater than on high land classes (Hartati et al. 2018)	This class is characterized by slightly sloping slopes, or very sensitive to erosion hazards, poor drainage, very slow soil permeability, shallow solum, low water holding capacity, low soil fertility and is not easily repaired.
Land class with low capability	This land can be planted, but the choice of crops that can be planted is very limited. Can be used for various types of agricultural uses with the threat and danger of greater damage to the land.	This class is characterized by steep slopes, great erosion sensitivity, low water holding capacity, and high salinity (Hossen et al. 2021)
Land class with very low capabilities	This land is usually not cultivated but is used as a protected area.	This land is characterized by a high risk of erosion, and frequently experiences flooding, rocky soil, and soil in swampy areas that are difficult for drainage.

Data analysis

Method used in this research is a field survey method with purposive sampling technique applied to each Index Potential Land (IPL) class. Purposive sampling was chosen because it allows researchers to deliberately select sample locations that are considered representative based on certain criteria, such as soil type, topography, and land use relevant to the research. In addition to the field survey, in-depth interviews with key informants were also conducted to support the final results. The key informants in this study were the head of the Agriculture Office and local farmers. These interviews aimed to obtain in-depth information on farming conditions and practices that could affect the potential of the land. For data analysis, tiered quantitative and qualitative methods were used with the support of Geographic Information System (GIS) technology (Montgomery et al. 2016). Tiered quantitative analysis was conducted by scoring each parameter that contributes to the determination of Land Management Index (LMI), such as soil fertility, water availability and other environmental factors however, for the analysis of agricultural land potential, the Index of Land Potential (IPL) is more often the first choice as its evaluation includes more attributes, resulting in a more complete and holistic assessment of land suitability for agriculture. Each parameter is given a weight based on its level of influence on agricultural land productivity (Kumar 2019). IPL is a method to identify the potential of land, which is very useful for sustainable management based on the capability and potential of the land. The determination of IPL uses parameters such as slope, hydrology, soil type, lithology, and disaster vulnerability, where each parameter has unique characteristics that contribute to the assessment of IPL. This research aims to provide a comprehensive understanding of land potential to support agricultural sustainability in Sleman District.

Land use generally depends on the capabilities of the land and on the location of the land (Wondimu and Ayansa 2022). For agricultural activities, land use depends on land capacity classes which are characterized by differences in properties that become obstacles to its use such as soil texture, slope of the land surface, ability to hold water and the level of erosion that has occurred. The Land Potential Index (IPL) is an approach that uses the assessment of several parameters according to their influence on the potential of a land. The parameters used in determining the land potential index are slope, relief, lithology, soil solum depth, soil texture, hydrology and disaster vulnerability (Li 2023). The land potential index is processed using the Geographic Information System (GIS) spatial method so that the location and area can be known in map form. Sleman based on relief or topography variables, slope, lithology, depth of soil solum, soil texture, hydrology and vulnerability to disasters (erosion) (Herzberg et al. 2019).

The score assessment for soil texture parameters and soil solum depth is mentioned in Tables 2 and 3. Table 2 presents the classification of soil texture, which includes different types of textures such as clay, sand, and silt. This classification is important for determining the ability of land to support organic farming, taking into account factors such as water retention ability, soil aeration, and nutrient availability. Soil texture can be used to determine the classification of soil texture distribution and suitability soil texture is based on land cover, soil texture is the level of fineness of the soil that is seen of the particles contained in a soil (Santos-Francés et al. 2022). Soil texture is one of the most common soil properties applied and is usually called the soil grain size. Soil texture is related closely related to the movement of water and dissolved substances, air, the movement of heat, weight land volume, specific surface area, ease soil compacts (compressibility) (Maleki et al. 2022).

In Table 3, soil depth is categorized based on the ability of the soil to support plant root systems and water retention. The categories include very shallow, shallow, medium, deep and very deep soils. Latosol soil type gets a texture score of 2 and a depth score of 5. The Andosol soil type gets a texture score of 5 and a depth score of 4. The Mediterranean soil type gets a texture score of 5 and a depth score of 5. The Regosol soil type gets a texture score of 1 and a depth score of 1. Soil type The one with the best score for assessing the land potential index is Mediteran. The type and texture of soil can chemically influence the availability of nutrients in the soil and physically the depth of the soil solum can influence soil permeability, soil structure and soil water availability. The assessment of slope, relief and erosion vulnerability parameter scores is mentioned in Tables 4 and 5.

The chapter on the land potential class index method in Table 4 related to slope and relief provides a detailed analysis of how slope and relief characteristics affect land potential. This method uses topographic criteria-based classification to determine the land potential index, where slope and relief are the main factors (Pimenta et al. 2021). Land slope is a certain height difference in the existing relief on a landform. Determination of the average land slope for each mapping groups can be done by creating relationships between points. The length of one line indicates the same slope. The slope of the land indicates the character of the area which must be considered in land use guidelines. Relief is the perpendicular (vertical) difference between the high and low parts of the earth's surface. Relief influences the potential of land based on the ease of access to the land for use or utilization (Maulida and Munir 2022).

The land potential class index in Table 5 shows the varying levels of disaster vulnerability for various land types in Sleman District. Based on the processed data, land with high potential tends to have a lower risk of disaster vulnerability compared to land with medium and low potential. Areas with low to high slopes and flat to mountainous relief, respectively, get a slope score and relief score of 5 to 1. Areas without disaster vulnerability get a score of 1, light vulnerability gets a score of 0.8, moderate vulnerability gets a score of 0.7, severe vulnerability gets a score of 0.6, and very severe vulnerability gets a score of 0.5. Erosion is the main barrier to sustainable land use. Identification of erosion on forest land is needed to determine the type and level of erosion and the percentage of the eroded area on a map unit to plan practical soil conservation efforts. The erosion hazard level can be predicted based on field conditions by paying attention to sheet erosion, rill erosion, and gully erosion. Another approach to predicting the level of erosion hazard, which is relatively more straightforward, is to pay attention to the soil surface lost (on average) per year compared to non-eroded soil, characterized by the presence of the A horizon. A dark color usually characterizes the A horizon because it relatively contains material higher organic (Mandal et al. 2022).

