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MORALITY BEFORE KNOWLEDGE

Influence of soil physical and chemical in supporting sorghum productivity and development

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ABSTRACT

Background: Sorghum has been known in Indonesia for a long time, but its development is not as good as rice and corn. This is because there are still few areas that utilize sorghum plants as food. Land evaluation is a process of assessing the potential of a land used as the basis for sector development in an area that is useful for reorganizing existing land use to assist in making land use planning decisions. This study lies in the integration of detailed soil physical and chemical characterization with land use change into practical, site-specific development directions for sorghum cultivation at the village scale. Previous studies focus mainly on general suitability classification, this research links soil directly to management recommendations and planning, providing a decision-support for promoting sorghum as an alternative food crop in marginal agricultural areas in Yogyakarta. **Methods:** This study was conducted in Sitimulyo Village, Bantul, from October to December 2023. Field surveys, soil sampling, laboratory analysis of physical and chemical properties, and water quality measurements were carried out to assess soil characteristics across various land uses. **Findings:** The results obtained show that in general the condition of land suitability in Sitimulyo Village has a level of moderately suitable (S2) to suitable (S1) with limiting factors of rainfall, slope, and Cation Exchange Capacity. **Conclusion:** Recommendations from this study are to make efforts to improve and sufficient level of management of limiting factors to improve the land suitability class. In addition, there is a need for more review and counselling on sorghum farming to improve the social and economic conditions of surrounding farmers. **Novelty/Originality of this article:** This study lies in the integration of detailed soil physical and chemical characterization with land use change into practical, site-specific development directions for sorghum cultivation at the village scale. Previous studies focus mainly on general suitability classification, this research links soil directly to management recommendations and planning, providing a decision-support for promoting sorghum as an alternative food crop in marginal agricultural areas in Yogyakarta.

KEYWORDS: soil morphology; soil characteristics; land use; sorghum land evaluation.

1. Introduction

Land is one of the main resources in agriculture. Soil has a function as a medium where plants grow and has very dynamic properties due to factors that affect the soil development process such as climate, topography, parent materials, organisms, and time that are always changing (Bockheim et al., 2014). Soil also has different properties and characteristics from one place to another. Soil is also a major regional physical resource that is very important to consider in land evaluation (Ebabu et al., 2020). Land evaluation is a process of assessing the potential of a land for certain uses (FAO and Agriculture Organization of the United Nations, 1976). Land evaluation is useful to determine the value or class of suitability of a

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land for a specific purpose. In addition to aspects of soil quality and characteristics, in land evaluation, it is necessary to pay attention to aspects such as social, economic, and environmental aspects related to land use planning (AbdelRahman et al., 2022; Bai et al., 2025; Rahmani et al., 2022; Vasu et al., 2018). The results of land evaluation can be described in the form of maps as a basis for rational land use planning, so that land can be used optimally and sustainably (Nguyen et al., 2015).

Sitimulyo Village, Piyungan District, Bantul Regency is one of the areas that is currently experiencing problems with land use changes because most of the land that was originally used for agriculture has turned into industrial land. This has an impact on reducing the quality of the land so that the community makes efforts so that the land does not suffer damage, one of which is by replanting it with food crops in the form of rice, corn, and cassava. Based on these conditions, it is necessary to make a handling effort to increase productivity both the quality and quantity of agricultural products and land regeneration. So that an evaluation of land suitability is needed, especially for the cultivation of food crops, one of which is sorghum plants. This study provides information about soil morphology and characteristics related to land use conditions and slope slopes.

Soil is one of the components of land that has an important role in plant growth and production because soil has a role in retaining and providing water for plants and providing nutrients needed by plants to support growth. Physically, soil functions as a place for growth and development of roots to support the upright growth of plants and supply water and air needs. Chemically it functions as a source and supplier of nutrients or nutrients (simple organic and inorganic compounds and essential elements such as: N, P, K, Ca, Mg, S, Cu, Zn, Fe, Mn, B, Cl). Biologically, it functions as a habitat for biota (organisms) that actively participate in the provision of nutrients and additives (growth stimulators. protection) for plants (John Huntley Terrestrial Biomes, 2023; Tang, 2025; Xing et al., 2024). Soil is formed from the results of rock weathering which is an interaction of soil-forming factors such as climate, organisms, parent materials, relief, and time. Meanwhile, the soil formation factor itself is an environmental condition that functions to drive the soil formation process that takes place physically, chemically, and biologically (Bockheim et al., 2014).

Climate is a very important factor in the process of soil formation. The most influential components of climate on soil formation are temperature and precipitation. Rainfall will affect the strength of erosion and soil washing. This is because rapid soil washing can cause the soil to become acidic (soil pH becomes low). In general, the higher the rainfall. then the acidity of the soil is higher or the pH of the soil is lower because many alkaline metal elements of the soil are protected such as Na, Ca, Mg, and K, and vice versa, the lower the rainfall, the lower the acidity level of the soil and the higher the pH of the soil (Bernhard et al., 2018; Dong et al., 2022; Zhang et al., 2019). Soil comes from the weathering of rocks mixed with the remains of organic matter and organisms (vegetation, carcasses, microorganisms, and animals) that live on it or in it (Ritschel et al., 2023). Organisms have a great influence on the soil formation process in terms of the weathering process, both organic and chemical weathering. Organic weathering is weathering carried out by living things (animals and plants), while chemical weathering is weathering that occurs by chemical processes such as limestone dissolved by water. In addition, organisms can help the process of humus formation. These organisms have a role in decomposing organic matter so that it is beneficial for soil fertility. Soil fertility does not only depend on its physical and chemical composition but also on the natural characteristics and diversity of soil biota (Bhattacharyya & Furtak, 2023; Lou et al., 2022; Piccolo & Drosos, 2025).

The parent material is derived from rocks or organic matter. The rock will decay, become the parent material and will perfectly form the soil, so that the minerals contained in the rock are also present in the parent material and the soil. Rocks are made up of igneous rocks, sedimentary rocks (deposits), and metamorphic rocks. The rock will be destroyed into the main material, then it will undergo weathering and become soil. Soil on the earth's surface partially exhibits the same properties (especially chemical properties) as the parent material (Earle, 2026; Panchuk, 2026; Ritschel et al., 2023). The chemical and mineral composition of the parent material will affect the intensity of the weathering level and vegetation on it. For example, the parent material that contains a lot of the element Ca will form soil with a large amount of Ca ions so that it can avoid silicic acid leaching and some can form gray soil. On the other hand, the parent material that has less lime content will form a redder soil (Kowalska et al., 2019).

Relief or topography is the difference in height or shape of an area, including slope slope, slope length, and slope shape. The relief condition of an area will affect the thickness or thinness of the soil layer, such as areas that have a sloping and hilly topography whose soil layer is thinner due to erosion, while areas that are flat have thick soil layers due to sedimentation. Topography is a factor in the soil formation process that affects the amount of rainwater absorbed by the soil, the depth of groundwater, the direction of water movement, and the amount of erosion that occurs on the land (Fu et al., 2011). In addition, relief can affect drainage or irrigation systems. If an area has poor drainage such as frequent flooding, it causes the soil to become acidic (Ding et al., 2019; Zhang et al., 2019). The period of time of formation will determine the type and properties of soil formed in an area. because time is another supporting factor for soil formation to influence soil formation processes, the longer the time for soil formation will be more intensive (Samouëlian & Cornu, 2008; Targulian & Krasilnikov, 2007).

Soil characteristics include the physical and chemical properties of the soil which are related to the suitability of land for planning and development of agricultural areas, especially sorghum cultivation. The effective depth of the soil is the depth at which the roots of the plant can still enter the soil. This depth is generally limited by an inhibitory layer. For example, hard rock, rocky, or other layers that interfere with or inhibit the development of roots. measured in cm. The effective depth of soil can affect root growth and development, drainage, and physical properties of the soil. Soil physics is one of the factors that affect plant growth and production. One of the important properties of soil physics is soil texture. The texture of the soil is one of the important properties of a soil map that has the composition and fraction of sand, dust, and clay. Soil texture is one of the physical properties of soil that is not easily changed. Soil texture analysis is an important component in determining soil quality and sustainability of agricultural management practices. Soil texture is a relative comparison of the three components that make up soil mineral fractions, namely sand, dust, and clay. These three soil fractions are distinguished from each other by the diameter of the particles concerned.

