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ABILITY OF SANDY SOIL TO RETAIN WATER IN VARIOUS COASTAL SAND LAND MANAGEMENT PRACTICES IN BUGEL VILLAGE, KULON PROGO REGENCY

KEMAMPUAN LAHAN PASIR MENAHAN AIR PADA BERBAGAI PRAKTIK PENGELOLAAN LAHAN DI DESA BUGEL KABUPATEN KULON PROGO

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ABSTRACT

The reduction of agricultural land due to land conversion has compelled farmers to explore alternative cultivation areas such as coastal sandy soils, despite their limited water retention capacity. Agricultural land in Bugel Village, Kulon Progo Regency, is predominantly composed of sand and exhibits various land management practices. This study aims to analyze the influence of land management strategies on the water retention capacity of coastal sand soils and to identify related soil properties. Soil samples were collected through purposive sampling based on land use maps and direct observation, resulting in three sampling locations that represent different land management practices. Descriptive statistical methods were employed, and the data were analyzed using Analysis of Variance (ANOVA) followed by the Duncan Multiple Range Test (DMRT). The results showed a significant difference in permanent wilting point moisture content ($P < 0.01$), available moisture content ($P < 0.05$), and air-dried moisture content ($P < 0.05$). These findings underscore the importance of appropriate land management in enhancing the water-holding capacity of coastal sandy soils.
Keywords: available water content, coastal sandy soil, land management, soil water retention

ABSTRAK

Berkurangnya lahan pertanian akibat alih fungsi lahan telah mendorong petani untuk memanfaatkan alternatif lahan pertanian yang ada seperti lahan pantai berpasir, meskipun kapasitas retensi airnya terbatas. Lahan pertanian di Desa Bugel, Kabupaten Kulon Progo, sebagian besar terdiri dari pasir dan menunjukkan berbagai praktik pengelolaan lahan. Penelitian ini bertujuan untuk menganalisis pengaruh strategi pengelolaan lahan terhadap kapasitas retensi air tanah berpasir pantai dan untuk mengidentifikasi sifat-sifat tanah terkait. Sampel tanah dilakukan dengan pengambilan sampel secara sengaja berdasarkan peta penggunaan lahan dan pengamatan langsung, menghasilkan tiga lokasi pengambilan sampel yang mewakili praktik pengelolaan lahan yang berbeda. Metode statistik deskriptif digunakan, dan data dianalisis menggunakan Analisis Varians (ANOVA) diikuti oleh *Duncan Multiple Range Test* (DMRT). Hasil penelitian menunjukkan perbedaan yang signifikan dalam kadar air titik layu permanen ($P < 0,01$), kadar air tersedia ($P < 0,05$), dan kadar air kering udara ($P < 0,05$). Temuan ini menggarisbawahi pentingnya pengelolaan lahan yang tepat dalam meningkatkan kapasitas retensi air tanah berpasir pantai.
Kata kunci: kadar air tersedia, tanah pesisir berpasir, pengelolaan lahan, retensi air tanah

INTRODUCTION

The reduction of agricultural land in the Special Region of Yogyakarta has forced farmers to seek alternatives to ensure the sustainability of agricultural practices. This includes the utilization of coastal sandy land. However, the use of coastal sandy land faces various challenges, one of which is its low water-holding capacity. Putra et al. (2020) reported that soil in sandy land is characterized by low fertility due to its sandy texture, single-grain structure to coarse texture, loose consistency, and further resulting in low water-holding capacity. Soils dominated by sand fractions have a significant number of macro pores. Macro pores are pores containing air or gravitational water, which is water that easily evaporates due to gravitational force (Hardjowigeno, 2007). The abundance of air in soil pores causes drying, resulting in low water content (Syukur, 2005).