In analyzing methods to determine the potential of organic farming land, it is necessary to conduct an in-depth evaluation of various environmental, economic, and social factors that affect land suitability. Using multi-criteria approaches such as the Analytic Hierarchy Process (AHP) or Geographic Information System (GIS) helps integrate spatial and non-spatial data to evaluate land suitability based on parameters such as soil quality, water availability, topography, and market accessibility. In addition, this analysis should also consider sustainable agricultural practices and their impact on biodiversity and climate change mitigation. This holistic approach ensures that organic farming is productive and profitable and contributes to the SDGs' overall achievement.

Table 2. Soil texture score assessment

Code	Texture	Type of soil	Honor
T1	Rough	Regosol, litosol, organosol	1
T2	Rather rough	Podsolic, andosol	4
T3	Currently	Brown alluvial, andosol, mediterranean	5
T4	Somewhat subtle	Gley humus, renzina, podsol	3
T5	Fine	Grumusol, latosol, alluvial gray	2

Table 3. Soil solum depth score assessment

Code	Depth (cm)	Type of soil	Honor
S1	Very deep >100	Alluvial, latosol, mediteran, podzolic, grumusol	5
S2	Within 75-100	Andosol, podsol	4
S3	Medium 50-75	Renzina, planosol	3
S4	Shallow 30-50	Gley humus, hydromorph	2
S5	Very shallow <30	Regosol, litosol	1

Source: (Nurda et al. 2020)

Table 4. Slope and relief score assessment

Class	Slope (%)	Honor	Relief	Honor
I	0-5	5	Flat-sloping	5
II	5-15	4	Wavy	4
III	15-25	3	Low hilly	3
IV	25-45	2	Hilly	2
V	>45	1	Mountainous	1

Source: (Nurda et al. 2020)

Table 5. Disaster Vulnerability Factors (Erosion)

Code	Disaster vulnerability level	Honor
E1	Very heavy	0.5
E2	Heavy	0.6
E3	Currently	0.7
E4	Light	0.8
E5	Without	1.0

Source: (Nurda et al. 2020)

RESULTS AND DISCUSSION

Land with high and very high potential values indicates the ability of the land to be utilized productively based on its soil type, groundwater availability, parent rock and slope conditions. The nutrient-rich soil and abundant groundwater make this land ideal for productive agriculture. The priority use of this land is for agricultural development, although some land is used for settlements due to few limiting factors This is due to several limiting factors, such as low land slope, good soil texture, and accessibility to infrastructure. These conditions make the land suitable not only for agriculture but also for housing development. The impact of this dual land use must be managed wisely through comprehensive spatial planning, taking into account the balance between the need for productive agricultural land and housing development in Sleman District. Land with a medium-class index of land potential (IPL) is usually utilized for limited cultivation, forest areas, tourist parks, or settlements. In contrast, land with a low IPL has limited potential due to disaster risk and poor relief conditions, making it more suitable for protected areas. This analysis uses the parameters of soil type, aquifer productivity, slope and rock type. However, for more accurate results, it is necessary to consider additional data such as soil texture, availability of irrigation channels, and other morphology. The implication is that land use must consider its potential and limitations to be optimal and sustainable.

The lithological parameter in Table 6 indicates that pyroclastic rocks achieve the highest lithology score of 8, followed by massive igneous and coarse-grained clastic sedimentary rocks with a score of 5, and fine-grained clastic sedimentary rocks with the lowest score of 2. The lithology factor represents the parent soil material that contains minerals that influence their availability nutrients in the soil (Peano et al. 2014). The content of nutrients that come from rocks, such as P and K, in the soil really depends on the rocks that make up the soil. The forms of P and K are basically contained in a form that is not available or is slowly available, but with certain treatments it can dissolve the P and K so that they can be available to plants. However, through specific treatments such as soil tillage and fertilizer application, phosphorus (P) and potassium (K) can be mobilized and become more available. Newly formed pyroclastic deposits from the volcanic activity of Mount Merapi contain high levels of potassium (K) but low levels of phosphorus (P). Over time, following volcanic disturbances, the nitrogen (N) content in the soil tends to increase (Utami et al. 2018).

Relief and slope

Based on the data in Table 7 and Figure 3, most of Sleman District has undulating relief conditions with an area of 30,063 hectares or around 52.43% of the total district area. This condition is spread evenly across all sub-districts in Sleman. In addition, flat to gentle relief conditions are also quite significant, covering an area of 19,457 hectares or 33.93% of the total area. This shows that almost half of Sleman District has varied topography, from flat to undulating, which can affect various aspects, including land use and agricultural practices. Next, there are low hilly conditions with an area of 4,714 Ha with a percentage of 8.22% in several areas, namely Prambanan, Berbah and Gamping, next in sequence you will find areas with hilly conditions with an area of 2,147 Ha with a percentage of 3.74%, conditions that will rarely found in the Sleman area with mountainous conditions, namely an area of 955 Ha, with a percentage of 1.66%, mostly in the Cangkringan and Pakem areas. Relief is a factor that is closely related to climate, especially temperature. The higher the relief, the lower the temperature on the land, thus affecting the soil formation process. This means that the relief affects the physical properties of the soil in an area (Nurda et al. 2020).

The slope gradient significantly affects the processes of weathering and soil development, washing and transport of soil (El Behairy et al. 2022). Based on the data listed in Table 8, most of the Sleman District area is in the 5-25% slope class, which is spread across all sub-districts with a land area of 30,063 hectares or around 52.43% of the total area. In addition, areas with a slope class of 0-5% cover a land area of 19,457 hectares, which represents 33.93% of the total area of Sleman District. These two slope classes show the dominance of land with low to moderate slope levels, which are generally more suitable for various types of agricultural and residential land uses. These slope classes play an important role in spatial planning and regional development, especially in supporting agricultural activities and infrastructure development with this class spread across all sub-district areas, then in class 15-25% with an area of 4,714 Ha with a percentage of 8.22% in this class in the Prambanan, Berbah and Gamping areas, in the slope class 25-45 area 2,147 with a percentage of 3.74% this cass is spread across several areas of Cangkringan, Pakem, Turi, Prambanan and Godean.