Cation exchange capacity (LCM) is a chemical property of the soil that is very closely related to soil fertility. Soil with a high cation exchange capacity (CEC) is able to absorb and provide nutrients better than soil with a low CEC. This is because these elements are in the soil absorption complex, so these nutrients are not easily lost or washed by water. Soils with organic matter content or with high clay content have a higher CEC than soils with low organic matter content or sandy soils (Räty et al., 2021). Saturation of the base shows the comparison between the number of alkaline cations and the number of all cations (alkaline cations and acid cations) present in the soil graft complex. The maximum number of cations that can be absorbed by the soil indicates the value of the cation exchange capacity of the soil. Alkaline cations are generally nutrients needed by plants. In addition, basas, are generally easy to wash, so the soil has not undergone much washing and is fertile soil. Alkaline saturation is closely related to soil pH, where soil with low pH has low alkaline saturation, while soil with high pH has high alkaline saturation (Kabala et al., 2025; Ma et al., 2024; Zhang et al., 2023a).

Soil pH is a value or degree that indicates the level of acidity or alkalinity of the soil. Soil pH can also be said to be a measure that indicates the number of hydrogen ions in a solution in the soil. Neutral pH is found on a scale of 7, pH with a value of low or less than 7 can be said to be acidic, while pH with a value high or more than 8 can be said to be alkaline (Zhang et al., 2019). Soil pH plays a role in plant growth, namely determining whether or not nutrients are easily absorbed by plants. In general, nutrients are easily absorbed by plants, namely at a neutral pH, because in a neutral state, most nutrients are easily soluble in water and affect the development of microorganisms (Barrow & Hartemink, 2023; Huang et al., 2025; Naz et al., 2022).

The pH content is required by the plant in a certain value to obtain optimal growth. Excessive or insufficient pH content results in inhibited growth in plants. The degree of acidity has a change in value over a certain period of time. pH will change and be erratic depending on the factors that can affect it (Barrow & Hartemink, 2023; Zhang et al., 2022). Soil pH variability is primarily controlled by several key factors, including parent material, climate, organic matter, and human activities. Parent material determines the initial chemical composition of the soil and thus influences whether soils tend to be acidic, neutral, or alkaline. Climate plays a critical role, as high precipitation in humid regions promotes leaching of base cations, resulting in acidic soils, whereas arid environments tend to accumulate basic cations, leading to alkaline conditions. Organic matter also significantly affects soil pH; incomplete decomposition of organic residues produces organic acids that can lower soil pH and delay neutralization processes. Furthermore, human activities such as fertilization and land management practices can accelerate soil acidification or alkalization depending on the inputs applied. These interacting factors collectively regulate soil chemical properties and are fundamental to soil formation and classification systems (Bockheim et al., 2014; Yescas-Coronado et al., 2022; Zhang et al., 2019)

Soil organic matter is a part of the soil which is the result of the decomposition of plant and or animal residues contained in the soil that continuously changes in shape, because it is influenced by biological, physical, and chemical factors. The role of organic matter is very important for soil fertility because it can improve plant growth. Through the mineralization process, organic matter is able to provide nutrients for plants, especially N, P, S and micronutrients. Organic matter has a major role in the formation of aggregates and good soil structure, so that it will indirectly improve the physical condition of the soil so that it will facilitate water penetration, water absorption, root development, and increase resistance to erosion. In addition, organic matter is also able to increase cation exchange capacity and soil resilience, photosynthesis, leachability, and pesticide biodegradation in the soil (Kuśmierz et al., 2023; Li et al., 2023; Zhao et al., 2023b). Organic matter is one of the related soil components and is the main source of C-organic producer. The more organic matter content in the soil, the higher the availability of C-organic. Loss of C-organic content in the soil can cause soil quality to deteriorate. A decrease in C-organic levels can be caused by intensive soil cultivation which has the potential to accelerate the rate of mineralization in soil organic matter. Rainfall and temperature can affect microbial activity in the decomposition process of root and plant residues, which can later affect the availability of C-organic in the soil. Poor land management can also cause the content of organic matter in the soil to decrease, and the level of C-organic matter is also reduced.

Electrical conductivity (EC) is a phenomenon of the flow or electric charge in the soil that comes from ions or soil colloids which then form an electric field. In other words, the earth's electrical conductivity is the earth's ability to conduct electric current (Corwin & Lesch, 2005; Friedman, 2005). The electrical conductivity of the soil occurs due to the existence of free salt content contained in the soil moisture content and the content of exchangeable ions found on the surface of soil solid particles. Salinity is the level of saltiness or dissolved salt content in water. Salinity can also refer to the salt content in the soil, the presence of salt affects the physical properties of the soil, including the shape of the soil structure, soil pH, and soil permeability (Zhang et al., 2024b).

2. Methods

2.1 Location and time of research

The research was conducted from October 2023 to December 2023. The research included field surveys, qualitative field observations, soil sampling, and quantitative laboratory analysis. Field observations were carried out in the area of Sitimulyo Village, Piyungan District, Bantul Regency. Yogyakarta while laboratory analysis was carried out at the General Soil Laboratory and Soil Physics Laboratory, Department of Soil, Faculty of Agriculture, Gadjah Mada University, Yogyakarta.

2.2 Data collected

The data collected in the study were primary data and secondary data. The research data collected were obtained from observations in the field, direct measurements in the field, and testing soil samples in the laboratory. The research data collected are as follows (Table 1):

Table 1. Data collected

No.	Data type	Data type	Data source
1.	Land morphology (coordinates, slope, vegetation density and type, land use, soil structure, rock material, soil material, soil depth, human activity)	Primary	Field survey
2.	Soil Physical Properties (soil texture)	Primary	Laboratory analysis
3.	Soil Chemical Properties (soil CEC, Base Saturation, pH H(2)O, organic matter, and DHL/salinity)	Primary	Laboratory analysis
4.	Rainfall, Temperature, and Air Humidity Data	Secondary	Climatology station
5.	Soil Type Map	Secondary	Land and spatial planning office

2.3 Research site selection

Sitimulyo Village is located in Piyungan Sub-district, Bantul Regency, which is included in Sub-Development Area (SWP) VI, which is directed as an agricultural area. In general, the development direction of Sitimulyo Village is agriculture and industry. As explained in the Bantul Regency RTRW, Sitimulyo Village itself is directed as an industrial development, tourism, and agricultural cultivation area. Sitimulyo Village is oriented towards the development of agriculture, which is the most superior sector among mining, building and construction, and so on. Furthermore, agricultural utilization areas according to the Bantul Regency RTRW include wetland agricultural areas and dryland agricultural areas, some of which are designated as Sustainable Food Agricultural Land and regulated separately by Regional Regulation.

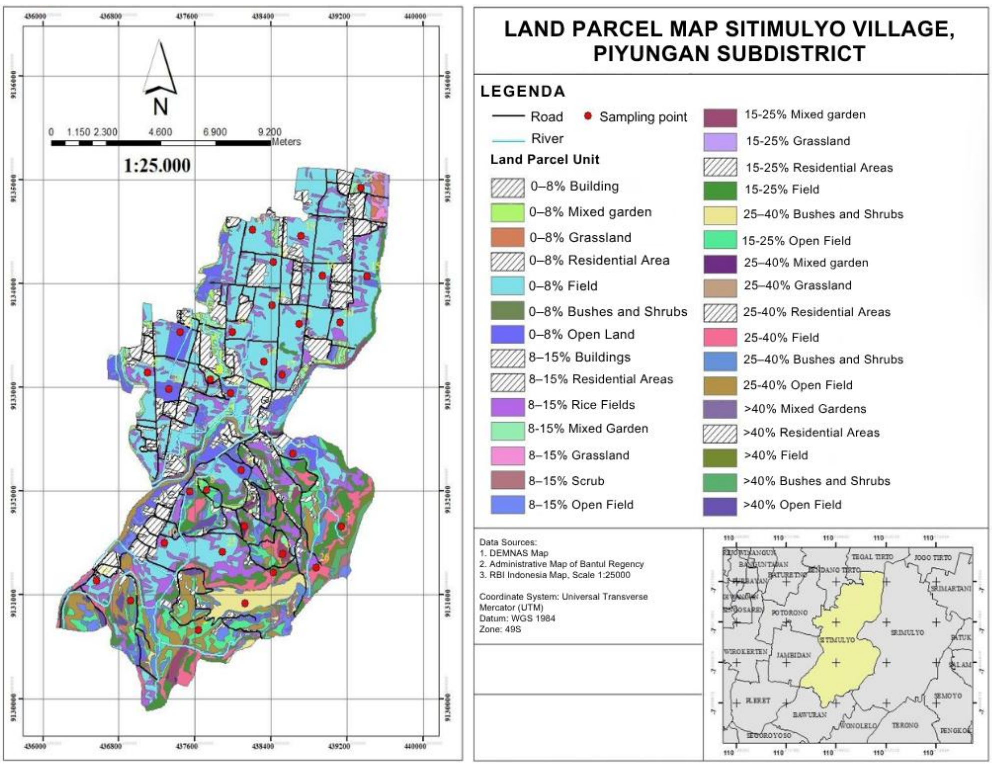

Fig. 1. Sitimulyo Village land unit map

Field observations were made in the form of observations of location coordinates, slope, effective soil depth (solum), geological aspects including rock material classes and rock outcrops, aspects of geomorphological processes including erosion, water quality aspects including color, odor, pH, and depth of the groundwater table. Furthermore, the data collected is testing soil samples at the Soil Physics laboratory, and the General Soils laboratory, Department of Soils, Faculty of Agriculture, Gadjah Mada University. Soil sample testing in the laboratory included texture, soil CEC, base saturation, pH H(2)O, organic matter, and DHL (salinity).