Bugel Village in Panjatan, Kulon Progo, has an extensive potential coastal sandy area, in which farmers have implemented various land management practices and techniques. Efforts have been made to enhance the water-holding capacity of coastal sandy soil, e.g., adding organic matter and intercropping systems. Organic matter is a collection of complex organic compounds that are undergoing or have undergone decomposition (Rusman, 2019). The addition of organic matter to the soil can improve soil structure, thereby enhancing the soil water-holding capacity (Martini, 2019). Meanwhile, the implementation of intercropping systems can serve as an additional source of organic matter derived from the residues of intercropped plants. According to research by Nugroho et al. (2015), the cropping system used by farmers on coastal sandy soils is predominantly a multi-cropping system. In addition to adding organic matter and implementing intercropping systems, some farmers have also adopted modern irrigation systems that can effectively and efficiently increase water availability. According to Mustawa et al. (2017), regarding the efficiency of drip irrigation on various soil types, sandy soil has lower irrigation efficiency compared to clay and loam soils.

Management practices on coastal sandy soils with various techniques have been applied for a long time and have significantly altered the characteristics of the soils. These management techniques appear to have been quite successful in improving the soil water-holding capacity indicated by the moist condition of the field soil. Soil water-holding capacity, also known as available water for plants, is the amount of water that soil can hold due to gravitational force. The amount of available water is the amount of water that soil can release between field capacity and permanent wilting point (Rachman et al., 2019). Soil water holding capacity (SWHC) describes the soil ability to retain water and reflects the influence of soil mineral composition, soil texture, soil structure, soil organic matter content, and soil management practices (Arya et al., 2008). The impact of different land management practices on the water-holding capacity of sandy soil has not been thoroughly studied, especially in the context of its sustainability and long-term effectiveness. Therefore, research is needed to assess the effect of different land management practices on the soil water-holding capacity in the coastal sandy soil of Bugel Village, Kulon Progo.

MATERIALS AND METHODS

The research was conducted from January to June 2025 in the agricultural area of the Bugel coast, Bugel Village, Panjatan Subdistrict, Kulon Progo Regency, Special Region of Yogyakarta. Sampling was conducted on three plots with different management practices (Table 1), where each plot was represented by five points selected using purposive sampling. Soil samples were taken at a depth of 0–20 cm. Soil sample analysis was conducted at the Soil Science Laboratory, Faculty of Agriculture, UPN "Veteran" Yogyakarta, and the Soil Chemistry and Fertility Laboratory, Sebelas Maret University, Surakarta.

The research method was a combination of descriptive and inferential statistical approaches. The soil water-holding capacity was analyzed by measuring four main parameters: 1) maximum moisture content using the gravimetric method, 2) field capacity moisture content using the gravimetric method, 3) permanent wilting point moisture content using color change limits (Balai Penelitian Tanah, 2022), and 4) available moisture content calculated as the difference between field capacity moisture content and permanent wilting point moisture content (Marsha *et al.,* 2014). Three supporting parameters were also measured: air-dried moisture content using the gravimetric method, organic carbon content using the Walkley and Black method, and soil permeability using the Constant Head Permeameter method (Balai Penelitian Tanah, 2022). The effect of land management practices on the ability of sandy soil to retain water and other related physical properties were analyzed with Analysis of Variance (ANOVA), followed with Duncan's Multiple Range Test (DMRT) at a significance level of 0.05.

Table. 1 Land Management Practices at Sample Collection Sites

No	Sample Point Location (area)	Management Method			Management Duration (Years)
		Fertilizer (Every planting season)	Planting System	Irrigation System	
1	Plot A1 (2600 m^2)	- Compost mixture of chicken manure and rice straw, ± 10 tons - NPK ± 0.15 ton - Phonska ± 0.1 ton	Intercropping chili with water spinach and corn	Manual watering with a hose	16 years
2	PlotA2 (2000 m^2)	- Compost mixture of chicken manure and rice straw ±6 tons - Quail manure compost ±4 tons - NPK ± 0.1 ton	No intercropping (chili peppers as the main crop)	Manual irrigation with a hose	4 years
3	Plot A3 (3500 m^2)	- Compost mixture of rice straw and chicken manure ± 5 tons - NPK ± 0.2 ton	Intercropping chili peppers with beans	Drip and sprinkle	5 years

RESULTS AND DISCUSSION

Soil Water Retention Capacity in Various Land Management Practices

Land management based on soil characteristics is essential in agricultural practices. Intensive land management without considering soil characteristics can trigger changes in the physical, chemical, and biological properties of the soil (Nita et al., 2015). Land management practices are one of the factors influencing soil properties, including the soil water-holding capacity.