Table 6. Lithological parameter assessment

Code	**Rock type**	**Honor**
Lb	Massive Igneous Rocks	5
Lp	Pyroclastic Rocks	8
Lk	Coarse Grained Clastic Sediment	5
Lh	Fine Grained Clastic Sediment	2
Lg	Calcareous and Metamorphic Sediments	3
Ll	Limestone	5
La	Alluvium/Coluvium	10

Source: Nurda et al. 2020

Table 7. Slope class in Sleman District, Yogyakarta, Indonesia

Relief			
Class	**Area (Ha)**	**Percentage**	**Region**
Mountainous	955	1.66%	Cangkringan, Pakem
Hilly	2147	3.74%	Cangkringan, Pakem, Turi, Prambanan, Godean
Low hilly	4714	8.22%	Prambanan, Berbah, Gamping
Wavy	30063	52.43%	Spread across all district areas
Flat-sloping	19457	33.93%	Spread across all district areas

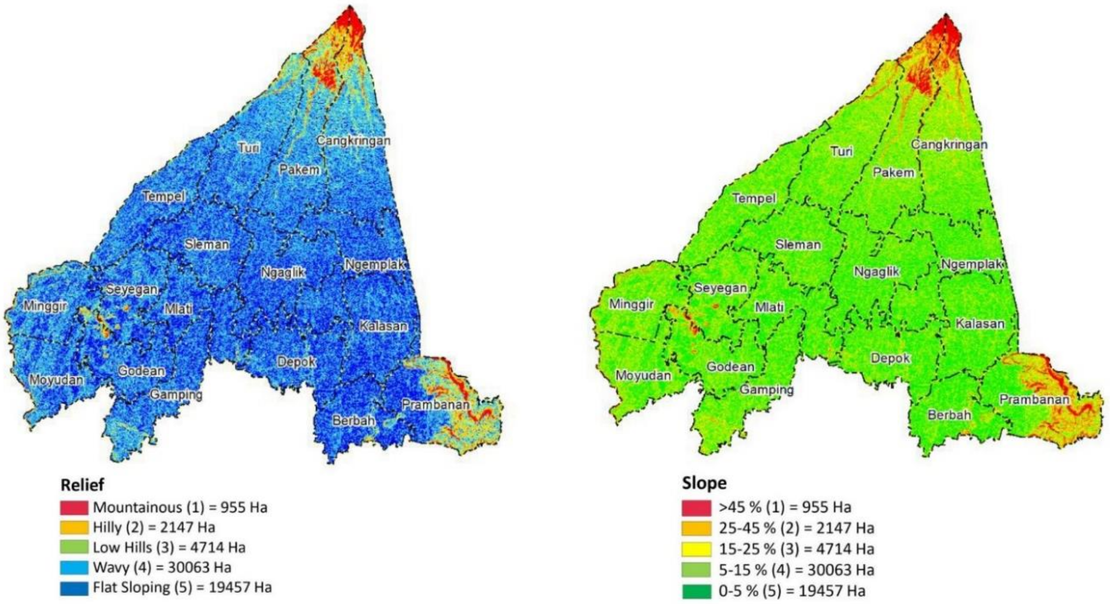

Figure 3. Relief map and slope map of Sleman District, Yogyakarta, Indonesia

Table 8. Slope class in Sleman District, Yogyakarta, Indonesia

Class	Area (Ha)	Percentage	Region
>45 %	955	1.66%	Cangkringan, Pakem
25-45 %	2147	3.74%	Cangkringan, Pakem, Turi, Prambanan, Godean
15-25 %	4714	8.22%	Prambanan, Berbah, Gamping
5-25 %	30063	52.43%	Spread across all district areas
0-5 %	19457	33.93%	Spread across all district areas

Connection between land slope and other parameters is quite dominant. Usually in different topography, which means the slope is different, the soil development is also different. Differences in soil development also mean there are differences in characteristics. Soil development is also influenced by the direction of the slope, because differences in slope will affect the speed of rock weathering into soil. Thus, the slope of the slope usually contains the consequences of differences in soil texture, drainage conditions, plant types and soil depth (Hossen et al. 2021).

Lithology and soil depth

Knowledge of lithology is very important in agriculture because it affects the physical and chemical properties of soil. Table 9 of the research results related to lithology in the research area shows that most of the lithological conditions in the Sleman District area, namely 98.88% or 56,694 Ha, are pyroclastic rocks. According to research conducted by (Astari et al. 2022) also explained that pyroclastic rocks are the result of volcanic activity, especially from the eruption of Mount Merapi which is located in the northern region and is part of Sleman District. The mountain is located on the boundary line between Yogyakarta and Central Java. These rocks consist of volcanic fragments such as volcanic ash, which are deposited during eruptions (Faozan et al. 2022). Pyroclastic sedimentary rocks are sedimentary rocks composed of volcanic material, the result of eruptions that have undergone transportation and deposition. The eruption of Mount Merapi that occurred had a negative impact on the community, but on the other hand there were great benefits in it, namely re-fertilizing the existing land. Soil becomes fertile again due to the nutrients contained in volcanic ash. This process is known as soil recovery, which helps improve the fertility of agricultural land. Shortly after the pyroclastic flow occurred, the process of soil formation began through the weathering of the elements and minerals contained therein. In the agricultural sector, apart from always providing new materials in the soil formation process, Pyroclastic material also provides a suitable growing place for plants by providing plant nutrients in the minerals it contains. Figure 4 map of the distribution of lithological research results in Sleman District shows massive igneous rocks, with 1.05% or 603 Ha, mostly spread in the Gamping area, then fine-grained clastic deposits with a percentage of 0.06% or 39 Ha, which are scattered in the Godean District area. The depth of the soil greatly determines plant growth. Shallow soil will be limited in its ability to provide water and other nutrients. Besides that, the depth of the soil really determines whether the land can be cultivated or not. In shallow soil, soil management will actually turn the subsoil upwards, which has consequences disruption of plant growth (Rachman et al. 2020). In the classification of land capability and suitability, the soil depth factor is very taken into account and determines. The depth of this soil can vary in various locations, and affects the productivity and quality of agricultural land. Regarding the depth of the soil in the Sleman District area, it is divided into 2 classes, namely very shallow and very deep. The effective depth factor of the soil will greatly influence the development of plant roots, if the depth is relatively thin it will inhibit root development.