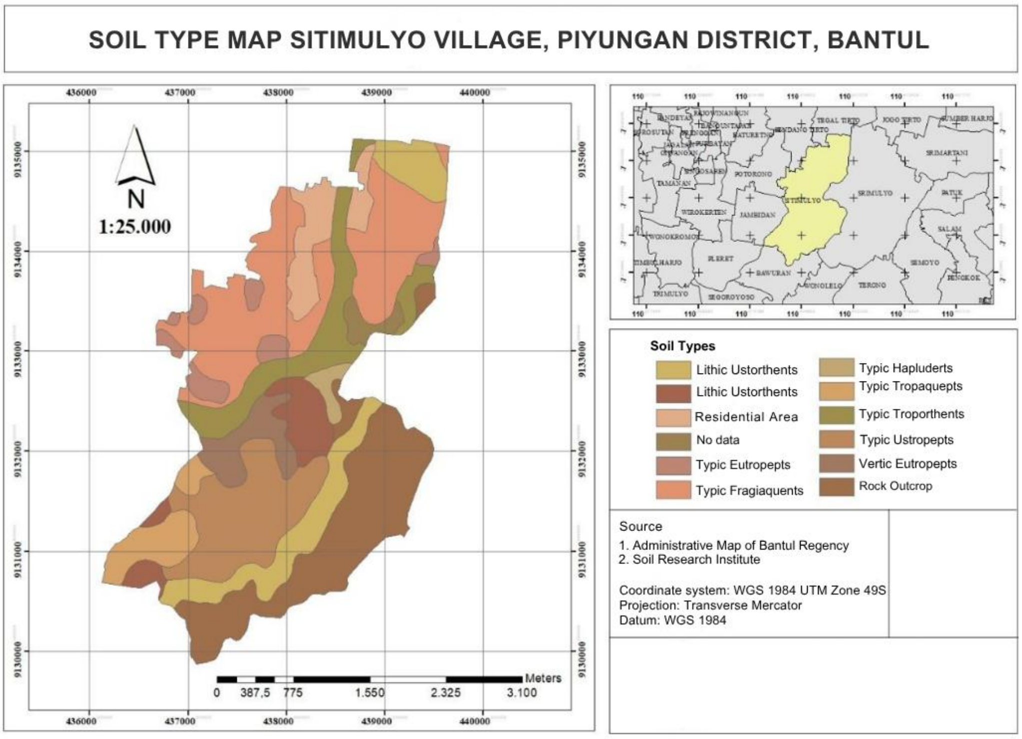

Fig. 2. Soil type map of Sitimulyo Village

2.4 Physical aspects and soil sampling in the field

The analysis of physical aspects was conducted using descriptive methods, namely explaining a situation in the field based on soil characteristics and water quality in each land use. The observed aspects are: Soil depth is measured using a hoe or soil drill and meter by measuring from the ground surface to the soil layer that cannot be penetrated by plant roots or layers that have rocks. Surface rocks are observed by looking at the presence or absence of small or large stones scattered on the soil surface or cultivation layer at the site. Rock outcrops are observed by looking at the presence or absence of rocks (large rocks) that are exposed at the study site. Rock outcrops are observed by looking at the presence or absence of rocks (large rocks) that are exposed at the study site. Color analysis of well water can be one of the parameters for determining water quality. Determination of water color is determined using the sense of sight. From the reading results, the turbidity level of the well water can be determined which will then be adjusted to the water turbidity standard. The observation results are compared with the clean water quality criteria according to the Minister of Health Regulation. Determination of water odor is determined using the sense of smell. The reading results are adjusted to the clean water odor standard. Water pH analysis is carried out by means of a 100 ml sample of well water that has been taken using a stock bottle inserted into a beaker glass. The water sample was then tested using a pH meter to determine the degree of acidity.

Measurement of the depth of the groundwater table is determined through field surveys by conducting direct interviews with residents who own wells for data accuracy.

Drainage observations were made by looking at the presence or absence of standing water or the presence or absence of gray color or rust spots on the soil layer of the study area. Homogeneous soil without yellow spots or iron rust, brown and gray means that the drainage of the soil is good. Soil with gray, brown and yellowish spots indicates that the soil has poor drainage. Soil samples were taken from different slope levels, namely flat (0-8%), gentle (8-15%), rather steep (15-25%), steep (25-40%), and very steep (>40%) and on several land uses such as moor, rice field, mixed garden, and shrubs. The soil samples taken were disturbed soil samples at a depth of 0-30 cm. Soil sampling has the purpose of obtaining data from laboratory measurements. Soil collection techniques were carried out using soil drills and hoes.

2.5 Laboratory data measurement

Laboratory measurements are carried out using disturbed soil samples. The disturbed soil samples to be analyzed in the laboratory were previously prepared until they were naturally wind-dried. Furthermore, physical and chemical analysis was carried out in the laboratory. The analysis carried out included:

2.5.1 Soil texture

Soil texture shows the composition of soil constituent particles expressed as a ratio of relative proportion (%) between sand, dust and clay fractions. Determination of soil texture is done through three stages, namely, the removal of cementation material, the dispersion stage, and the separation (fractionation) stage. The method used is the pipette method which is a direct method of sampling soil particles from the suspension using a pipette at depth (h) and time (t) that particles with a diameter >X are already at a depth >h. Organic matter is oxidized with H(2)O2and soluble salts are removed from the soil with HCl while heating. The remaining material is mineral consisting of sand, dust and clay. The soil retained on the sieve is the sand fraction. All soil fractions from the pipetting were then put into a vaporizer cup for baking. Then weighed by weight according to the gravimetric method in order to obtain the percentage of each fraction (Balitbang Pertanian, 2006). Data from the percentage of soil fractions were then analyzed using a texture triangle to determine the soil texture class. Determination of soil texture value is entered into the formula:

$$\text{Sand (\%)} = \frac{P}{P+D+L} \times 100\% \qquad \text{(Eq. 1)}$$

$$\text{Silt (\%)} = \frac{D}{P+D+L} \times 100\% \qquad \text{(Eq. 2)}$$

$$\text{Clay (\%)} = \frac{L}{P+D+L} \times 100\% \qquad \text{(Eq. 3)}$$

P is weight of sand fraction (g), D is weight of dust fraction (g), L is weight of clay fraction (g). The percentage of each known fraction is entered into the texture triangle to determine the soil texture class.

Data from the percentage of soil fractions were then analyzed using a soil texture triangle (Fig. 3) to determine the soil texture class. The soil texture triangle is a triangular diagram that represents the relative proportions of sand, dust (silt), and clay in soil. Each side of the triangle corresponds to 0–100% of one soil fraction. By plotting the percentages of sand, dust, and clay on the triangle, the intersection point determines the soil texture class, such as sand, sandy loam, clay loam, silty clay, or clay. This diagram helps classify soil based on particle size distribution and is commonly used in soil science to interpret soil physical properties.

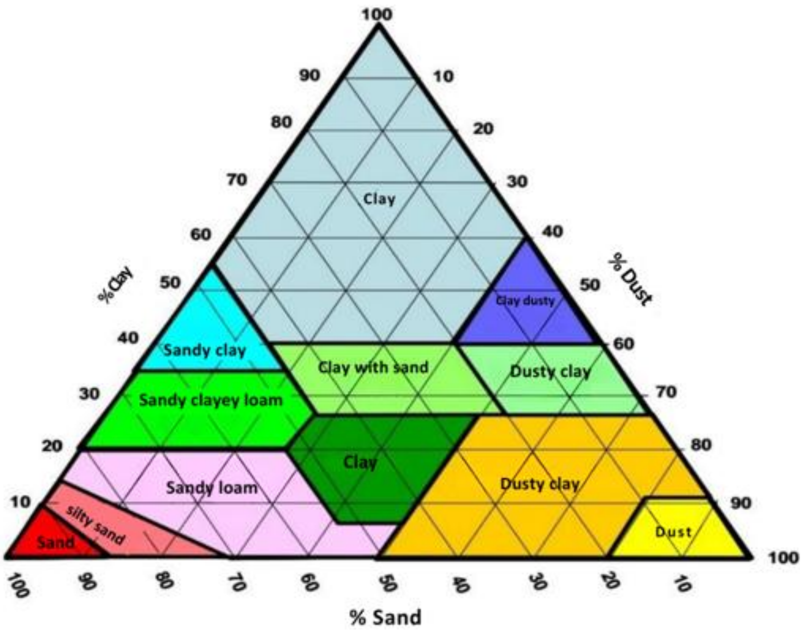

Fig. 3. Soil texture triangle

2.5.2 Cation exchange capacity of soil (cmol)

CEC analysis is done by direct distillation. In the direct distillation method, the analysis is carried out like the determination of soil N-Kjeldahl. The contents of the percolation tube (after completing the washing stage with 96% ethanol) were transferred quantitatively into a boiling flask. The percolation tube is rinsed using ion-free water (distilled water is used in this analysis). A reservoir was prepared for the liberated NH3 which was an erlenmeyer containing 20 ml of 2% boric acid to which three drops of Conway (BCG+MR) indicator (red in color) were added and connected to the distillation apparatus. With a measuring cup, 20 ml of 40% NaOH and 250 ml of distilled water were added to the boiling flask containing the sample and immediately closed. Distillation was carried out until the volume of the container reached 150 ml or about 40 minutes (until green). The distillate was titrated with 0.1N HCl to a pink color. The sample volume (Vc) and blank (Vb) were recorded. The data were processed into soil CEC values and classified based on the following calculation formula:

