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SOIL QUALITY ALONG A DISTANCE GRADIENT FROM SHORELINES IN SAMAS COASTAL SANDY LAND, BANTUL, YOGYAKARTA

KUALITAS TANAH PADA JARAKGARIS PANTAI DI LAHAN PERTANIAN PASIR PANTAI SAMAS YOGYAKARTA

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ABSTRACT

ABSTRACT Samas' coastal sandy land is characterized as a marginal agricultural area, approximately 4 km from the shoreline. This study aimed to evaluate the soil characteristics, calculate the soil quality index (SQI), and identify limiting factors affecting soil quality. This study used a purposive sampling method at different distances from the coastline. Soil quality parameters analyzed included root density, bulk density, porosity, clay content, organic C, total N, available N/P/K, pH, and microbial counts (CFU/g). Soil quality was evaluated based on the criteria by Mausbach & Seybold (1998) and the scoring function from Karlen et al. (1996) with adjustment for local conditions. The results showed that the soil 1 km from the coastline had the highest sand content (62.041%) but the lowest microbial counts (6.7×10^5 CFU/g). In comparison, soils at 4 km showed the lowest sand content (19.819%) and highest organic C (1.297%), total N (0.392%), C/N ratio (3.309), and microbial activity (19.1×10^5 CFU/g). Available N, P, and K were consistently high across all sites. The SQI increased with distance from the coast, ranging from "moderate" (SQI 0.472 at 1 km) to "good" (SQI 0.774 at 4 km). The limiting factors identified were porosity, non-capillary porosity (NPD), organic C, and available N. These findings highlight how shoreline proximity affects soil quality gradients and underscore the necessity for location-specific soil management strategies in Samas' coastal sandy agroecosystems.

Keywords: Coastal sandy land, distance, soil quality, soil quality index

ABSTRAK

ABSTRAK Lahan pasir pantai Samas dicirikan sebagai kawasan pertanian marginal, sekitar 4 km dari garis pantai. Penelitian ini bertujuan untuk mengevaluasi karakteristik tanah, menghitung indeks kualitas tanah (SQI), dan mengidentifikasi faktor-faktor pembatas yang memengaruhi kualitas tanah. Penelitian ini menggunakan metode purposive sampling pada jarak yang bervariasi dari garis pantai. Parameter penilaian kualitas tanah meliputi jeluk perakaran, berat volume, porositas, kandungan debu lempung, C-organik, N-total, N-tersedia, P-tersedia, K-tersedia, pH, dan jumlah mikroba. Analisis kualitas tanah berdasarkan kriteria Mausbach dan Seybold (1998) dan fungsi penilaian menurut Karlen et al. (1996) yang telah disesuaikan dengan kondisi lapangan. Hasil penelitian menunjukkan bahwa tanah yang berjarak 1 km dari garis pantai memiliki kadar pasir tertinggi (62,041%) tetapi jumlah mikroba terendah ($6{,}7\times10^5$ CFU/g), sementara tanah yang berjarak 4 km ke daratan menunjukkan kadar pasir terendah (19,819%) dan C organik tertinggi (1,297%), N total (0,392%), rasio C/N (3,309%), serta aktivitas mikroba ($19{,}1\times10^5$ CFU/g). Kandungan N-tersedia, P-tersedia, dan K-tersedia disetiap titik pengambilan sampel tergolong tinggi. Indeks kualitas tanah meningkat seiring dengan rentang jarak lahan pertanian dari pantai dengan dengan nilai IKT 0,472 (sedang) pada 1 km menjadi IKT 0,774 (baik) pada jarak 4 km. Faktor pembatas pada kualitas tanah yaitu porositas, NPD, C-organik, N-tersedia tanah. Temuan ini menyoroti bagaimana kedekatan garis pantai memengaruhi gradien kualitas tanah dan menggarisbawahi perlunya strategi pengelolaan tanah spesifik lokasi di agroekosistem berpasir pesisir Samas.

Kata kunci:* *indeks kualitas tanah, jarak, kualitas tanah, lahan pertanian pesisir pantai

INTRODUCTION

The coastal sandy land in Srigading Village, Sanden District, Bantul, Yogyakarta, covers approximately 48 hectares, with 24 hectares currently used for seasonal crop cultivation. However, the crop productivity, such as rice, corn, chili, and shallots, is still below the optimal level due to the dominant sandy texture of the soil. Sandy soils are limited by low water holding capacity, reduced fertility, minimal organic matter content, low cation exchange capacity (CEC), and high rates of infiltration and evaporation rates (Scoop, 2014). Degraded soil consistency significantly impairs the soil's ability to support plant growth and development (Sefiana, 2022). Poor soil consistency is strongly associated with land degradation and directly impacts soil workability.