Table 10 shows that the soil depth condition in Sleman District is very deep with a land area of 55,779 Ha or 97.28% of the area with very deep class soil depth characteristics spread throughout the sub-district area, then the soil depth condition is very shallow with a land area of 1557 Ha or 2.71% of the area with very shallow in Figure 4 can be explained related to the distribution of the soil depth distribution map covering Pakem and Tempel sub-districts. Deeper soil layers can also contain more nutrients due to the process of accumulating organic matter and minerals over thousands of years. Plants planted in deep soil solums are usually more fertile and productive because they have better access to nutritional resources.

Soil texture and hydrogeology

The soil texture most sensitive to erosion is very fine sand and dust. Therefore, the higher the dust content in the soil will maintain soil quality, Table 11 shows the condition of soil texture in the Sleman District area mostly with a land area of 34.686 Ha or 60.49% of the area can be explained in Figure 5 related to the distribution of soil texture in this condition, which is scattered in Tempel, Turi, Sleman, Ngaglik, Ngemplak, Kalasan, Mlati and Seyegan sub-districts, then with a medium soil texture class with an area of 18,121 Ha or 31.60% of conditions with medium texture spread in the Minggir, Moyudan, Godean, Gamping, Depok, Berbah and Prambanan sub-district, next in sequence namely the moderate class fine with a land area of 2,972 Ha or 5.18% spread across the Prambanan, Gamping and Berbah Sub-districts, next is the coarse soil texture class with an area of 1,557 Ha or 2, influence of soil texture on agricultural land is related to the soil's ability to store water, provide nutrients, support plant roots, and influence aeration and drainage (Mishra et al. 2015).

Hydrogeology affects the availability of groundwater in an area. If the land is located in an area with abundant groundwater, agriculture or activities that require water will be easier to carry out. On the other hand, if the land is located in an area with limited access to groundwater, then land use must be regulated. Table 12 shows that most of the hydrogeological conditions in Sleman District fall into the High Productivity class with a fairly wide distribution in this class with a total area of 46,119 Ha or 80.43% which can be seen in Figure 5 hydrogeology distribution map spread across all sub-district areas, then the Medium Productivity class with a total distribution area of 6444 Ha or 11.23%. Next in sequence is the medium-small productivity class with a total land area of 1390 Ha or with a percentage of 2.42%, then the rare groundwater class with a total area of 3382 Ha or 5.89%.

Table 9. Lithology class of Sleman District, Yogyakarta, Indonesia

Class	Area (Ha)	Percentage	Region
Fine Grained Clastic Sediment	39	0.06%	Godean
Massive Igneous Rocks	603	1.05%	Gamping
Pyroclastic Rocks	56694	98.88%	Spread across all sub-district areas

Table 10. Soil depth classes in Sleman District, Yogyakarta, Indonesia

Class	Area (Ha)	Percentage	Region
Very shallow	1557	2.71%	Pakem, Tempel
Very deep	55779	97.28%	Spread across all sub-district areas

Table 11. Soil texture classes of Sleman District, Yogyakarta, Indonesia

Class	Area (Ha)	Percentage	Region
Rough	1557	2.71%	Pakem, Cangkringan
Fine	34686	60.49%	Tempel, Turi, Sleman, Ngaglik, Ngemplak, Kalasan, Mlati, Sayegan
It's a bit subtle	2972	5.18%	Prambanan, Gamping, Berbah
Currently	18121	31.60%	Moyudan, Godean, Gamping. Depok, Berbah, Prambanan

