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AGGREGATE STABILITY UNDER DIFFERENT LAND USES IN MUNTUK VILLAGE, DLINGO SUBDISTRICT, BANTUL REGENCY

STABILITAS AGREGAT PADA BERBAGAI PENGGUNAAN LAHAN DI DESA MUNTUK, KECAMATAN DLINGO, KABUPATEN BANTUL

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ABSTRACT

Stable soil aggregates improve soil structure and create a suitable medium for plant growth. Meanwhile. unstable aggregates break down easily under rainfall and accelerate erosion. This study aims to determine soil aggregate stability and the factors that control it under different land uses. The research used a survey approach. A land system map was produced by overlaying land use, slope, and soil type, resulting in 40 land system units. Sampling points were selected purposively based on land system units, accessibility, and land area. A total of 21 samples were collected. Aggregate stability was measured using wet and dry sieving. Observed parameters included field soil structure, texture, organic carbon, equivalent lime, specific gravity, bulk density, and clay content. Pearson correlation was used to identify the relationship between each parameter and aggregate stability. The results showed that aggregate stability ranged from 29.51-61.67 (unstable-slightly stable) in forest land, 52.02-84.90 (slightly stable-very stable) in mixed gardens, 34.22-64.25 (unstable-slightly stable) in rainfed rice fields, and 22.67-60.29 (unstable-slightly stable) in drylands. Soil organic matter and the dispersion ratio (DR) were the main factors influencing aggregate stability in Muntuk Village. Improving stability requires soil and water conservation practices that protect aggregates from breakdown by water or external disturbance. Agricultural land generally had lower stability, so proper management is needed. Recommended practices include returning crop residues, applying organic amendments, adopting minimum tillage, and implementing suitable cropping patterns.

Keywords: Dispersion ratio (DR), land use, soil aggregate stability, soil and water conservation, soil organic matter

ABSTRAK

Agregat tanah yang stabil meningkatkan struktur tanah dan mendukung pertumbuhan tanaman. Sedangkan, agregat yang tidak stabil mudah hancur saat terkena hujan dan mempercepat erosi. Penelitian ini bertujuan menilai stabilitas agregat tanah dan faktor yang memengaruhinya pada berbagai penggunaan lahan. Penelitian menggunakan metode survei. Peta sistem lahan dibuat dengan tumpang susun peta penggunaan lahan, kemiringan lereng, dan jenis tanah sehingga terbentuk 40 unit sistem lahan. Titik sampel ditentukan secara *purposive* berdasarkan unit sistem lahan, aksesibilitas, dan luas lahan. Total 21 sampel dikumpulkan. Stabilitas agregat diuji dengan ayakan basah dan kering. Parameter yang diamati meliputi struktur tanah, tekstur, C-organik, kapur ekuivalen, berat jenis partikel, berat volume, dan kadar lempung. Hubungan antara setiap parameter dan stabilitas agregat dianalisis dengan korelasi Pearson. Hasil penelitian menunjukkan bahwa stabilitas agregat pada hutan berkisar 29.51-61.67 (tidak stabil-agak stabil), kebun campuran 52.02-84.90 (agak stabil-sangat stabil), sawah tadah hujan 34.22–64.25 (tidak stabil-cukup stabil), dan lahan kering 22.67-60.29 (tidak stabil-cukup stabil). Bahan organik tanah dan nilai perbandingan dispersi (NPD) merupakan faktor utama yang mengendalikan stabilitas agregat di Desa Muntuk. Upaya peningkatan stabilitas perlu dilakukan melalui teknik konservasi tanah dan air yang menjaga agregat dari kerusakan akibat air atau gangguan luar. Lahan pertanian cenderung memiliki agregat yang kurang stabil sehingga membutuhkan pengelolaan yang tepat. Praktik yang disarankan antara lain pengembalian sisa tanaman, pemberian bahan organik, pengolahan tanah minimum, dan pola tanam yang sesuai.

Kata kunci: Bahan organik tanah, konservasi tanah dan air, nilai perbandingan disperse (NPD), penggunaan lahan, stabilitas agregat tanah

INTRODUCTION

Soil aggregate stability is a key indicator of soil quality in agricultural systems. It describes the ability of soil aggregates to withstand destructive forces such as rainfall impact and mechanical disturbance (Damanik et al., 2022). Stable aggregates enhance soil structure by improving water and air movement within the soil, thereby supporting plant growth and contributing to the long-term productivity of agricultural land. Aggregate stability is influenced by several factors, including slope, land use, and soil type.