The sandy coastal area has notable challenges; however, it possesses a significant advantage due to its high-quality, shallow groundwater. According to the criteria established by FAO (1983), Handiri and Wirasto (2009) classified the South Coast sandy land in the Special Region of Yogyakarta as unsuitable (N) for food crops and vegetables. Nevertheless, the research indicates that clay amendments can improve soil properties and enhance agricultural productivity.

The agricultural sandy land along Samas Beach extends 4 kilometers from south to north, where local farmers utilize a variety of management practices. Variations in tillage practices, fertilization, and the application of ameliorants have led to significant spatial variability in soil conditions. Additionally, the proximity to the coastline further influences the landscape dynamics, shaping both land management strategies and human activities.

Farmers' practices, such as irrigation, mechanized tillage, and nutrient management, also play a critical role in determining soil quality. This study employs a Soil Quality Index (SQI) analysis to evaluate the agricultural sandy land at Samas Beach. The findings aim to guide sustainable soil management strategies for maintaining, rehabilitating, and enhancing soil quality.

MATERIALS AND METHODS

The research was conducted in the sandy land of Samas Beach, located in Srigading Village, Sanden District, Bantul Regency, Special Region of Yogyakarta. The physical, chemical, and biological properties of the soil were analyzed at the Land Resources Laboratory, the Soil Conservation and Land Reclamation Laboratory, and the Soil and Environmental Biology Laboratory at UPN "Veteran" Yogyakarta. The research was conducted from December 2023 to April 2024. Sampling used a purposive method on agricultural land located 1 to 4 kilometers from the Samas coastline. Each sampling site was replicated three times.

The analysis of soil samples included several parameters: volume weight retention, porosity, and aggregate stability, which were assessed based on dispersion comparison values. Soil texture was determined using the pipetting method, pH was measured using a 1:5 soil: water suspension test, and soil organic carbon levels were analyzed using the Walkey and Black method. Available N was measured through the Kjeldahl method, available P using the Olsen method, and available K with NH_4OAc saturation. Total N was also determined with the Kjeldahl method, and microbial counts were obtained using the pour plate method. The soil quality index was calculated following the criteria established by Mausbach and Seybold (1998) (Table 1).

Table 1. Modify the scoring of the soil quality index

Soil Function	Weight 1	Soil Indicators	Weight 2	Weight 3	Indexes
Microbial Biomass Preservation	0.4	Depth of soil and rooting	0.3		
		Rooting Depth (cm)		0.6	0.072
		Volume weight (g/cm3)		0.4	0.048
		Moisture	0.3		
		Porosity (%)		0.2	0.024
		Organic C (%)		0.4	0.048
		Dust-clay (%)		0.4	0.048
		Necessities	0.4		
		pH		0.1	0.016
		Available P (mg/kg)		0.2	0.032
		Available K (mg/kg)		0.2	0.032
		Organic C (%)		0.3	0.048
		N-available (mg/kg)		0.2	0.032
Water Regulation and Distribution	0.3	Dust-clay (%)	0.6		0.18
		Porosity (%)	0.2		0.06
		Volume weight (g/cm3)	0.2		0.06
Filter dan Buffering	0.3	Dust-clay (%)	0.6		0.18
		Porosity (%)	0.1		0.03
		Microbiological process	0.3		
		Organic C (%)		0.4	0.036
		Total nitrogen (mg/kg)		0.4	0.036
		Total microbes (*cfu*/gram)		0.2	0.018

The SQI was determined by multiplying the weights assigned to various functions, indicators, and soil parameters. Indicator scores were derived by comparing observed soil data against assessment limits that range from 0 (very low) to 1 (very high), utilizing interpolation or linear equations. Subsequently, the weight index of the calculated results is multiplied by the corresponding indicator score. The final value is then categorized based on the suitability aligned with the existing classification (Table 2).

Table 2. Soil quality class based on soil quality index

No	Soil Quality Class	Soil Quality Indexes
1	0.80 – 1.00	Very High
2	0.60 – 0.79	High
3	0.40 – 0.59	Moderate
4	0.20 – 0.39	Low
5	0.00 – 0.19	Very Low

RESULTS AND DISCUSSION

A. Site Sampling Condition

The sampling was conducted in four areas at varying distances from the coast. The first site (1 km from the coastline) was a 21-day-old shallot plantation located in Dukuh Tegalrejo. The second site (2 km from the coastline) was another 21-day-old shallot plantation in Dukuh Baran. The third site (3 km from the coastline) consisted of a post-shallot plantation in Dukuh Dengokan. Lastly, the fourth site (4 km from the coastline) was a post-shallot plantation in Dukuh Wuluhadeng. The land management practices in this last area included tillage using a mini tractor and the application of both organic and inorganic fertilizers (NPK), applied at varying times and intensities.