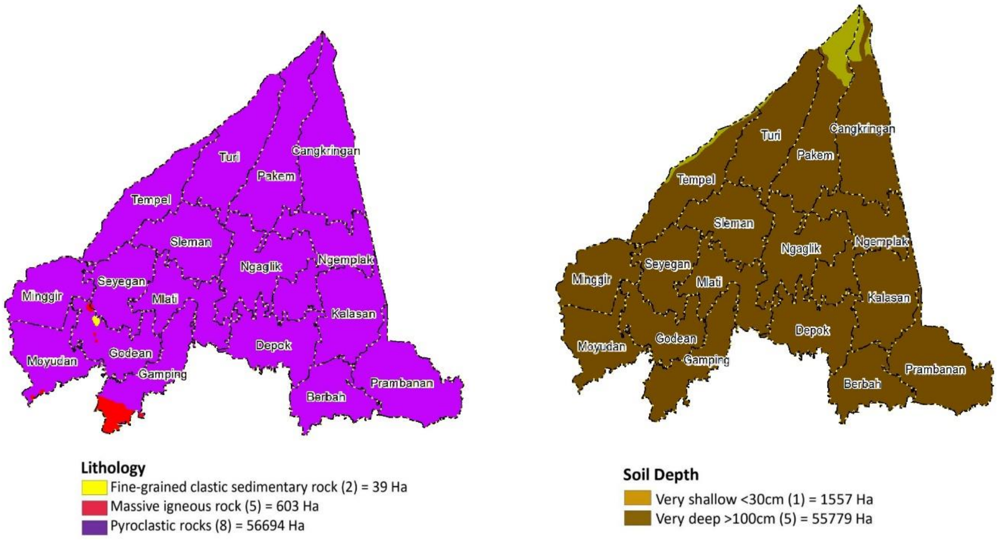

Figure 4. Lithology and soil depth of Sleman District, Yogyakarta, Indonesia

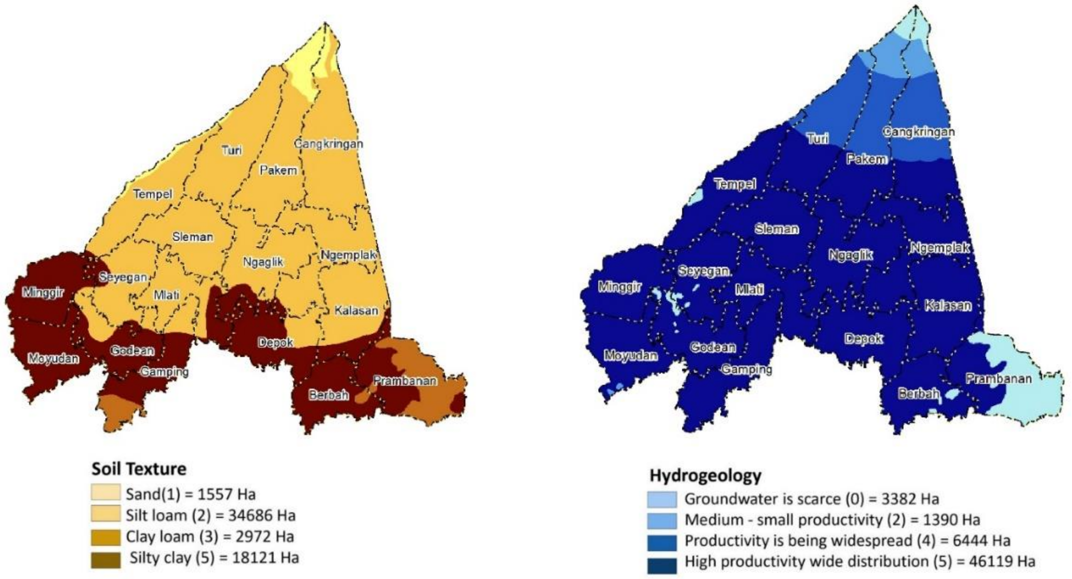

Figure 5. Soil texture and hydrogeology of Sleman District, Yogyakarta, Indonesia

Table 12. Hydrogeological class of Sleman District, Yogyakarta, Indonesia

Class	Area (Ha)	Percentage	Region
Rare groundwater	3382	5.89%	Pakem, Cangkringan, Prambanan, Sayegan
Medium-small productivity	1390	2.42%	Cangkringan, Pakem, Turi
Medium productivity-widespread	6444	11.23%	Cangkringan, Pakem, Turi
High productivity-wide distribution	46119	80.43 %	Spread across all sub-district areas

Erosion disasters and land potential index

Erosion can remove nutrient-rich soil layers and reduce the fertility of agricultural land. This can reduce crop yields and plant productivity. In addition, sedimentation caused by erosion can clog irrigation canals and rivers, cause flooding, and damage aquatic ecosystems. The conditions of erosion disaster classes in Sleman District can be illustrated in Table 13, where the majority are in a severe condition, spread throughout the entire region of Sleman District, covering an area of 28,765 hectares or 50.16%. Additionally, an area of 19,010 hectares or 33.15% falls into the class where no erosion disaster occurs. This distribution is also depicted in Figure 6, which shows the spread throughout the entire region. Next in sequence are the medium class with a land area of 8855 Ha or 15.44%, the light class with a total area of only 67 Ha or 0.11%, then the very heavy class with a total area of 640 Ha or 1.11%.

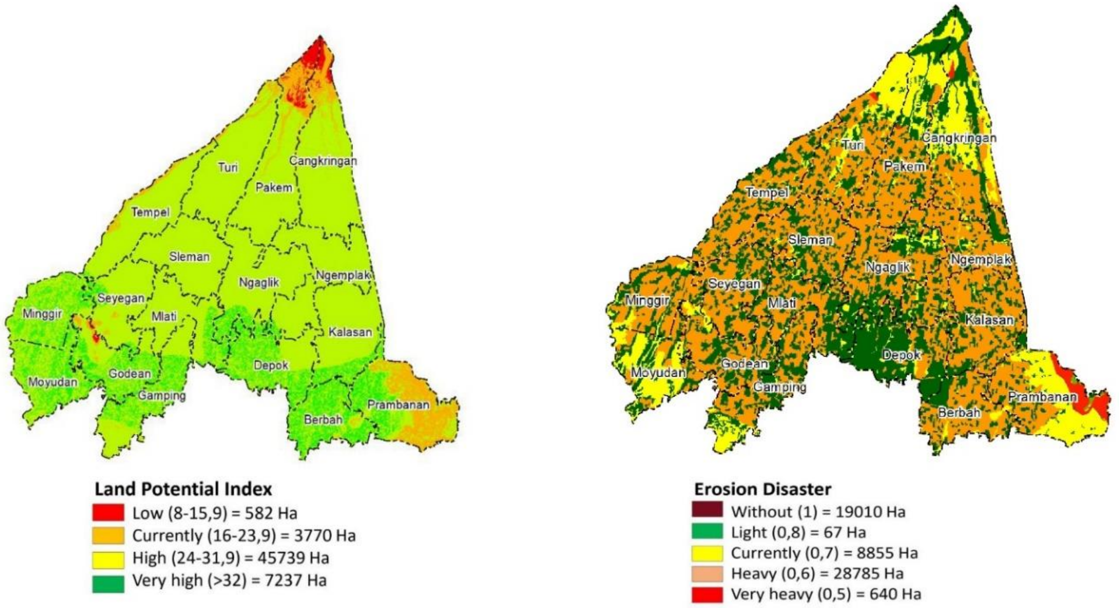

Figure 6. Erosion disasters and land potential index of Sleman District, Yogyakarta, Indonesia