Muntuk Village, located in the Dlingo Subdistrict of Bantul Regency, Yogyakarta Special Region is an area with active erosion processes. According to Ma'arif (2025), erosion has been reported in several hamlets, including Tangkil, Karangasem, Banjarharjo 2, and Seropan 2. High rainfall, combined with diverse slope gradients, land uses, and soil types, contributes to erosion occurrence in this village. Increasingly intensive land use may further reduce aggregate stability, especially when land management practices involve frequent or deep tillage.

Muntuk Village comprises various land uses such as forests, rainfed rice fields, mixed gardens, and dryland agriculture. These land-use types differ in vegetation cover, organic matter input, and soil disturbance intensity, all of which influence aggregate stability. Areas with steep slopes tend to have less stable aggregates due to greater runoff, which transports organic matter downslope and leaves the upper landscape dominated by subsoil material with lower organic matter content.

The village has two dominant soil types, namely Latosols and Mediterranean soils. Latosols, which are generally clay-rich, tend to form more stable aggregates. Mediterranean soils, with loamy to clay textures, also have the capacity to form stable aggregates. Soil minerals such as silica, alumina, and iron oxides contribute to aggregate formation through chemical and electrochemical interactions that bind soil particles together (Hidayat et al., 2002).

Aggregate stability is therefore an essential parameter in evaluating soil function as a medium for plant growth. Stable aggregates promote good soil structure and root development, whereas unstable aggregates are easily dispersed by rainwater, accelerating erosion and reducing soil fertility. Understanding the level of aggregate stability and the factors that control it is crucial for developing sustainable land-use and soil-management strategies in Muntuk Village.

MATERIALS AND METHODS

The research was conducted from February to June 2025 in Muntuk Village, Dlingo Subdistrict, Bantul Regency, Yogyakarta. The materials used included soil samples, chemical reagents, and several thematic maps, namely land use, slope, soil type, land systems, and sampling-point distribution maps. The equipment used consisted of ring samplers, knives, clinometers, sample containers, labels, and standard laboratory instruments.

Land System Mapping and Sampling Design

The study employed a survey method. Land system maps were generated by overlaying land use, soil type, and slope maps using ArcGIS, resulting in 40 land system units. Sampling points were selected using purposive sampling based on land system units, accessibility, and land area. A total of 21 sampling points were established. Land systems located on steep slopes without access roads and units with an area smaller than 8 ha were excluded. Scrubland was also excluded because the study focused on agricultural land.

Soil Sampling and Field Observation

Field observations included identifying soil structure at each sampling point. Disturbed and undisturbed soil samples were then collected from representative land system units for laboratory analysis.

Aggregate Stability Analysis

Soil aggregate stability was measured using dry and wet sieving methods. Dry sieving was used to determine the proportion of aggregate size classes and obtain the mean weight diameter (MWD-dry). The dry aggregates were subsequently subjected to wet sieving to measure their resistance to dispersion in water, producing the mean weight diameter under wet conditions (MWD-wet). The stability index was then calculated and classified into six stability classes: very very stable (>200), very stable (80-200), stable (66-80), slightly stable (50-66), less stable (40-50), and unstable (<40) (Kurnia et al., 2006).

Laboratory Analyses

The laboratory analyses included determining soil texture using the pipette method, measuring soil organic carbon with the Walkley and Black method, analyzing equivalent lime content through titration, determining bulk density using the ring method, measuring particle density with the pycnometer method, and determining the actual clay and silt content using the pipette method.

Data Analysis

Pearson's correlation analysis was used to determine the strength of the relationship between soil properties and aggregate stability.

RESULTS AND DISCUSSION

A. Analysis of Soil Physical Properties

The analysis of soil physical properties plays an important role in understanding aggregate stability, as several physical properties such as soil structure, texture, particle density, bulk density, porosity, and actual clay content, influence the ability of soil aggregates to maintain their stability against physical disturbance. The results of the soil physical property analysis are presented in Table 1.

1. Soil Structure

The results of soil structure analysis (Table 1) show that Muntuk Village has several types of structures including subangular blocky, angular blocky, and granular. The most favorable structure for aggregate stability is the granular type, found in samples 17 and 18 under dryland agricultural use. Granular structure promotes the separation of aggregates without excessive abrasion, thereby reducing the likelihood of aggregate breakdown. Agricultural activities often produce a granular structure because tillage operations, such as plowing and hoeing that break larger aggregates into smaller units. Granular soils typically contain abundant macropores, which enhance aeration and support microbial processes and root development (Zega, 2024).