B. Soil Quality Index (SQI)

The value of the soil quality index was calculated by multiplying the index weight by the score. The value of this index will describe the quality of the soil at a specific location. The average results of the SQI values for agricultural land along the coast of Samas Beach, within a certain radius from the beach, are shown in Table 3 and Figure 1.

Based on the average soil quality index (Table 3), land at a distance of 1 kilometer from the coast has an index of 0.472 (moderate criteria), while land at a distance of 2 kilometers has an index of 0.600, 3 kilometers has 0.650, and 4 kilometers has 0.776, all with good criteria. Optimal soil capacity as a growing medium depends on good physical, chemical, and biological properties (Brady, 1982). High soil fertility reflects good soil quality, which supports soil function in plant growth, regulating water flow, and creating a good environment (Juarti, 2016).

On land 1 kilometer from the coast, the soil quality index is 0.472 (moderate criteria), indicating the need for improvement in several parameters, such as the addition of clay to reduce NPD and increase N availability, and the addition of organic matter to increase porosity. Meanwhile, land 4 kilometers from the coast has an index of 0.776 (good criteria), which means that soil quality needs to be maintained at good parameters and improved on parameters that remain suboptimal.

The soil quality in coastal sandy agricultural land increases with distance from the coastline. The difference in distance does not directly affect soil quality, but it impacts farmer management patterns and land management. Near the coast, the sand fraction dominates the soil texture, while the further away, the more dominant the clay fraction. Soil near the coast is Regosol, while soil far from the coast is Cambisol, with clay content increasing with distance from the coastline (Diyanti, 2022). It can be concluded that the soil quality index (SQI) depends on the physical, chemical, and biological conditions of the soil. The better these properties, the higher the assessment score and SQI value.

C. Physical, Chemical, and Biological Soil Characteristics

Analysis of soil physical properties reveals that root depth increases as agricultural land moves away from the coast, accompanied by increased porosity and decreased volumetric weight. Bulk density was affected by the number of pores; more pores led to lighter soil particles, resulting in lower volumetric weight over four kilometers of land. Conversely, decreased pores cause high volumetric weight and low porosity, resulting in low root depth (1 kilometer of land). 2 kilometers of land has higher porosity because there is more organic material than 1 kilometer of land. Organic matter affects the stability of soil aggregates, which affects the ability of roots to penetrate the soil. Short root depth is caused by less stable soil aggregates, with the highest dispersion value and the lowest clay dust content (Brady, 1982). All lands have high NPD (<19%), indicating that the dust and clay content do not strongly bind the sand. Soil texture improves as land moves away from the coast due to the addition of clay dust fractions and organic matter.

Based on the analysis of the soil's chemical characteristics, the pH level across all lands was neutral (6.5-7.5), which is ideal for the nutrients' availability. The available P, K, and total N in the soil were high due to the use of cow dung and NPK fertilizers. The soil total N increased as the land moved away from Samas Beach, due to the higher clay dust fraction in the further land, which has a large surface area and better colloidal ability to bind N. Nitrogen is easily mobile, so its availability in the land near the coast is more susceptible to leaching (Brady, 1982).