Table 13. Sleman District erosion disaster class

Class	Area (Ha)	Percentage	Region
Without (1)	19010	33.15%	Spread across all regions
Light (0.8)	67	0.11%	Spread across all regions
Medium (0.7)	8855	15.44%	Spread across all regions
Weight (0.6)	28765	50.16%	Spread across all regions
Very Heavy (0.5)	640	1.11%	Spread across all regions

Erosion removes important nutrients such as nitrogen, phosphorus, potassium and other micronutrients from the soil. Plants on organic farms depend on the natural nutrients of the soil to grow without the use of chemical fertilizers. If nutrients are lost due to erosion, plants can become weak and susceptible to pest and disease attacks. Basically, every soil has a different level of sensitivity to erosion, depending on the physical properties and rocks that form it. Thus, apart from being related to land form, erosion conditions are also related to soil properties and rock types Plants can become weak and susceptible to pest and disease attacks. Basically, every soil has a different level of sensitivity to erosion, depending on the physical properties and rocks that form it. Thus, apart from being related to land form, erosion conditions are also related to soil properties and rock types Plants can become weak and susceptible to pest and disease attacks. Basically, every soil has a different level of sensitivity to erosion, depending on the physical properties and rocks that form it. Thus, apart from being related to land form, erosion conditions are also related to soil properties and rock types (Stellacci et al. 2021).

Discussion

Determination of land criteria class

Based on the data presented in Table 14, which represents the overall results of the Land Potential Index parameters in Sleman District, there are four classes of land potential with varying distributions. The low land potential class covers 583 hectares or 1.01% of the area, spread across Seyegan, Godean, and Cangkringan Sub-districts. The medium land potential class has an area of 3,772 hectares or 6.57% of the area, completely shown in Figure 7 which includes the sub-districts of Moyudan, Minggir, Seyegan, Godean, Gamping, Berbah, Prambanan, Kalasan, Tempel, Turi, Pakem and Cangkringan. The high land potential class is the most dominant with an area of 45,741 hectares or 79.77%, spread evenly across all sub-districts. Meanwhile, the very high land potential class covers an area of 7,239 hectares or 12.62%, found in Moyudan, Minggir, Seyegan, Godean, Gamping, Mlati, Depok, Berbah, Prambanan, Kalasan, Ngemplak, Ngaglik, Tempel, Turi, and Pakem.

Table 14. Land potential index class for Sleman District, Yogyakarta, Indonesia

Class	Area (Ha)	Percentage	Region
Low	583	1.01%	Seyegan, Godean, Cangkringan
Currently	3772	6.57%	Moyudan, Minggir, Seyegan, Godean, Gamping, Berbah, Prambanan, Kalasan, Tempel, Turi, Pakem and Cangkringan
Tall	45741	79.77%	Spread throughout the sub-district
Very high	7239	12.62%	Moyudan, Minggir, Seyegan, Godean, Gamping, Mlati, Depok, Berbah, Prambanan, Kalasan, Ngemplak, Ngaglik, Temple and Pakem

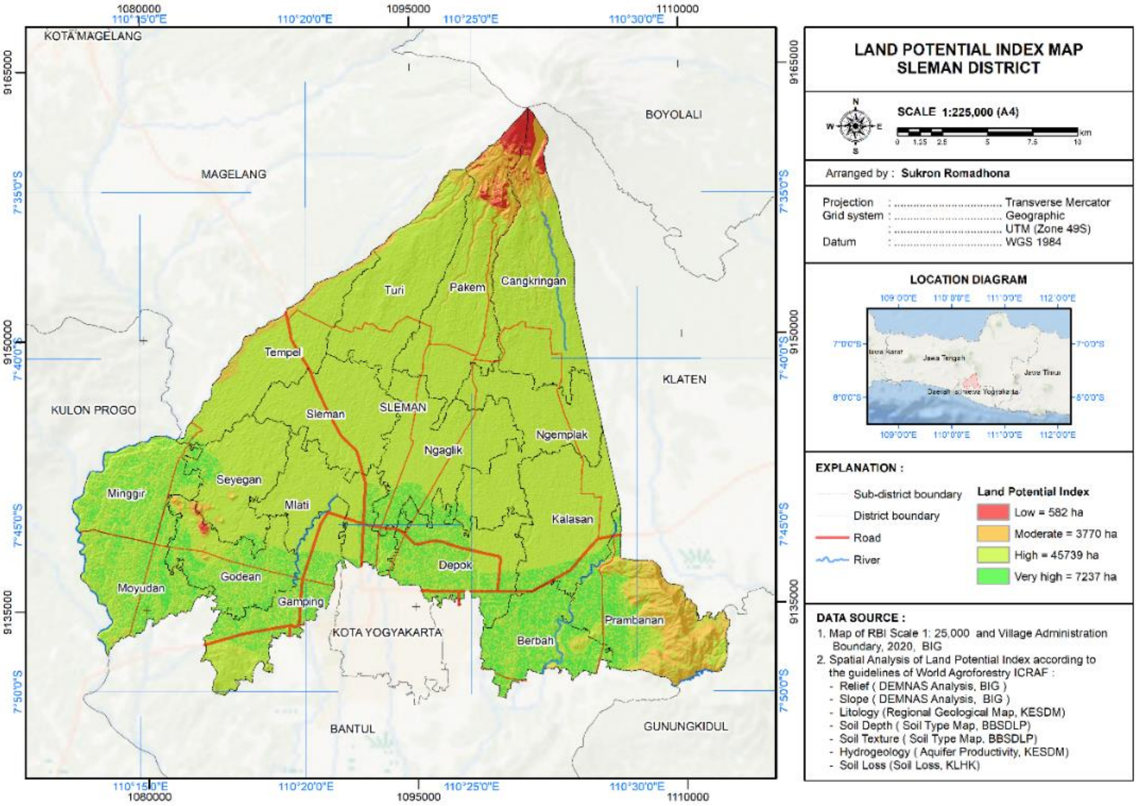

Figure 7. Map of Land Potential Index distribution classes in Sleman District

Analysis of this data shows that most of Sleman District has high land potential, which is evenly distributed across all sub-districts. This indicates excellent opportunities for developing the agricultural sector in this region. Sub-districts with very high land potential, such as Moyudan, Minggir, and Godean, have more significant opportunities for intensive sustainable agricultural development, including organic crops. Although more limited, areas with low and medium potential still have essential contributions to make in land use diversification and agricultural risk mitigation. The implication is that the government and stakeholders in Sleman District must focus on optimizing high and very high-potential land through sustainable agricultural practices and advanced agricultural technologies. In addition, adaptive and sustainable land management strategies are needed to address environmental challenges and support the economic welfare of local farmers.