$$\text{CEC (me/100 g)} = (A - B) \times N \times 0.1 \times fk \times \left(\frac{1000}{w}\right) \quad \text{(Eq. 4)}$$

The Cation Exchange Capacity (CEC) can be calculated using the formula CEC (me/100 g) = (A − B) × N × 0.1 × fk × (1000 / w), where A represents the volume of titrant used for the sample, B is the volume of titrant used for the blank, N is the normality of the titrant, fk is the correction factor, and w is the weight of the soil sample in grams. This formula is used to determine the soil's ability to hold and exchange cations, which is an important indicator of soil fertility and nutrient availability.

2.5.3 Base saturation (%)

The analysis of base saturation is determined by the relationship with the pH of H_2O. This relationship is obtained with the pH of H2O determined by using the ratio of soil: water = 1: 2,5. In other comparisons the relationship is not necessarily the same. This relationship is influenced by organic matter, clay minerals, exchangeable cations, and texture. This relationship cannot apply to soils that are rich in organic matter, contain a lot of clay, have exchangeable cation values that contain a lot of Na, or are very coarse textured (very high sand content). The determination of base saturation is calculated from the value of S (total exchangeable metal cations) according to Brown and the determination of H (exchangeable H ions) according to Brown.

2.5.4 pH H2O and organic matter

The pH value indicates the amount of hydrogen ion concentration (H^+) and (OH ($^-$)) in the soil, the actual pH (H2O) is measured by measuring the amount of H^+ ions in the soil solution. C-Organic analysis was carried out using the Walkley and Black method, the principle of the Walkley and Black method is that K2Cr2) O72 which is given in excess and then reduced when reacting with soil, is considered equivalent to C-Organic in the soil sample. The determination of the soil organic matter value is entered into the formula:

$$\text{CI (\%)} = \frac{(B-A)\times fk\times N\times 3}{w}\times\frac{50}{5}\times\frac{100}{77}\times 100\% \quad \text{(Eq. 5)}$$

The Cation Index (CI) is calculated using the titrant volume of the blank (B), the sample (A), the correction factor (fk), the normality of the titrant (N), and the sample weight (w). This calculation is used to quantify the percentage of cation-related properties in the sample. The CI value is also important for assessing soil organic matter characteristics and overall soil fertility. The organic matter content (OM), where C represents the percentage of organic carbon in the sample. This equation is commonly used to estimate organic matter based on measured carbon content, assuming that organic matter contains approximately 58% carbon. Soil organic matter:

$$\text{OM} = \text{C} \times \left(\frac{100}{58}\right) \quad \text{(Eq. 6)}$$

2.5.5 Electrical conductivity (Salinity) (dS/m) and effective soil depth

The value of electrical conductivity (DHL) reflects the dissolved salt content. The DHL or salinity of a soil suspension is measured with a conductometer that has been calibrated using NaCl standard solution. Every time you calibrate and measure soil samples, the electrodes are washed and dried with paper towels. DHL values are reported in dS m-1 using three decimals. Effective soil depth (solum) can be a limiting factor for plant growth as it relates to root penetration (Table 2).

Table 2. Soil depth hierarchy

No.	Class	Depth (cm)	Score
1.	Very shallow	<25	1
2.	Shallow	25-50	2
3.	Medium	50-90	3
4.	In	>90	4

2.5.6 Soil texture and base saturation (%)

Effective Soil texture is one of the important soil characteristics for plant growth, related to the provision of water for plants and the development of plant roots. Knowing these land characteristics will facilitate the selection and determination of suitable commodities to be developed in an area, especially sorghum (*Sorghum bicolor L. Moench*). The order of soil particle surface area based on soil texture from smallest to largest is silt < sandy clay < loamy clay < clay < loam.

Table 3. Classification of soil texture classes

No.	Class	Soil texture	Movement
1.	Fine somewhat	Sandy loam, dusty loam, loam	1
2.	Fine	Loamy loam, sandy loam, and dusty loam	2

No.	Class	Soil texture	Movement
3.	Medium somewhat	Sandy tuff, tuff, dusty tuff, and dusty	3
4.	Coarse	Sandy muddy, fine sandy muddy, and slightly fine sandy muddy	4
5.	Coarse	Sand, muddied, and sandy	5

Cation exchange capacity (CEC) refers to the ability of soil colloids to adsorb and exchange cations. It is determined through laboratory analysis of soil samples using standard extraction methods. The results are expressed in milliequivalents per 100 g of soil (me/100 g).

Table 4. Soil Cation exchange rate

No.	Soil CEC class	Value	Value
1.	Very low	<5	1
2.	Low	5-16	2
3.	Medium	17-24	3
4.	High	25-40	4
5.	Very high	>40	5

Base saturation represents the proportion of base cations relative to the total cations (both base and acidic) present in the soil sorption complex. It is determined by comparing the amount of exchangeable base cations to the cation exchange capacity. The results are expressed as a percentage to indicate soil fertility status.

Table 5. Base saturation score (%)

No.	Soil CEC Class	Value	Value
1.	Very low	<20	1
2.	Low	20-40	2
3.	Medium	41-60	3
4.	High	61-80	4
5.	Very high	>80	5

2.5.7 pH H_2O and organic water

Soil reaction indicates the acidity or alkalinity of the soil and is expressed as pH. It is determined by measuring the concentration of hydrogen ions (H^+) in the soil using a pH meter. Higher H^+ concentrations correspond to lower pH values, indicating more acidic soil conditions.

Table 6. H2O pH hierarchy

No.	Soil CEC Class	Value	Value
1.	Very acidic	<4.5	1
2.	Acidic	4.5-5.5	2
3.	Somewhat sour	5.5-6.5	3
4.	Neutral	6.6-7.5	4
5.	Somewhat Alkaline	7.6-8.5	5
6.	Alkaline	>8.5	6

Soil organic matter plays an important role in improving soil fertility. It is commonly evaluated through total C-organic content using standard laboratory analysis. Higher C-organic values indicate better soil quality and enhanced nutrient availability.

Table 7. Organic matter movement

No.	Organic matter class	Value	Score
1.	Very low	<1	1
2.	Low	1-2	2
3.	Medium	2.1-4.2	3

4.	High	4.3-6	4
5.	Very high	>6	5

2.5.8 Electrical conductivity/salinity (dS/m)

Soil salinity in the field is indicated by the high condition of Na salts as a result of seawater intrusion or salt. High salinity in the root zone will inhibit the absorption of water and nutrients dissolved therein. Salt-free soil indicates that the plants are not disturbed by the amount of DHL, because the higher the DHL value, the more it inhibits plant growth.

Table 8. Electrical conductivity/Salinity (dS/m)

No.	Electrical conductivity/salinity class	Value	Score
1.	Very low	<1	1
2.	Low	1-2	2
3.	Medium	2-3	3
4.	High	3-4	4
5.	Very high	>4	5

Surface rocks refer to coarse materials of medium to large size found on the soil surface and within the soil profile. They are part of the solid materials forming the Earth's crust. The presence of surface rocks is usually assessed through field observation to describe soil physical conditions.