Table 3. Result of soil quality index in several area at Samas Beach

Soil Function	Indicator	Weight Indexes	Soil Quality Indexes											
			1 km			2 km			3 km			4 km		
			A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3
Microbial Biomass Preservation	Rooting Depth (cm)	0.072	0.020	0.039	0.039	0.026	0.052	0.065	0.020	0.059	0.072	0.033	0.039	0.072
	Volume weight (g/cm3)	0.048	0.016	0.041	0.038	0.022	0.025	0.010	0.016	0.020	0.023	0.010	0.004	0.009
	Porosity (%)	0.024	0.009	0.017	0.015	0.023	0.014	0.021	0.015	0.019	0.015	0.015	0.023	0.021
	Organic C (%)	0.048	0.004	0.002	0.018	0.025	0.026	0.024	0.029	0.030	0.028	0.023	0.047	0.042
	Dust-clay (%)	0.048	0.025	0.021	0.021	0.030	0.033	0.033	0.034	0.039	0.032	0.048	0.048	0.047
	pH	0.016	0.015	0.011	0.012	0.011	0.015	0.014	0.016	0.013	0.013	0.014	0.013	0.015
	Available P (mg/kg)	0.032	0.0004	0.017	0.030	0.0003	0.030	0.017	0.024	0.026	0.030	0.020	0.027	0.030
	Available K (mg/kg)	0.032	0.026	0.030	0.028	0.018	0.006	0.011	0.0004	0.023	0.0004	0.010	0.030	0.021
	Organic C (%)	0.048	0.004	0.002	0.018	0.025	0.026	0.024	0.029	0.030	0.028	0.023	0.047	0.042
	Available N (mg/kg)	0.032	0.001	0.026	0.029	0.002	0.029	0.025	0.028	0.030	0.026	0.021	0.016	0.023
Water Regulation and Distribution	Dust-clay (%)	0.18	0.092	0.078	0.079	0.112	0.123	0.122	0.126	0.147	0.121	0.180	0.178	0.176
	Porosity (%)	0.06	0.024	0.043	0.039	0.057	0.035	0.052	0.036	0.046	0.037	0.038	0.058	0.052
	Volume weight(g/cm3)	0.06	0.019	0.051	0.048	0.027	0.031	0.013	0.020	0.025	0.029	0.012	0.005	0.011
Filter dan Buffering	Dust-clay (%)	0.18	0.092	0.078	0.079	0.112	0.123	0.122	0.126	0.147	0.121	0.180	0.178	0.176
	Porosity (%)	0.03	0.012	0.021	0.019	0.028	0.017	0.026	0.018	0.023	0.018	0.019	0.029	0.026
	Organic C (%)	0.036	0.003	0.002	0.014	0.018	0.019	0.018	0.022	0.022	0.021	0.017	0.035	0.031
	Total nitrogen (mg/kg)	0.036	0.002	0.014	0.022	0.009	0.016	0.026	0.0001	0.027	0.024	0.009	0.014	0.030
	Total Microbes (*cfu*/gram)	0.018	0.0002	0.007	0.00001	0.008	0.002	0.002	0.004	0.005	0.018	0.005	0.016	0.014
Total Soil Quality Indexes		0.366	0.366	0.500	0.551	0.553	0.620	0.626	0.562	0.733	0.657	0.675	0.808	0.840
			Low	Moderate	Moderate	Moderate	High	High	Moderate	High	High	High	Very High	Very High
				0,472 Moderate			0,600 High			0,650 High			0,774 High	

Analysis of soil biological properties showed that the levels of organic C in all lands were relatively low due to the perfect decomposition of organic matter, reflected in the low C/N ratio. The high total N content contributed to the low organic C. The organic C content increased as the land moved away from Samas Beach, along with a higher C/N ratio. The source of organic C came from plant litter and the addition of organic matter. The number of soil microbes increased as the land was further away from Samas Beach, supported by neutral soil pH. The availability of microbes was positively related to organic C, which was higher in lands with a greater dominance of clay dust fractions, with another Entisol by volcanic material source.

D. Limiting Factor in Soil Quality

The agricultural soils of Samas Beach, Yogyakarta, exhibit several low-value parameters that act as limiting factors for optimal soil functionality and plant growth. The limiting factors of soil physical properties in the sandy agricultural land of Samas Beach are porosity and dispersion ratio (NPD) values. Soil porosity in all research locations is classified as poor and bad, with values below 50%, which affects water distribution and storage. NPD in all locations also shows soil easily eroded, exceeding the critical threshold of 19% for stable soil aggregates. NPD is related to aggregate stability; high values indicate soil is easily dispersed, indicating weak clay dust bonds to sand. The limiting factors of soil quality in chemical properties are organic C and available N content.

Organic C content in all research locations is low, which reduces the Criteria score and soil quality index value. Organic matter plays a role in improving soil physical properties, such as reducing density and increasing porosity. Available N content is also low, inhibiting plant growth because nitrogen is an important macronutrient. Meanwhile, there are no limiting factors on the biological properties of the soil, because the values of Organic C, N-total, C/N ratio, and number of soil microbes already meet the criteria for plant growth. The primary limiting factors across the study area are poor porosity, high dispersion ratio, and low organic C and nitrogen content, especially near the coastline.

CONCLUSION

1. The organic C content in the soil is related to the number of soil microbes, which increases as the distance from the agricultural land of Samas Beach. Conversely, the sand fraction decreases, while the C/N ratio increases along the same gradient. Although total N, available P, and K are high, the organic C content remains low across all sites.
2. Samas Beach exhibits varying SQI based on the distance from the coastline. At 1 kilometer from the beach, the soil quality is classified as moderate, with an index of 0.472. However, by 2 kilometers, it improves to good, with an index of 0.600. At 3 kilometers, the soil quality remains good, with an index of 0.650. Finally, at 4 kilometers from the beach, the soil quality continues to be good, reaching an index of 0.774. This trend indicates that the SQI improves as one move further away Samas Beach.
3. The limiting factors for soil quality on sandy agricultural land at Samas Beach are porosity, NPD, organic C, and available N.

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