Table 2. Characteristics of Soil Water Retention Capacity Parameters in Various Land Management Practices

Field	Parameter			
	Maximum Moisture Content (%)	Field Capacity Moisture Content (%)	Permanent Wilting Point Moisture Content (%)	Moisture Content (%)
A1	37.85^{a}	23.55^{d}	17.02^{q}	6.53^{fg}
A2	38.74^{a}	20.91^{d}	7.95^{p}	12.96^{g}
A3	28.30^{a}	17.74^{d}	13.47^{q}	4.27^{f}
P-Value 5 %	.078	.246	.01	.033

Note: $\alpha < 0.01$ = highly significant, $\alpha < 0.05$ = significant, $\alpha > 0.05$ = not significant. Numbers followed by the same letter in the same column indicate no significant difference according to Duncan's test at the 5% level (α=0.05).

Land management practices influence the soil ability to retain water, as indicated by statistically significant differences in the permanent wilting point moisture content ($P = 0.01$) and the available moisture content ($P = 0.033$). The permanent wilting point moisture content reflects the condition when soil water is no longer available for plants due to its strong bound to the soil particles. Factors influencing this include soil texture and salinity, where fine-textured soils with high salinity have greater water-holding capacity, thereby reducing water availability for plants.

The available water content, i.e., the maximal amount of water that plants can absorb, was also significantly affected by land management practices. This was primarily influenced by soil organic matter content, which was the key factor influencing soil moisture levels. According to Hardjowigeno (2007), adding organic matter to the soil simultaneously affects the physical, chemical, and biological properties of the soil, improving soil aeration, enhancing the soil ability to retain nutrients, and increasing water-holding capacity

Meanwhile, the effect of different land management practices was not evident in field capacity moisture content and maximum moisture content. This is because management changes have not been able to significantly alter soil structure, while maximum moisture content is more influenced by total soil porosity and the soil type itself (Subagyono et al., 2004).

Physical and Chemical Properties of Soil in Different Land Management Practices

Different land management practices affect the physical and chemical properties of cultivated soil, although not all observed differences were statistically significant. The physical properties analyzed in this study were air-dried moisture content and permeability. Meanwhile, the chemical property analyzed in this study was organic carbon content. The results of the physical and chemical analysis of soil properties in plots A1, A2, and A3 are shown in Table 3.

Table 3. Physical and Chemical Properties of Coastal Sand Soil with Differences in Land Management

Field	Parameters			
	Air-dried moisture content (%)	Organic Carbon Content (%)	Permeability	
			Value	Category
A1	1.54^{a}	1.08^{x}	20.15^{z}	Fast
A2	1.37^{ab}	0.97^{x}	13.22^{z}	Fast
A3	0.62^{b}	0.60^{x}	25.80^{z}	Very Fast
P-Value 5 %	.048	.128	.529	

Note: α< 0.01 = highly significant, α < 0.05 = significant, α > 0.05 = not significant. Numbers followed by the same letter in the same column indicate no significant difference according to Duncan's test at the 5% level (α=0.05).

The highest air-dried moisture content was found in plot A1 with a value of 1.54, which was managed using a mixed cropping system and had dense vegetation cover, thereby reducing evaporation and increasing water retention. In contrast, plot A3 had the lowest value (0.62), due to its coarse sand texture, high porosity, and low organic matter content, which caused water to escape more easily from the soil profile. According to Brady & Weil (2008), soil moisture content is related to soil crumb structure, soil structure, and vegetation cover, which influence water retention.