Table 9. Surface rock movement

No.	Class	Value	Score
1.	None	Less than 2% of land surface covered	0
2.	Little	2%-10% of soil surface covered, tillage and planting slightly disturbed,	1
3.	Moderate	10%-50% of the soil surface is covered, tillage planting are disturbed	2
4.	Heavy	50%-90% of the soil surface is covered, tillage and planting are severely disrupted	3
5.	Very much	>90% of soil surface covered, soil cannot be cultivated at all	4

2.6 Analysis of results, presentation of results, discussion, and drawing conclusions

The analysis of research results used is quantitative descriptive analysis in the form of tabulation. Data from laboratory analysis and field observations were compared descriptively quantitatively based on tabulations at each point to compare water quality, physical characteristics of soil, soil chemistry, geological conditions, and geomorphological conditions of land use types. Presentation of results is shown in tables and graphs. Presentation in the form of tables and graphs is used to present differences in soil physical characteristics, soil chemistry, geological conditions, and land geomorphology conditions in each land use type. Discussion of the results is carried out by understanding each physical, chemical, and land condition characteristics that exist in each land use type.

3. Results and Discussion

3.1 Description of the area (location/area, land development directive, and geomorphologhy)

Sitimulyo Village is located in the northeastern part of Bantul Regency with a distance of 5 km from the district capital and 18 km from the district capital. Sitimulyo Village is administratively located in the area of Piyungan District, Bantul Regency, D.I. Yogyakarta Province. Geographically, Sitimulyo Village is bordered by Tegaltirto Village in the north, Srimulyo Village in the east, Bawuran and Wonolelo Villages in the South, and Potorono Village in the west. Sitimulyo Village has a flat area of 130 ha, hilly 572 ha, and an overall area of 940,962 ha. According to the Regional Long-Term Development Plan (RPJPD) of Bantul Regency for 2006-2025, in general, Sitimulyo Village has a development direction which is an agricultural and industrial area which includes: protected forest areas around settlements, with the development of community forests and agroforestry; tourism areas including natural, cultural and industrial tourism; small industrial development areas (home industry); and large industrial development areas. The geology of Sitimulyo Village develops from the Semilir Formation (Tmse) and Younger Merapi Volcano Deposits (Qmi) (Fig. 4).

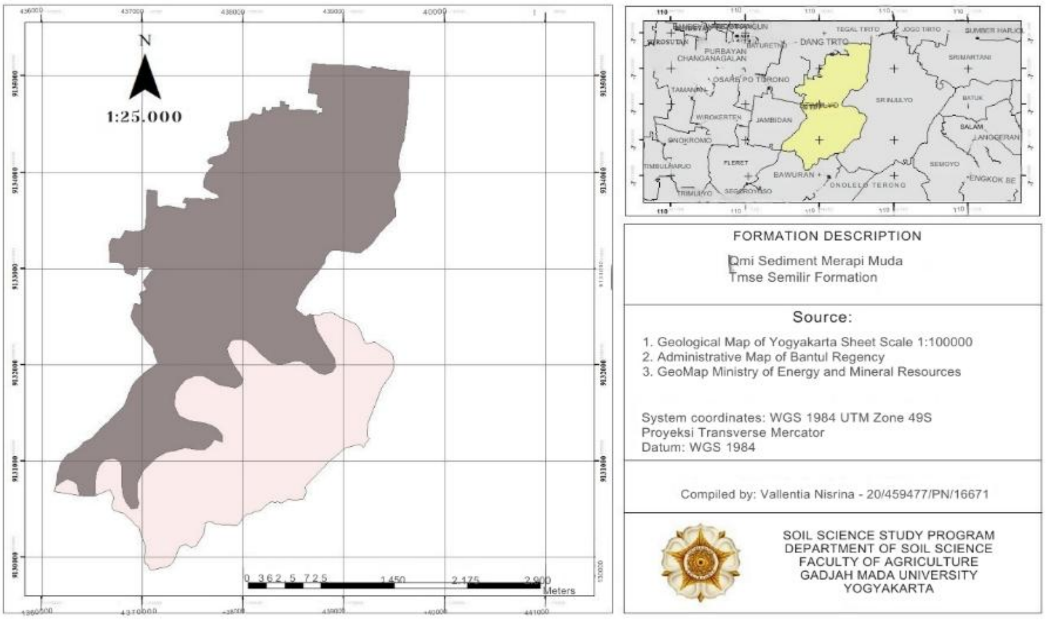

Fig. 4. Geological map of Sitimulyo Village

Mount Semilir around Baturagung, consisting of tuff, lapillary tuff, tuffaceous sandstone, claystone, shale and siltstone with breccia inserts, as gravity flow deposits in a deep marine environment. This formation is of Early Oligocene age (N1- N2). Furthermore, the Young Merapi Volcanic Deposits are volcanic rocks in the form of volcanic deposits of Mount Merapi which are relatively young, formed in the Quaternary period. Soil types in Sitimulyo Village based on spatial analysis include entisol and inceptisol soils (Fig. 5).

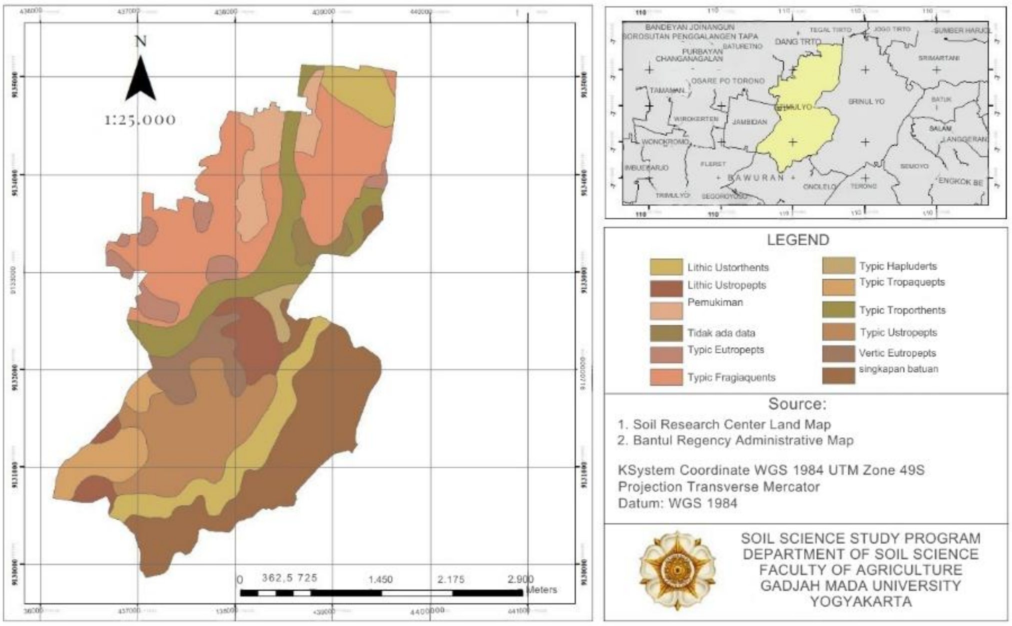

Fig. 5. Map of soil type in Sitimulyo Village

The soil in Sitimulyo Village develops from the Semilir Formation with lithology of brimming stones, tufan sand, and tuf. The soil has a thin layer of soil, many rocks, less fertile soil, and the existing potential is white stone quarrying materials, especially in the areas of Banyakan Hamlet, Ngablak Hamlet, and Pagergunung Hamlet (Bronto et al., 2009; Nugrahini et al., 2019; Rizky et al., 2025; Surono, 2008). In general, the inceptisol soil in Sitimulyo Village has soil characteristics that are still new in the developing stage, so there are no signs of development on the soil horizon. Inceptisol soilhas a thin solum, dark brown in color, has a dusty texture, dusty clay, clay, the soil structure is angular clumps, and has a pH content of 5.0 – 6.0. Inceptisol soils are mostly found in areas with steep to very steep slopes. Entisol soil in Sitimulyo Village has various textures, ranging from sand, clay, dust, and has brighter and lighter colors. The colors can range from white, gray, light brown.

According to village monographic data, the Sitimulyo Village area is located at an altitude of 110 m above sea level. The distribution of slope slope classes in Sitimulyo Village is divided into 5 hill classes. Most of the plains in Sitimulyo Village are sloping and a small part is included in the distribution of steep slope classes. The distribution of steep slope classes is located on the south and east sides of Sitimulyo Village (Fig. 6). These conditions affect the geomorphological processes that occur in Sitimulyo Village, one of which is erosion. Erosion of grooves and ditches is found in most of the land use of Sitimulyo Village which is on a steep to very steep slope.