Table 1. Analysis of the physical properties of the soil in the Village of Muntuk

Sample Point	Land System	Structure			Texture	Particle Density (g/cm^3)	Bulk Density (g/cm^3)	Porosity	DR
		Shape	Size	Degree					
TS 1	Forest, Steep, Latosol	Subangular Blocky	Moderate	Fair	Clay	2.77	1.45	Poor	Somewhat Sensitive
TS 2	Forest, Moderately Steep, Latosol	Subangular Blocky	Moderate	Fair	Clay	2.38	1.09	Good	Durable
TS 3	Garden, Moderately Steep, Latosol	Subangular Blocky	Moderate	Fair	Clay	2.61	1.11	Good	Durable
TS 4	Garden, Gentle Slope, Latosol	Angular Blocky	Moderate	Sufficient	Clay	2.56	1.09	Good	Durable
TS 5	Garden, Flat, Latosol	Subangular Blocky	Very Coarse	Solid	Clay	2.47	1.03	Good	Durable
TS 6	Rainfed Paddy Field, Gentle Slope, Latosol	Subangular Blocky	Moderate	Sufficient	Clay	2.56	1.28	Good	Durable
TS 7	Rainfed Paddy Field, Flat, Latosol	Subangular Blocky	Moderate	Sufficient	Silt Loam	2.48	1.16	Good	Durable
TS 8	Dryland Farming, Steep, Latosol	Subangular Blocky	Coarse	Sufficient	Clay Loam	2.48	1.28	Not Good	Durable
TS 9	Dryland Farming, Moderately Steep, Latosol	Subangular Blocky	Moderate	Fair	Clay	2.65	1.49	Poor	Somewhat Sensitive
TS 10	Dryland Farming, Gentle Slope, Latosol	Subangular Blocky	Moderate	Fair	Clay	2.46	1.25	Poor	Durable
TS 11	Dryland Farming, Flat, Latosol	Subangular Blocky	Coarse	Fair	Clay	2.53	1.39	Poor Good	Durable
TS 12	Garden, Moderately Steep, Mediterranean	Angular Blocky	Moderate	Sturdy	Clay Loam	2.55	1.12	Good	Durable
TS 13	Garden, Gentle Slope, Mediterranean	Subangular Blocky	Rough	Solid	Clay Loam	2.44	1.16	Good	Durable
TS 14	Garden, Flat, Mediterranean	Subangular Blocky	Moderate	Weak	Clay	2.60	1.28	Good	Resistant
TS 15	Rainfed Paddy Field, Steep, Mediterranean	Subangular Blocky	Moderate	Sufficient	Clay	2.42	1.12	Good	Durable
TS 16	Rainfed Paddy Field, Moderately Steep, Mediterranean	Subangular Blocky	Moderate	Fair	Clay	2.42	1.19	Good	Durable
TS 17	Dryland Farming, Very Steep, Mediterranean	Granular	Fine	Weak	Loam	2.80	1.28	Good	Sensitive
TS 18	Dryland Farming, Steep, Mediterranean	Granular	Fine	Weak	Loam	2.82	1.35	Good	Somewhat Sensitive
TS 19	Dryland Farming, Moderately Steep, Mediterranean	Subangular Blocky	Rough	Fair	Clay	2.49	1.07	Good	Sensitive
TS 20	Dryland Farming, Gentle Slope, Mediterranean	Subangular Blocky	Rough	Weak	Clay	2.62	1.01	Porous	Sensitive
TS 21	Dryland Farming, Flat, Mediterranean	Subangular Blocky	Coarse	Fair	Clay	2.63	1.19	Good	Resistant

A subbangular blocky soil structure is generally considered better than an angular blocky structure for agricultural and soil conservation. According to Vallensiana et al. (2023), favorable soil structure tends to be more rounded because rounded aggregates reduce direct contact between particles, thereby improving stability. Subangular blocky structures typically exhibit higher porosity which enhances water infiltration and reduce surface runoff.

In contrast, angular blocky aggregates have sharp edges. This indicates that they are harder and less stable compared to subangular blocky aggregates. This type of structure is often associated with soils containing high clay content. Hight clay proportions strengthen cohesive forces between particles that resulting in the formation of angular and more rigid aggregate (Mulya, 2022).

2. Soil Texture

Soil texture refers to the relative ratio of silt, clay, and sand in the soil (Apriani, 2015). The results of texture analysis (Table 1) show that the Latosol soil in Muntuk Village has a clay, silt loam, and clay loam texture classes. Latosol are typically dominated by fine particles such as clay and silt due to prolonged weathering of their parent materials, particularly igneous and sedimentary rock. Over long periods, intensive leaching removes coarse minerals such as sand, leaving behind higher proportions of clay and silt (Sutrisno et al., 2023).