Land potential index provides information regarding land use directions in accordance with land potential and resources. Agricultural land potential data is important data because it is used to evaluate the suitability of agricultural land and determine good land use. The condition of the land potential index in the Sleman District area is mostly in the high class based on the potential index data of Land Potential Index Level (IPL) which is produced from the overlay of slope parameters, lithology, soil type, groundwater productivity and disaster vulnerability erosion.

Figure 7 related to the land potential index class distribution map can explain that in the high class with a total land area of 45,741 Ha or 79.77% of the high class area is spread throughout the sub-district area. Next is the very high Land Potential Index (IPL) class with a total land area of 7239 Ha or 12.62% of the very high class spread across the areas of Moyudan, Minggir, Seyegan, Godean, Gamping, Mlati, Depok, Berbah, Prambanan, Kalasan, Ngemplak, Ngaglik, Temple and Pakem. In sequence, the land potential index class is medium with a total land area of 3772 Ha or a percentage of 6.57%, the next most rarely found is the low class with a total land area of 583 Ha or a percentage of 1.01%. The level of land potential can be determined from several supporting parameters, the higher the land potential index, the greater the potential for land use.

Distribution and development potential of food crops and horticulture lands

The map of potential distribution of food and horticultural crops in Sleman District can be shown in Figure 8 shows that certified organic rice plants are scattered in Berbah District (Sido Rukun Farmer Group) and Pakem (Rukun Farmer Group). Figure 9 shows the distribution of salak farmer groups in the Sleman District area, in more detail the distribution includes in Turi Sub-district (Gemilang Farmer Group), certified organic salak is a leading horticultural commodity.

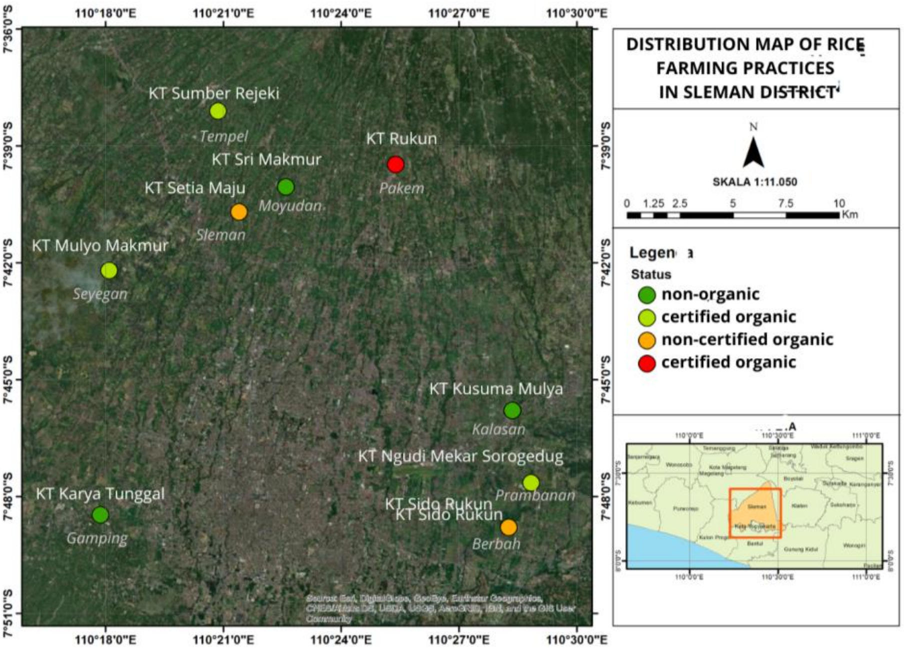

Figure 8. Distribution of rice fields with different farming practices in Sleman District, Yogyakarta, Indonesia

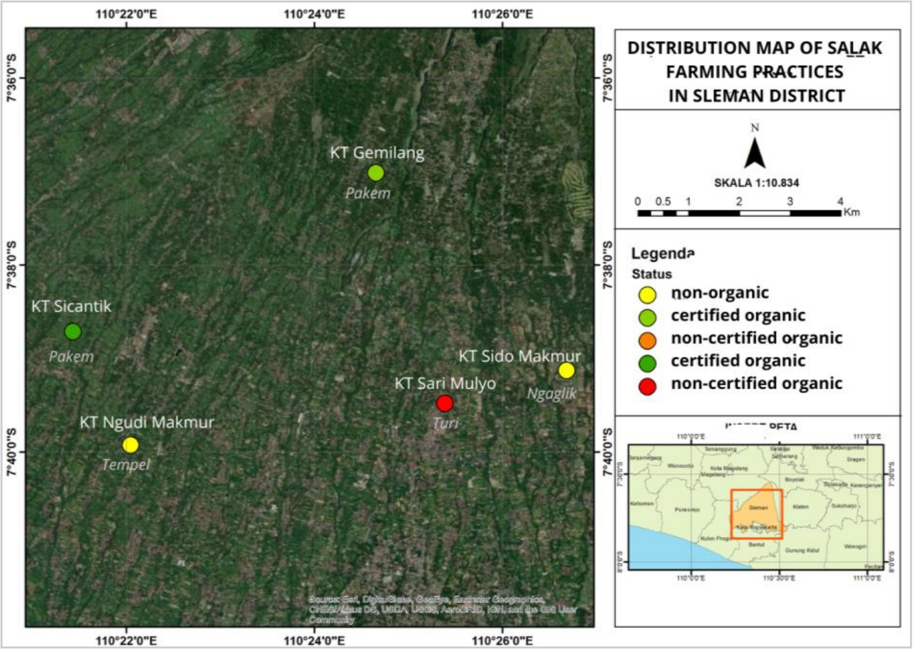

Figure 9. Distribution of *salak* fields with different farming practices in Sleman District, Yogyakarta, Indonesia