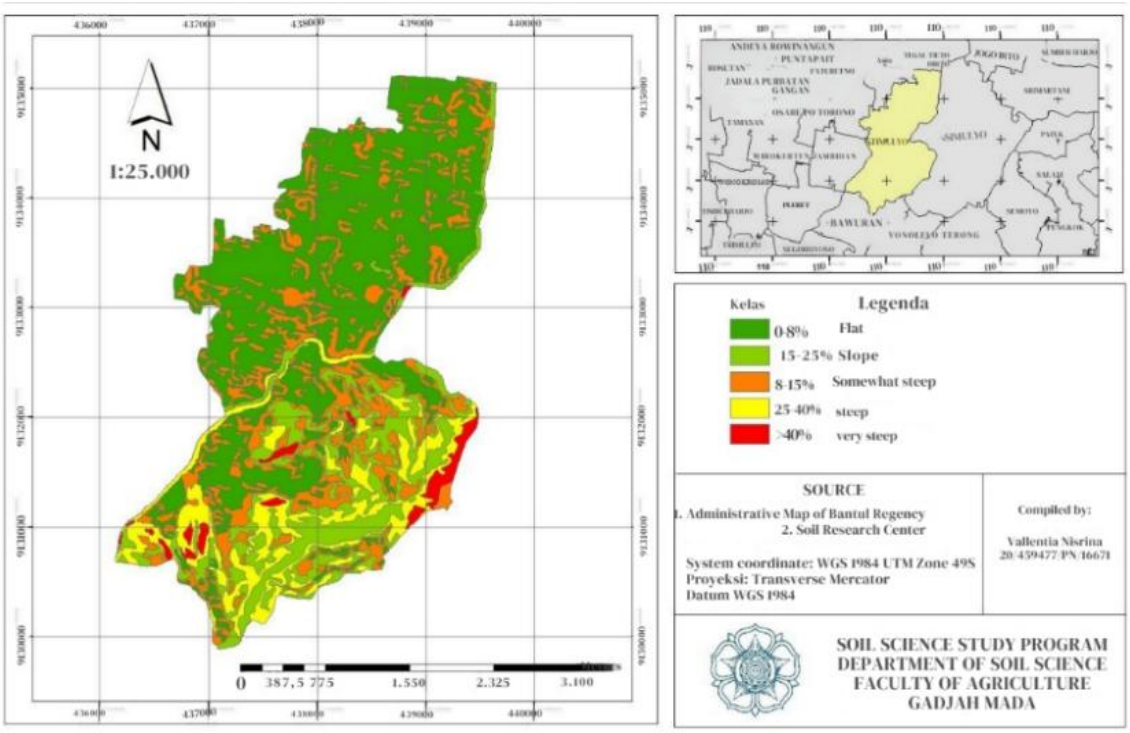

Fig. 6. Map of the slope of Sitimulyo Village

The use of land in Sitimulyo Village is generally used as agricultural and non-agricultural land. According to Bantul Regency Regional Regulation Number 04 of 2011 concerning the Bantul Regency Regional Spatial Plan for 2010-2030, agricultural areas include wetland agricultural areas, dryland agricultural areas, and livestock areas. The wetland area in Sitimulyo Village includes rainfed rice fields and irrigated rice fields, while the dryland agricultural area includes moors, mixed gardens, shrubs, and grasslands. The use of non-agricultural land includes for settlements, public buildings, factories, roads, and so on (Fig. 7).

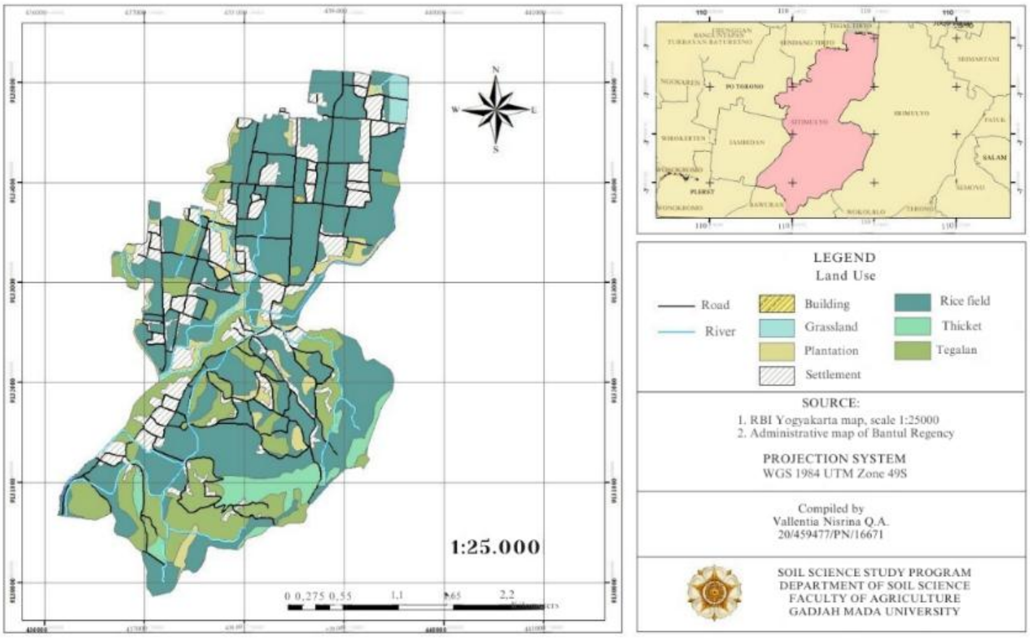

Fig. 7. Land use map of Sitimulyo Village

3.2 Rock

In Bantul Regency there are several formations, namely the Sentolo Formation, the Yogyakarta Formation, the Semilir Formation, the Nglanggran Formation, the Wonosari Formation, the Sambipitu Formation, and the Sand Gum Formation. According to the Geological Map of the Yogyakarta Sheet, Sitimulyo Village has a Semilir Formation and Merapi Muda Volcanic Deposit. The Semilir Formation was revealed well in Mount Semilir around Baturagung, consisting of interludes of tufa, lapili tufa, tufaan sandstone, clay rock, shale and silt with breccia inserts, as gravitational flow deposits in the deepsea environment. This formation is of Early Oligocene (N1-N2) age. Furthermore, the Merapi Muda Volcano Sediment is a volcanic rock in the form of volcanic deposits of Mount Merapi which is relatively young formed in the quaternary period.

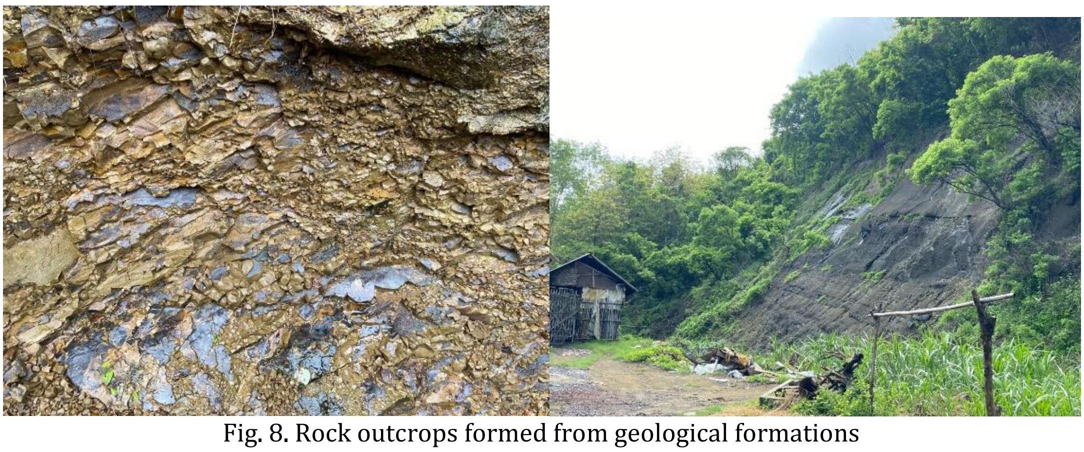

Fig. 8. Rock outcrops formed from geological formations

The lower part of the Semilir Formation is one of the Opak Watersheds located in Sitimulyo Village. where there is basalt andesite as a pillow lava flow. Sandstone is generally graded to form layers, parallel or corrugated laminates and erosional, and forms loops with fine tuf. The Semilir Formation rides in harmony over the Kebobutak Formation, but locally it is not in harmony. Meanwhile, the Merapi Muda Volcanic Sediment (Qmi) consists of tuf, ash, breccia, agglomerates and inseparable lava flows. These geological factors can affect the structure and texture of soils and rocks, soil and rock types, river flow patterns, topography, geological structures (folds and faults), tectonics and volcanoes, surface rocks, and rock outcrops.

Based on the results of observations in the field, the surface rocks found in Sitimulyo Village range from 2%-50% (Table 10). Surface rocks at the research site are generally included in the class of barriers with light to medium value. Surface rocks in some land uses are an obstacle because the percentage is quite high, which is >10%. The high percentage of surface rocks and rock outcrops will complicate land management and inhibit plant root growth (Yang et al., 2022; Zhang et al., 2024a; Zhang et al., 2016). Rock outcrops show the abundance of rocks present in the soil solum. The number of rocks at the research site in several land uses is included in the low to moderate classification with a range of <5% and 5-15%.