Mediterranean soils in the study area exhibit silt loam, loam, and clay textures. The dominance of fine fraction in Mediterranean soils is attributable to intense weathering and leaching process. These soils are formed from the weathering of limestone and generally contain high amounts of clay (Muslimawati & Widayani, 2016). In Muntuk Village, Mediterranean soils are associated with the Sambipitu and Wonosari Formation. These formations originate from calcareous igneous rocks or tuffaceous sandstone with high carbonate and silica (SiO_2) contents. Weathering of tuffaceous sandstone produce abundant fine particles (silt and clay), resulting in a range of textures from silt loam to clay in soils withing the Sambipitu Formation (Purbantoro & Nuraini, 2020).

Soil texture is also influenced by land use. Dryland soils tend to contain higher proportion of silt and silt loam, whereas paddy fields typically have finer textures dominated by clay. The differences is partly due to erosions, which is more pronounced in dryland areas, especially those with steep slopes that causing the upper fine-textured horizons to be removed and leaving coarser material behind (Solekhah et al., 2024). Meanwhile, soils in mixed gardens and forested areas may exhibit variable textures depending on the vegetation and associated organic matter dynamics.

3. Soil Porosity

Porosity represents the percentage of total pores in soil filled with water and air. Soil porosity is determined based on particle density and bulk density. The results of soil particle density analysis in Muntuk Village show varying values, ranging from 2.38 to 2.82 g/cm^3 which are relatively low compared with typical mineral soils (Table 1). This low particle density is associated with the presence of organic matter and predominance of medium-texture materials. Organic matter has low particle density, lighter mass, and contributes to greater pore space, thereby reducing particle density. In addition, the dominance of clay textures in both soil types also contributes to lower particle density as fine particles with small pore spaces generally exhibit lower particle density that coarse-textured soil (Mansyur et al., 2023).

Bulk density values in the study area range from 1.01-1.49 g/cm^3 (Table 1), which are also considered low for mineral soils. This low bulk density may be due to the fact that Muntuk Village has land use with good root systems, especially in forest and mixed garden (Risamasu & Marlissa, 2020). Rainfed paddy fields have low bulk density due to the addition of manure and the return of crop residues in the form of straw. Moderate organic matter content further contributes to reduced bulk density. In dryland system, tillage activities increase soil looseness and porosity by breaking down aggregates and enlarging pore space, thereby lowering the mass of soil per unit volume (Fuady & Mustaqim, 2015).

Overall, soil porosity in Muntuk Village is generally favorable. However, porosity tends to be lower in cultivated dryland areas due to soil disturbance that breaks aggregates into finer particles, filling pore spaces and reducing overall porosity. Poor porosity is also observed in forest land with very steep slopes where intensive erosion removed the organic matter-rich topsoil. The loss of this surface layer results in a denser subsurfaces horizon, increased bulk density, and reduces porosity. is caused by the erosion of the topsoil, which results in the loss of the top layer rich in organic matter, leaving the remaining soil layer more compact (increased volume weight) and decreasing porosity.

In contrast, Mediterranean soils in the study are exhibit predominantly good porosity due to their coarse structural characteristics. Coarse soil structure promotes higher porosity because larger soil particles and aggregates create wider and more continuous pore spaces that facilitate the movement of air and water through the soil (Salawangi et al., 2020).

4. Actual Clay Dust

The results of the actual clay dust analysis were used to determine the dispersion ratio (DR). Most samples exhibited resistant DR values. The high resistance is associated with Latosol soil type which is dominated by clay texture. Soils with a high clay fractions have fine particles that bind strongly, forming a stable aggregate. The cohesive forces among clay particles increase the internal bonding of the soil, making it more resistant to detachment and erosion by raindrop impact or surface runoff (Anggraini et al., 2023).

Mixed garden land use also contributes to the higher DR resistance dure to greater organic input. High organic matter content enhances soil water absorption and retention and reducing surface runoff, which is one of the main factors that cause erosion. With more water infiltrating the soil, the kinetic energy of overland flow decreases, resulting in lower erosion susceptibility.

In contast, sample 17 (Table 1) shows the highest sensitivity to erosion. This sample was collected from dryland agriculture located on a very steep slope under Mediterranean soil. The dryland area has low organic matter, which decreased the supply of binding agents that help stabilize soil aggregates. As a result, soil particles become more susceptible to physical disturbances such as rainfall and overland flow (Juarsah, 2011).