The highest organic carbon content was found in plot A1 at 1.08, and the lowest in A3 at 0.6. The input of organic matter from intercropped plant residues increases the organic carbon content in plot A1, while the minimal vegetation in plot A3 results in low organic carbon content. The organic carbon content is closely related to the input of organic matter such as compost, green manure, or plant residues (Novizan, 2002). Plot A1 has more diverse and denser vegetation. This influences the greater quantity of crop residues as a source of organic matter contributed through the decomposition of roots, stems, leaves, and even flowers that fall onto the soil surface.

Meanwhile, soil permeability analysis indicates that Plot A3 has the highest permeability value, with a rate of 25.8 cm/hr, indicating that water easily permeates through the soil profile, resulting in low soil capacity to retain water. On the other hand, the lowest permeability is found in plot A2. Low permeability means the soil does not easily allow water to pass through. The high permeability in plot A3 may be due to the soil being more porous with a looser structure. Additionally, the lack of organic matter in plot A3 also contributes to the high permeability value of the soil in that area.

Field Moisture Content with Different Land Management Practices

The difference in field moisture content was presented in Figure 1. Plot A1 shows the maximum moisture content and the highest field capacity compared to the other two plots. This correlates with the high organic C content and the application of a mixed cropping system that supports the formation of stable soil aggregates. Meanwhile, plot A2 has the highest available moisture content, although its organic C content is slightly lower than A1. The use of a combination of organic fertilizers and low permeability values also supports optimal water retention. Conversely, plot A3 shows the lowest moisture content under almost all conditions, due to low organic matter content and high soil permeability. Although modern irrigation systems (drip and sprinkler) have been implemented, their efficiency is not optimal due to the soil structure that does not support water retention.

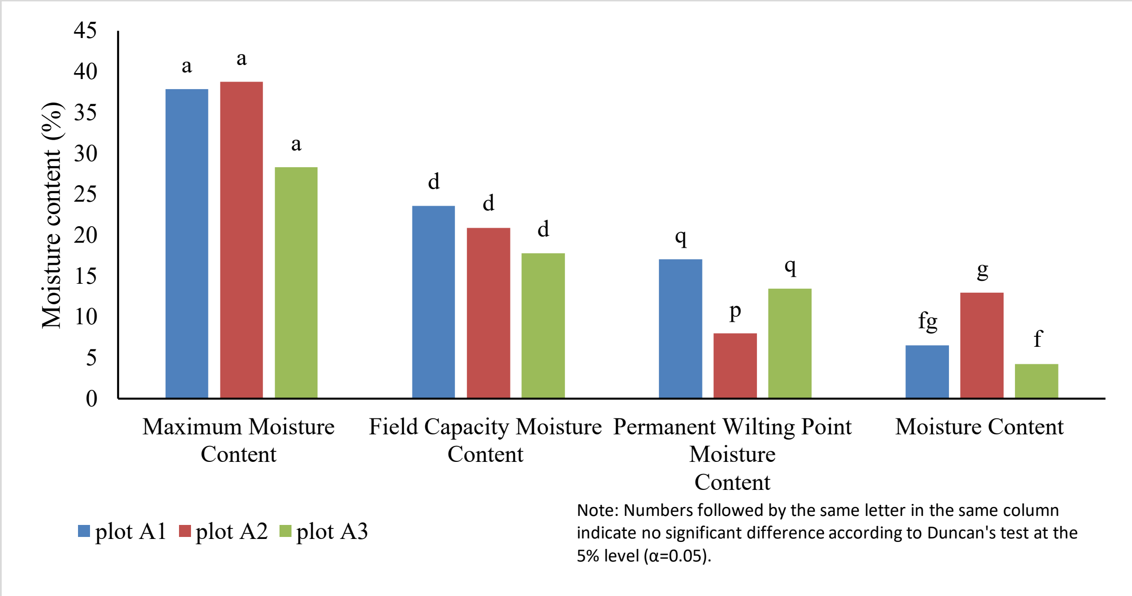

Figure 1. Moisture content under various conditions in each plot with different land management practices

Figure 1 presents data on moisture content under various conditions, reflecting water availability for plants. Field capacity moisture content is the optimal condition for water absorption by roots, while saturated and permanent wilting point conditions are unsuitable for plant growth. Maximum moisture content or saturated water conditions are conditions where both micro and macro soil pores are filled with water. This condition causes excess water in the soil, which can negatively impact the plants, such as root rot. Similarly, when the soil is at the wilting point, typically at -1500 kPa soil water potential, water becomes strongly bound to soil particles, preventing roots from absorbing water effectively, leading to water deficiency and plant death.