Table 10. Surface rocks and rock outcrops in various land uses

No	Slope slope (%)	Land use	Surface rock (%)	Score	Rock outcrops (%)
1	0-8	Paddy	10-50	2	<5
2		Mixed gardens	10-50	2	<5
3		Paddy	2-10	2	<5
4		Paddy	2-10	2	<5
5		Paddy	10-50	2	<5
6		Farm	10-50	2	<5
7		Paddy	10-50	2	<5
8		Paddy	2-10	1	<5
9		Paddy	2-10	1	<5
10		Farm	10-50	2	5-15
11		Farm	2-10	1	<5
12		Farm	10-50	2	<5
13		Paddy	10-50	2	<5
14		Paddy	10-50	2	<5
15		Paddy	2-10	1	<5
16		Paddy	10-50	2	<5
17		Farm	10-50	2	5-15
18		Farm	10-50	2	<5
19	8-15	Paddy	10-50	2	<5
20		Farm	10-50	2	5-15
21		Paddy	10-50	2	<5
22		paddy	2-10	1	<5
23		Mixed gardens	10-50	2	<5
24	15-25	Farm	10-50	2	5-15
25		Bush	10-50	2	5-15
26		Paddy	10-50	2	5-15
27		Mixed gardens	10-50	2	5-15
28		Mixed gardens	10-50	2	<5
29		Farm	10-50	2	<5
30		Paddy	10-50	2	5-15
31	25-40	Paddy	10-50	2	5-15
32	>40	Bush	10-50	2	5-15

3.3 Soil

3.3.1 Soil morphological characteristics

Based on observations at the research site, it is suspected that the inceptisol soil is on the upper slope with a steep slope to very steep slope and is located in land use such as moorlands and mixed gardens planted with mahogany, sweet potato, and so on (Fig. 9). Most of the inceptisol soils in Sitimulyo Village develop on steep slopes, where soil erosion has transported some of the topsoil continuously. The soil is a newly developed soil and has a diverse texture from coarse to fine depending on the level of weathering of the parent material. According to (Herdiansyah et al., 2022), low inceptisol soil fertility, its effective depth from shallow to deep. In addition, the type of soil in Sitimulyo Village, which is located on a flat slope to a sloping slope, is suspected to be a type of entisol soil that developed from the deposits of young Mount Merapi (Qmi) (Fig. 9).

Fig. 9. Soil outcrops on slopes (a) slightly steep to very steep; (b) sloping to flat

Based on the results of observations in the field, the characteristics of the soil in Sitimulyo Village have characteristics that are distinguished by several parameters such as soil depth (solum), horizon, color, texture, structure, consistency, root conditions, and amount of coarse material. The outcrops were taken at different slopes and different geological formations. Outcrop (a) is taken in a location with a slope slope between slightly steep to steep with the Semilir Formation (Tmse), while outcrop (b) is taken in a location that has a slope between slopes to flat in the form of the Mount Merapi Muda Sediment Formation (Qmi). In general, both have five horizon layers, with the Ap horizon on the first layer for both overhangs, while the second through fifth layers have different horizons. The two outcrops are dominated by the texture of clay in the form of sand clay with a type of angular clump structure and plate.

The most significant differences in the two outcrops are in soil depth, soil color, consistency, root conditions, and amount of coarse material. The depth of soil in the outcrop with a slope of the slope is slightly steeper to steeper than the outcrop found on the slope of the slope to the flat. According to (García-Gamero et al., 2022; Zhang et al., 2023b; Zhao et al., 2023a), the difference in land cover provides a significant difference in the depth of the soil, because the steeper the slope of a land, the shallower the soil depth. The soil on the upper slope tends to be shallower as a result of the erosion process so that there is soil erosion on the upper slope and buried on the lower slope (lower slope). This causes the depth of the soil on the lower slope to tend to be deeper compared to the slope above. The different soil colors in the two outcrops can be influenced by several factors such as the formation of the rocks that form the parent material of the soil, organic matter, the type of minerals contained in it, and the moisture content of the soil. The soil color in the outcrop with a slightly steep to steep slope is dominated by dark brown, while the soil color in the outcrop with a slope slope to flat has a light brown to grayish-white color. According to research conducted by (Vodyanitskii & Savichev, 2017), soil color can be influenced by several factors, such as high organic matter can cause dark or black soil color, while the content of light fractional primary minerals such as quartz and plastic clasts gives it a grayish-white color. In addition, the paler soil color (grayish-white) in the second outcrop can be caused by the mineral content in the Merapi Muda Volcano Sediment Formation, one of which is an agglomerate characterized by a gray color (Moritsuka et al., 2014, 2019; Sirisathitkul & Sirisathitkul, 2025; Vodyanitskii & Savichev, 2017).

The consistency of the soil in the two outcrops also has differences. The consistency in the outcrop with a slope is slightly steep to steep, which is rather sticky. Meanwhile, the consistency in the outcrop with a slope of flat to sloping slopes is soft. This can be influenced by the type of clay on the adhesion of the soil both in a dry, humid, or wet state because when pressed there is a strong tensile force because it still contains clay (Almasoudi et al., 2023). Soil consistency can also affect roots in outcrops. Outcrops with a slightly steep to steep slope have a large meso size in each layer, while outcrops with a sloping to flat slope have a micro size with a small amount and are only found in the first layer (Jin et al., 2013).

Inceptisol soil that develops based on field observations is still classified as young soil with better soil profile development when compared to entisol. Inceptisol soil has an epipedon that characterizes the umbric and ochric horizons with a subsurface horizon or cambric endopedon which is characterized by a change in soil color or structure. Other horizons that are commonly found are duripan, fragipan, calcic, gypsy and sulfidic. The inceptisol soil in Sitimulyo Village has diagnostic characteristics in the form of a cambric endopedon marked by the presence of a Bw horizon. Entisol soils tend not to experience deep solum development due to climatic factors, in this case low rainfall, where the process of water infiltration and water leaching into the soil solum is lacking, so that the formation of the soil horizon is hampered (Kafle, 2022). This is also supported by the low rainfall level in Sitimulyo Village with an average value of 1634.52 mm/year in the last ten years. According to (Adam et al., 2021; Dai et al., 2022), entisol is a type of soil that is commonly found around active volcanoes and is relatively young with a dominant texture of sand so that the water storage capacity is also low due to the high level of soil porosity. The epipedon is only an occlusion while the lower horizon is non-existent.

3.3.2 Characteristics of soil physics

The characteristics of soil physics are one of the environmental elements that greatly affect the availability of soil water and air. The physical properties of the soil are properties that are related to soil fertility and affect the growth and production of plants, so that the physical properties of the soil can be used as an indicator in plant development. The characteristics of soil physics properties in this study are soil texture and effective soil depth. The soil texture at the study site had a fluctuating number of fractions (sand, dust, and clay) with each land use and different slope slopes. The most significant difference in the number of fractions is in the use of shrub land with a slope of 15-25%, which is dominated by a lot of dust fractions. The research location was dominated by a dust fraction with a content of more than 20%. Soil with a texture dominated by dust will have many meso (medium) pores that are slightly porous so that they are very susceptible to landslides compared to clay textures which have better water holding capacity.

Based on the results of the classification of soil texture types and harkation values, the soil texture in Sitimulyo Village is dominated by slit and clay textures (Table 11). The classification of soil texture at a slope of 0-8% in some land uses is dusty, slit sand very coarse, slit sand very fine, and clay. The texture of the soil with a slope of 8-15% is dust, clay, slit, and dusty, while on a slope of 15-25% it is dusty clay, dust, and slit, on a slope of 25-40% it has a texture of dusty soil and on a slope slope >40% has a texture of dirt. Clay or clay textured soil has the ability to store water in the soil for a long time than soil with a sandy and sandy clay texture, this is influenced by its adsorptive surface area. It can be seen that the smoother the texture of the soil. the greater the soil's ability to store water (Wang et al., 2020). The results show that soil textures in several land-use types within certain slope classes are suitable for sorghum development. Sorghum is adaptable to a wide range of soil textures, including fine textures (sandy clay, silty clay, and clay), moderately fine textures (clay loam, sandy clay loam, and silty clay loam), and medium textures (sandy loam, loam, silt loam, and silt). According to (Reinhardt et al., 2021; Sauer et al., 2024), the development of sorghum plants on soils that have the characteristics of clay texture. sandy clay. and dusty clay are very suitable. The texture of the soil is one of the growing requirements of the plant. Also applies to sorghum plants. Sorghum plants can grow very well in soils that have the characteristics of clay, sandy clay, dusty clay, clay.