Sensitive dispersion rations were primarily found in Mediterranean soil moist texture. This texture allows moderate water infiltration but also increases vulnerability to aggregate breakdown and dispersion, particularly during the early rainy season when the soil has not yet reached full moisture saturation. Under these condition, aggregates are more easily detached and transported by surface flow (Mey et al., 2021).

B. Analysis of Soil Chemical Properties

Analysis of soil chemical properties is essential for understanding their relationship to aggregate stability. The parameters analyzed include organic matter content and equivalent lime content. The results of the analysis of soil chemical properties are presented in Table 2.

Table 2. Soil chemical properties in Muntuk Village

Sample Point	Land System	OM (%)	Organic Matter Class	Equivalent Lime Content (%)	Equivalent Lime Content Class
TS 1	Forest, Steep, Latosol	1.49	Very Low	6.91	Keep
TS 2	Forest, Moderately Steep, Latosol	4.03	Keep	11.83	Tall
TS 3	Garden, Moderately Steep, Latosol	3.37	Low	27.56	Very High
TS 4	Garden, Gentle Slope, Latosol	4.06	Keep	31.14	Very High
TS 5	Garden, Flat, Latosol	6.20	Keep	20.49	Very High
TS 6	Rainfed Paddy Field, Gentle Slope, Latosol	5.24	Keep	25.83	Very High
TS 7	Rainfed Paddy Field, Flat, Latosol	4.11	Keep	30.52	Very High
TS 8	Dryland Farming, Steep, Latosol	5.04	Keep	26.46	Very High
TS 9	Dryland Farming, Moderately Steep, Latosol	2.15	Low	32.30	Very High
TS 10	Dryland Farming, Gentle Slope, Latosol	3.97	Low	38.00	Very High
TS 11	Dryland Farming, Flat, Latosol	3.62	Low	12.78	Tall
TS 12	Garden, Moderately Steep, Mediterranean	5.66	Keep	30.75	Very High
TS 13	Garden, Gentle Slope, Mediterranean	6.74	Keep	65.71	Very High
TS 14	Garden, Flat, Mediterranean	6.61	Keep	30.28	Very High
TS 15	Rainfed Paddy Field, Steep, Mediterranean	4.97	Keep	10.99	Keep
TS 16	Rainfed Paddy Field, Moderately Steep, Mediterranean	5.42	Keep	28.07	Very High
TS 17	Dryland Farming, Very Steep, Mediterranean	1.41	Very Low	13.48	Tall
TS 18	Dryland Farming, Steep, Mediterranean	2.41	Low	21.13	Very High
TS 19	Dryland Farming, Moderately Steep, Mediterranean	5.14	Keep	11.94	Tall
TS 20	Dryland Farming, Gentle Slope, Mediterranean	4.16	Keep	48.40	Very High
TS 21	Dryland Farming, Flat, Mediterranean	4.03	Keep	33.37	Very High

1. Soil Organic Matter

The analysis of soil organic matter in Muntuk Village shows considerable variation across land uses, soil types, and slope classes. In forest areas developed on Latosol soils, organic matter content ranged from 1.49% to 4.03%, categorized as very low to medium. Although forests generally provide abundant organic inputs, the steep slopes at the sampling sites contributed to lower organic matter levels. Steep topography accelerates erosion, removing the organic-rich topsoil layer (Septianugraha & Suriadikusumah, 2014).

In mixed gardens on Latosol soils, organic matter content range from low to medium and tended to increase from slightly steep to flat slopes. This is because there is a lot of accumulation of organic matter on flat slopes that are transported from steep slopes. In contrast, mixed gardens on Mediterranean soils exhibited higher organic matter content on the sloping than flat areas. This is because at the sampling location, the vegetation on a flat slope is not too tight. Organic matter levels are strongly influenced by the quantity of litter that coves and decomposes on the soil surface (Bachtiar, 2020).

Rainfed paddy fields on Latosol soils showed medium organic matter content (5.24% and 4.11%) on sloping and flat areas. The slightly higher value on sloping land is attributed to the application of cow manure as basal fertilizer. In Mediterranean soils, rainfed paddy fields also exhibited moderate organic matter levels due to the incorporation of rice straw, which returns organic input to the soil.