Figure 10. Farmland for rice crops. A. Organic rice farmland; B. Non-organic rice farmland

Figure 11. Salak farmland. A. Salak farmland with organic practices; B. Salak field with non-organic practices

Meanwhile, non-organic rice is dominated in Gamping (Karya Tunggal Farmer Group) and Kalasan (Kusuma Mulya Farmer Group) Sub-districts. Non-organic salak is found in Tempel Sub-district (Ngudi Makmur Farmer Group). In addition, non-certified organic rice is scattered in Prambanan (Farmer Group Ngudi Mekar Sorogedug Lor) and Seyegan (Farmer Group Mulyo Makmur) Sub-districts, while non-certified organic salak is found in Pakem Sub-district (Farmer Group Mandiri). This map reflects the diversification of agricultural commodities in various sub-districts in Sleman District, with differences in certification status indicating variations in agricultural practices and the potential for local commodity development.

Figure 10 shows the area of rice farmland in Sleman District. Certified organic rice farming areas in Sleman District have physical characteristics that support sustainable agricultural practices. The soil in this area is generally fertile with a sandy loam texture that is good for water absorption and air circulation, allowing plants to grow optimally. The land is located in the low to medium plains with altitudes between 100-500 meters above sea level, providing ideal climatic conditions for organic farming. The availability of sufficient irrigation water sources from rivers and boreholes also ensures the sustainability of water supply for crops. Non-organic farmland is often located in areas with easier access to infrastructure and markets, but tends to face challenges of soil degradation due to intensive use of chemical fertilizers and pesticides. Soil structure on non-organic land is often denser, with lower organic matter content and soil pH that can vary more widely. The sustainability of these lands depends on more intensive soil management practices to maintain productivity.

Figure 11 shows the area of salak farmland in Sleman District. Certified organic salak farmland areas in Sleman District show better physical characteristics compared to non-organic land. Certified organic land generally has a looser soil structure, higher fertility levels, and better biodiversity due to the implementation of sustainable agricultural practices that avoid the use of synthetic chemicals. In contrast, non-organic salak land tends to experience soil degradation due to excessive use of chemical fertilizers and pesticides, which can lead to decreased soil and water quality, and reduced biodiversity. In addition, certified organic land is often managed with better soil and water conservation techniques, thus retaining soil moisture and reducing erosion. Overall, certified organic farming practices in Sleman District have a positive impact on land physical characteristics compared to non-organic practices.

Linkages between organic farming and SDGs in Sleman District

Organic farming promotes environmentally friendly practices that improve soil fertility, reduce water pollution, and increase biodiversity. Determining the right land potential for organic farming is crucial in achieving these SDGs, as suitable land will support sustainable productivity without harming the environment. Land suitability evaluation based on ecological and socio-economic criteria ensures that agricultural practices can support food security, farmer welfare, and climate change mitigation. Thus, organic farming carried out on suitable land not only contributes to the production of healthy and safe food but also to the achievement of holistic, sustainable development.

SDG 2: End Hunger. Organic farming in Sleman can increase food production and food security through sustainable techniques such as crop rotation, crop diversity, and agroforestry. Crop rotation can prevent soil degradation and maintain soil fertility, while crop diversity helps reduce the risk of crop failure due to certain diseases or pests. Agroforestry, which combines agriculture with forestry, increases land productivity while maintaining environmental sustainability. SDG 3: Healthy and Prosperous Lives Organic farming promotes healthy diets by producing nutrient-rich foods without harmful pesticides and chemical fertilizers. This improves consumer health and reduces farmers' exposure to harmful chemicals. Using organic materials and natural farming techniques helps retain nutrients in the soil and plants, resulting in healthier and more nutritious food products. SDG 9: Industry, Innovation, and Infrastructure: Innovation and technology in organic agriculture, such as precision farming, can increase productivity and reduce environmental impact. In Sleman, using modern technology and innovative practices in organic farming can improve production efficiency and environmental sustainability. Developing infrastructure supporting organic farming is also essential to strengthen local agricultural systems.

In conclusion, land potential (IPL) is in the high class with a total land area of 45741 Ha or 79.77% of the high class area spread across all sub-district areas. Next is the very high Land Potential Index (IPL) class with a total land area of 7239 Ha or 12.62% of the very high class spread across the areas of Moyudan, Minggir, Seyegan, Godean, Gamping, Mlati, Depok, Berbah, Prambanan, Kalasan, Ngemplak, Ngaglik, Temple and Pakem. In sequence, the land potential index class is medium with a total land area of 3772 Ha or a percentage of 6.57%, the next most rarely found is the low class with a total land area of 583 Ha or a percentage of 1.01%. The distribution and land development potential of food crops and horticulture in Sleman show significant variations related to geographical conditions, soil quality, and infrastructure support. Based on the land potential analysis, the northern and central parts of Sleman have high suitability for the development of food crops such as rice and secondary crops, especially in areas with moderate elevation and adequate irrigation systems. Research and observations show that organic farming in Sleman contributes to the SDGs by reducing hunger through increased sustainable food production (SDG 2), promoting health by providing food free of harmful chemicals (SDG 3), and encouraging technological innovation for efficiency and sustainability (SDG 9). This practice provides positive results and a new outlook on the importance of organic farming in the region.

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