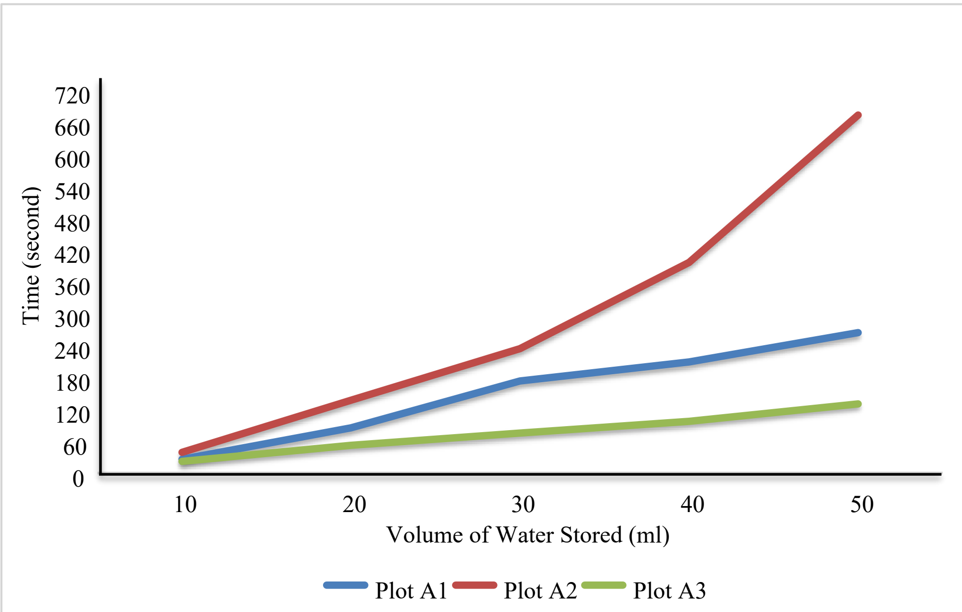

Figure 2. Graph of Water Percolation Rate on Land with Different Management Practices

Water Percolation Rate in Soil with Different Land Management Practices

Differences in soil characteristics affect the rate of groundwater percolation on the land. These differences are related to the ability of each soil to drain and retain water. Figure 2 illustrates the water flow rate as a function of the volume of water retained (ml) and the time required to reach that volume (seconds) in three plots representing different management practices. Plot A2 exhibited the slowest infiltration rate, requiring the longest time to reach a given water volume, while plot A3 displayed the fastest percolation. The difference in the time required to reach each water volume between the three types of land may be due to differences in soil characteristics among the three sites.

Plot A2 has the lowest average permeability value compared to the other two sites, at 13.22 cm/hr. The low permeability value may be one of the factors causing the slowest water flow rate in plot A2. A low permeability value means that the soil does not easily allow water to pass through. Additionally, a relatively high organic matter content can also affect the slow rate of water percolation. Plot A2 exhibits an organic matter content of 0.97% (Table 3). This organic matter enriches the soil with humus (Clivot et al., 2020), increasing the soil water storage capacity (Masnang, 2023), causing the water to be retained by the soil for a longer period.

CONCLUSION

In general, land management practices affect the ability of sandy soil to retain water, particularly in terms of permanent wilting point moisture content and available moisture content parameters. Additionally, differences in land management practices also affect the characteristics of the soil, as indicated by the highest wind-dried moisture content values found on plot A1 and the lowest on plot A3.

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