In dryland on Latosol soils, organic matter content was moderate on steep slopes but low on slightly steep, sloping, and flat areas. The moderate value on steep land may be attributed to the use of goat manure by farmers, whereas other sites relied primarily on inorganic fertilizers. In me Mediterranean soils, organic matter content ranged from very low to medium, with the lowestvalues found on very steep and steep slopes due to minimal vegetation cover and the absence of crop residue return. As noted by Septianugraha & Suriadikusumah (2014), dryland systems often experience reduced organic matter inputs because intensice land use limits the accumulation of litter from leaves, twigs, and roots.

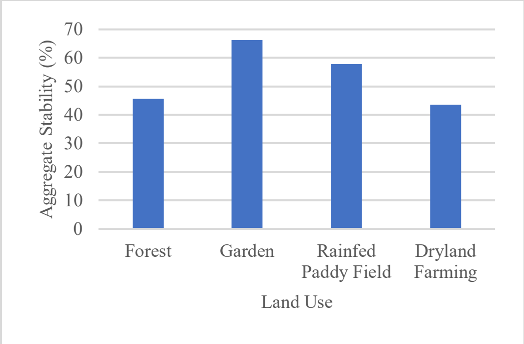
2. Equivalent Lime Content

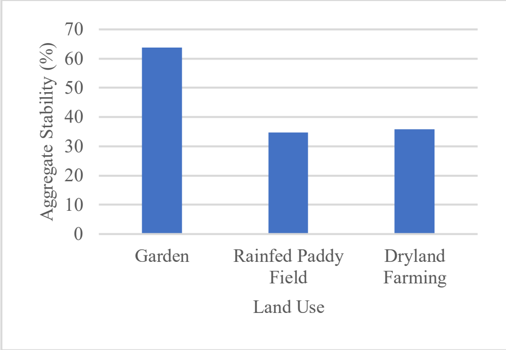
Equivalent lime content in Muntuk Village ranges from low to very high, with the very high class being most dominant. The highest lime content was obtained in sample 13 with a value of 65.71% (Table 2). The high level of lime in sample 13 was due to sampling located in the Wonosari Formation. The lime content in the Wonosari Formation is relatively high because this formation is dominated by limestone which generally consists of calcium carbonate ($CaCO_3$). This finding is consistent with Sipayung et al. (2025), who reported that thick and widespread limestone layers in the northern and northeastern parts of the Wonosari basin result in high carbonate content across the formation.

In contrast, the lowest equivalent lime content was observed in sample 1 (Table 2). This low value may be attributed to the leaching of calcium (Ca^{2+}) from the soil. Calcium is a mobile cation that can be readily transported downward through the soil profile, especially under conditions of high runoff. The very steep slope at the sampling location likely intensified erosion and leaching processes, preventing water from infiltrating the soil and instead allowing it to flow rapidly downslope. As a result, calcium may accumulate at lower elevations or be lost entirely from the root zone (Ariyanti et al., 2010).

C. Soil Aggregate Stability Analysis

The results of the aggregate stability analysis based on land use and slope are presented in Figure 1 and 2. The soil aggregate stability values for Muntuk village are shown in Table 3.





(a) (b)

Figure 1. Aggregate Stability based on Land Use in (a) Latosol Soil, (b) Mediterranean Soil