Table 11. Soil texture analysis results

Yes	Slope (%)	Land use	Texture	Score
1	0-8	Rice field	Coarse sandy loam	4
2		Mixed garden	Clay	1
3		Rice field	Sandy loam	4
4		Rice field	Loam	3
5		Rice field	Loam	3
6		Dryland farming	Clay	1
7		Rice field	Loam	3
8		Rice field	Loam	3
9		Rice field	Silty loam	3
10		Dryland farming	Clay	1
11		Dryland farming	Silty loam	3
12		Dryland farming	Loam	3
13		Rice field	Silty loam	3
14		Rice field	Silty loam	3
15		Rice field	Silty loam	3
16		Rice field	Clay	1
17		Dryland farming	Very fine sandy loam	4
18		Dryland farming	Silty Loam	3
19	8-15	Rice field	Silt	3
20		Dryland farming	Clay	1
21		Rice field	Loam	3
22		Rice field	Silty loam	3
23		Mixed garden	Loam	3
24	15-25	Dryland farming	Silty clay loam	2
25		Shrubland	Loam	3
26		Rice field	Silty clay loam	2
27		Mixed garden	Silty clay loam	2
28		Mixed garden	Loam	3
29		Dryland farming	Silt	3
30		Rice field	Loam	3
31	25-40	Rice field	Silt	3
32	>40	Shrubland	Loam	3

Soil with a clay texture has a limiting factor, namely drainage. While sandy clay has a limiting factor that easily passes through water and nutrients. Based on the observation results of Sitimulyo Village, which has an area of 940,962 ha, most of it has a deep relative soil depth, as evidenced by the measurement of outcrops in several land uses with different slopes (Fig. 10). The effective depth of the soil at the study site showed a value of >60 cm with deep values (Table 11).

Fig. 10. Soil depth at the outcrop for the use of rice fields and moorlands

The effective depth of the soil is one of the parameters of land preparation in the evaluation of land suitability which is important to consider because the depth of the soil can be a limiting factor of some plants. The shallower and deeper the effective depth of the soil will affect other physical properties of the soil such as providing or storing water so that there is no inundation that damages plants that cannot withstand inundation (El Behairy et al., 2022; Guo, 2020).

3.3.3 Chemical characteristics of soil

The characteristics of soil chemical properties indirectly affect the availability of plant nutrients so that they play a very important role in determining the properties and characteristics of the soil that determine soil fertility. The characteristics of soil chemical properties reviewed in this study include pH, organic matter, LCM, alkaline saturation, and salinity. The influence of organic matter on soil chemical fertility affects the cation exchange capacity, anion exchange capacity, soil pH, soil strength, and soil fertility. The low C-organic value indicates that the soil organic matter in Sitimulyo Village is low so that the soil CEC is low. In addition, the low C-organic value at the study site was caused by the slope of some sample points which could cause surface flow and soil texture in some land uses to affect C-organic storage in the soil. According to (Balík et al., 2025; Paul, 2016; Šimanský et al., 2025), differences in the topographical conditions of an area can affect the soil in binding the content of organic matter in the soil. Organic matter has a very important role for soil fertility. This is because organic matter has an influence that can be short-term or long-term. The short-term effect is affected by non-humus materials, while the long-term effect is given by the humus material. Both influences can improve plant growth. The availability of organic matter in the soil indicates the availability of carbon and energy sources for soil microorganisms that have a very dominant role in the C-organic remodeling process. Through the mineralization process, organic matter is able to provide nutrients for plants, especially N, P, S, and micronutrients (Gan et al., 2020; Jing et al., 2026; Vilkienė et al., 2016; Xie et al., 2022).

Organic matter plays an important role in the physical and chemical properties of the soil. Physically organic matter can help in maintaining moisture, adhesives between soil aggregates, and the formation of soil structures. Organic matter is one of the adhesives that affects the stability of soil aggregates. Meanwhile, chemically, organic matter affects the cation exchange capacity, anion exchange capacity, soil pH, and nutrient availability for plants (Li et al., 2024; Song et al., 2025). Based on the results of laboratory analysis, the value of the soil CEC in several land uses in Sitimulyo Village showed very low to low values with an average value ranging from 0.41 cmol/kg – 6.19 cmol/kg (Figure 4.11). The lowest CEC value is 0.41 cmol/kg for land use in the form of mixed gardens with a slope of 0-8%, while the highest CEC value is 6.42 cmol/kg for land use in the form of rice fields with a slope of 15-25% (Table 11). This value is not suitable for the development of sorghum plants because the plant can grow optimally with a soil CEC value of >16 cmol/kg. It can be suspected that the soil at the research site has the ability to exchange cations such as Ca, Mg, Na, and K whose availability is classified as very low to low, so that the availability of elemental elements needed by plants ranges from very low to low.

The value of soil CEC has a relationship with other soil properties, especially pH and organic matter. If a type of soil has a sour pH and low C-organic content, then the soil is classified as low soil fertility. Mixed alkalines found in organic matter are the main factors that play a role in increasing soil pH, these alkalines will act as lime material (liming material) in their effect on soil pH. Organic matter with high mixed bases will have a noticeable effect on increasing soil pH. This is evidenced by the low value of organic matter at the research site and the pH value of the soil, which is mostly classified as a rather acidic soil type.

The amount of soil CEC also depends on the texture of the soil and the type of soil clay minerals. The higher the clay content or the smoother the texture, the larger the soil CEC. The low CEC at the research site is partly due to the very low organic matter content of the soil and the texture of sandy clay soil. The size of the CEC depends on the texture of the soil and the content of organic matter. According to (Kweon et al., 2013), the higher the organic matter content and the smoother the soil texture, the higher the soil CEC and vice versa, the lower the organic organic matter content and the rougher the soil texture, the lower the soil CEC visibility.

3.4 Slope

Piyungan District is included in the physiography of the eastern part of Bantul Regency which is a hilly area that extends from South to North with lower soil fertility, so that the south and east of Piyungan District are widely used for rainfed agriculture, especially Sitimulyo Village. The slope slope affects land quality and is one of the parameters in determining the level of land suitability of a certain crop (AbdelRahman et al., 2025; Gasparini et al., 2026). The slope slope is a factor that needs to be considered from the preparation of agricultural land, planting business, taking products and land preservation. Land that has a slope can be more easily disturbed or disturbed, especially if the degree of slope is large. Soil that has a slope of >15% with high rainfall can result in landslides. The steeper and longer slopes will increase the speed of surface flow and the volume of surface water will be larger so that there will be more objects that can be transported. One of the efforts to reduce the level of erosion hazard on the slope of the land is by making terraces.

Fig. 11. Examples of erosion found in the land use of Sitimulyo Village

In addition, slopes can affect land formation, namely the existence of a different pattern of geomorphological processes caused by differences in height, slope slope, and relief of an area. The difference in height between one place and another will result in the two places having a causal relationship. Higher places are one of the causes of land form deformation for places located below, for example, the increase in floodplains in downstream areas is due to the increasing intensity of erosion upstream (Faisal & Hayakawa, 2022). Geomorphological processes that occur in an area can be caused by various factors such as natural factors and the influence of human activities that control it. Erosion is one of the geomorphological processes that plays a role in the development of land forms (Bollati et al., 2017; Morino et al., 2022; Nair et al., 2024). The erosion that occurred in Sitimulyo Village included groove erosion and trench erosion in most land uses on steep to very steep slopes (Fig. 9). Topographic changes in land use have a significant impact on the intensity of geomorphological processes. This geomorphological process is increasing due to low vegetation cover. caused by silence along with soil material. In addition, the geomorphological process between one land use and another land use will be different. These differences are one of the reasons that cause differences in land form as well. The intensity of geomorphological processes and differences in land forms are highly dependent on climate, topography, proximity to subduction, lithology, and environmental changes (Chen & Zhang, 2022; Gudino-Elizondo et al., 2018; Maulana et al., 2025; Zhu et al., 2021).

Sitimulyo Village has seven forms of land that are formed through various processes, namely structural, denudational, and fluvial. The hills of origin of this structural process can be further divided into three forms of land, namely the form of land of structural hills of the upper slope, and structural hills of the middle slope. and structural hills of the lower slopes. The division of structural hills is based on the grouping of contour density in structural hills (Minár et al., 2024).

4. Conclusion

On land use such as rice fields. Field. and mixed gardens with slope to slightly steep slope classes have the potential to develop sorghum plants. This is supported by the results of research in the form of physical and chemical characteristics of the soil in the form of textures in the form of dust, clay, and clay; pH values that tend to be neutral, moderate organic matter values, high alkaline saturation values, and low salinity values. The next research can be done to sample soil samples in several land uses and slopes should be added so that the data obtained is more and more representative.

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Author Contribution
The author was responsible for conceptualizing the study, conducting experiments, analyzing data, and writing the manuscript, ensuring accuracy, originality, and overall integrity of the research work.

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Declaration of Generative AI Use
During the preparation of this work, the author(s) used a generative AI tool to assist in paraphrasing certain sections for clarity and Grammarly to assist in improving the grammar and academic tone of the manuscript. After using these tools, the author(s) reviewed and edited the content as needed and took full responsibility for the content of the publication.

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