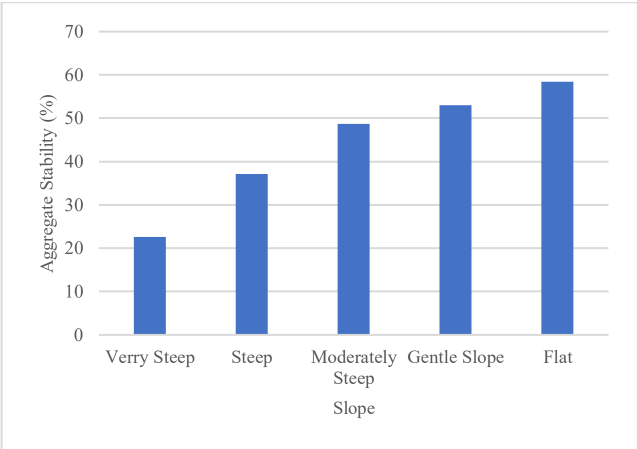


Figure 2. Aggregate Stability based on Slope

Table 3. An Analysis of the Aggregate Stability in the Village of Muntuk

Point Sample	Land System	Aggregate Stability	Class
TS 1	Forest, Steep, Latosol	29.51	Unstable
TS 2	Forest, Moderately Steep, Latosol	61.67	Stable
TS 3	Garden, Moderately Steep, Latosol	52.02	Stable
TS 4	Garden, Gentle Slope, Latosol	61.93	Stable
TS 5	Garden, Flat, Latosol	84.75	Very Stable
TS 6	Rainfed Paddy Field, Gentle Slope, Latosol	64.27	Stable
TS 7	Rainfed Paddy Field, Flat, Latosol	51.54	Stable
TS 8	Dryland Farming, Steep, Latosol	60.29	Stable
TS 9	Dryland Farming, Moderately Steep, Latosol	43.69	Slightly Stable
TS 10	Dryland Farming, Gentle Slope, Latosol	31.04	Unstable
TS 11	Dryland Farming, Flat, Latosol	39.28	Unstable
TS 12	Garden, Moderately Steep, Mediterranean	54.24	Stable
TS 13	Garden, Gentle Slope, Mediterranean	63.59	Stable
TS 14	Garden, Flat, Mediterranean	73.64	Stable
TS 15	Rainfed Paddy Field, Steep, Mediterranean	35.31	Unstable
TS 16	Rainfed Paddy Field, Moderately Steep, Mediterranean	34.22	Unstable
TS 17	Dryland Farming, Very Steep, Mediterranean	22.67	Unstable
TS 18	Dryland Farming, Steep, Mediterranean	23.62	Unstable

Point Sample	Land System	Aggregate Stability	Class
TS 19	Dryland Farming, Moderately Steep, Mediterranean	46.45	Slightly stable
TS 20	Dryland Farming, Gentle Slope, Mediterranean	43.95	Slightly stable
TS 21	Dryland Farming, Flat, Mediterranean	42.80	Slightly stable

Based on Table 3, forest land mixed plantations on very steep and flat slopes show relatively stable aggregate stability, with stability increasing as the slope becomes flatter. Very steep slopes experience significant topsoil transport. Increased slope steepness elevates the amount and velocity of surface runoff. As a result, topsoil detached by raindrop impact is more easily transported downslope. This process can alter soil physical properties, including organic matter content. Soil organic matter is essential for microbial activity and strongly influences soil physical characteristics, such as water-holding capacity and aggregate formation (Mansyur et al., 2023).

Rainfed paddy fields on Latosol soils show more aggregate stability on sloping land than on flat areas. This condition is associated with the organic fertilization practices of farmers, particularly the application of cow manure. Manure is able to improve the stability of soil aggregates by improving soil structure through the addition of organic matter that unites soil particles into stable aggregates, increasing porosity, and water-holding capacity (Jumarni et al., 2021).

Rainfed rice fields on Mediterranean soils exhibit unstable aggregate stability on steep and moderately steep slopes, even though crop residues have been returned to the soil. This may be influenced by the long dry period followed by high rainfall typical of these areas. The rapid alternation between saturation and drying can weaken aggregate structure, making aggregates more prone to breakdown or preventing the formation of optimally stable aggregates, even when organic matter is replenished (Agus et al., 2004).

Dryland on the Latosol soils show less stable aggregate on flatter slopes This condition is related to land management practices carried out by farmers, including the addition of manure and conservation actions such as minimum tillage and terracing. The application of manure promotes aggregate formation and improves soil structure by binding soil particles into stable aggregates. On very steep land, tillage is not conducted intensively due to the high erosion risk. Minimum tillage helps reduce mechanical disturbance to the soil, thereby maintaining soil structure and stability. Chandra et al. (2018) states that minimum tillage is a soil management approach involving as little soil disturbance as possible while still ensuring conditions that support plant growth.

Dryland in Mediterranean soils shows increasingly stable aggregate stability as the slope becomes flatter. This is influenced by the increasing content of organic matter as the slope gets flatter. Organic matter acts as a cementing agent that stabilizes soil aggregates by improving aeration, drainage, total pore space, and water retention. This finding aligns with Surya and Hasibuan (2015) in Mujiyo et al. (2021), which conveys that organic matter can improve the physical, chemical, and biological properties of soil, as well as physically improve soil structure.

The higher aggregate stability in rainfed paddy fields compared to dryland is associated with better water retention and greater biological activity in the soil. This is consistent with the findings of Supit (2000), who reported that soils lacking water are more susceptible to structural degradation and particle breakdown. As soil moisture decreases, organic matter also tends to decline, reducing the population of microorganisms that contribute to aggregate binding.

The data indicate that Mediterranean soils are predominantly characterized by unstable aggregate classes. This instability is influenced by the very high lime content typical of

Mediterranean soils. Excessive calcium levels can cause an imbalance in particle-size distribution and soil chemistry. High calcium concentrations reduce the availability of alumina and silicate compounds that play important roles in binding soil particles into stable aggregates. This is consistent with Ningrum et al. (2024), who describe Mediterranean soils as limestone-derived soils with alkaline properties resulting from elevated calcium carbonate content. Such conditions affect soil physical properties, including water availability and aggregate cohesion, ultimately leading to reduced aggregate stability.

Efforts to improve aggregate stability in Muntuk Village should focus on soil and water conservation practices. The use of agricultural land tends to have less stable aggregates, so good land management is needed. Recommended practices include returning crop residues to the soil, applying organic fertilizers, minimizing soil tillage, and implementing improved cropping patterns. On forest land, soil and water conservation can be supported through the adoption of agroforestry systems. Agroforestry integrates trees with agricultural or livestock production systems, providing ecological and structural benefits that help maintain soil stability.

D. Influence of Soil Properties Several Soil Traits with Aggregate Stability in Muntuk Village

The results of the regression analysis are summarized in Table 4. Overall, soil texture variables (sand, silt, and clay) show *very weak* correlations with aggregate stability, while organic matter and the dispersion ratio exhibit *strong* relationships.

Table 4. Regression Analysis of Soil Properties on Aggregate Stability

No.	Independent Variables	Regression equations	Determination Value (R^2)	Correlation Value (r)	Relationship Level
1.	Soil Texture				
	a. Sand	y = -0.0316x + 26.19	0.002	-0.0445	Very weak
	b. Silt	y = -0.0325x + 48.125	0.0013	-0.0365	Very weak
	c. Clay	y = 0.0551x + 26.561	0.0095	0.0976	Very weak
2.	Soil Organic Matter	y = 7.6322x + 16.007	0.4979	0.705	Strong
3.	Bulk Density	y = -51.383x + 110.72	0.1746	-0.417	Keep
4.	Particle Density	y = -61.597x + 206.23	0.2168	-0.465	Keep
5.	Soil Porosity	y = 0.9317x - 0.4906	0.0644	0.253	Weak
6.	Equivalent Lime Content	y = 0.5192x + 28.777	0.2974	0.259	Weak
7.	Dispersion Ration\	y = -1.2332x + 63.674	0.362	-0.601	Strong

The regression analysis shows that soil texture (sand, silt, and clay) has a very weak relationship with aggregate stability. The correlations for sand (r = -0.0445), silt (r = -0.0365), and clay (r = 0.0976) indicate minimal influence, with coefficients of determination ($R^2 < 0.01$). This means that soil texture contributes less than 1% to aggregate stability, while more than 99% is affected by other factors. Sand and silt tend to decrease stability, whereas clay provides a slight positive effect.

In contrast, soil organic matter exhibits a strong positive relationship with aggregate stability (r = 0.705; R^2 = 0.4979), contributing nearly half of the total variation. Higher organic matter enhances aggregate cohesion, improves soil structure, and increases resistance to disintegration. Bulk density and particle density both show moderate negative correlations with aggregate stability (r = -0.417 and -0.465). Their R^2 values (0.1746 and 0.2168) indicate that soils with lower bulk density, typically those with higher organic matter and porosity, tend to have more stable aggregates.

Soil porosity demonstrates a weak positive correlation with aggregate stability (r = 0.253; R^2 = 0.0644). Greater porosity facilitates air and water movement and supports microbial processes that strengthen aggregate formation. Equivalent lime content also has a weak positive effect (r = 0.259; R^2 = 0.2974). Although calcium can enhance particle bonding, its overall influence is less substantial compared to organic matter. The dispersion ratio (DR) shows a strong negative correlation with aggregate stability (r = -0.601; R^2 = 0.362), indicating that lower DR values reflect more cohesive soil particles and more stable aggregates.

CONCLUSION

1. Soil aggregate stability in Muntuk Village varies across land uses, even within the same category. Forest land (1.97 ha; 0.15%) exhibits aggregate stability values of 29.51–61.67 (unstable to slightly stable). Mixed gardens (461.88 ha; 36.02%) show higher stability, ranging from 52.02–84.90 (sligtly stable to very stable). Rainfed paddy fields (92.32 ha; 7.2%) have stability values of 34.22–64.25 (unstable to slightly stable). Dryland (347.67 ha; 27.11%) shows stability values of 22.67–60.29 (unstable to slightly stable).
2. Within the same land use, flatter slopes consistently produce more stable soil aggregates. In addition, Latosol soils exhibit more stable aggregates than Mediterranean soils.
3. Organic matter content and the Dispersion Ratio (DR) are the soil properties that most strongly influence aggregate stability in the study area.

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