

Site-specific planting design: Linking soil texture analysis to ecological landscape design strategies

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ABSTRACT

Despite the growing emphasis on sustainable campus landscapes, planting decisions often rely on generic species palettes that overlook micro-site soil variability, resulting in poor plant performance and increased maintenance demands. Additionally, insufficient consideration of soil analysis during the landscape design process affects overall landscape performance by disrupting the intended design concept, ultimately hindering the spatial aesthetic, ecological, and functional goals. Addressing this gap, the study explores the use of basic and cost-effective soil texture analysis as an educational tool to inform site-responsive planting strategies. Two accessible soil analysis techniques, namely the soil jar test and the ribbon method, were used to assess soil texture collected as composite samples across eight selected zones ($n = 8$) within Universiti Malaysia Kelantan, specifically on the Bachok and Jeli campuses. By combining visual sedimentation and tactile assessment, the study translated the findings into site-based planting recommendations for landscape design. The results reveal distinct differences on both campuses, which yielded two soil texture classes with contrasting plant species selections. Bachok's campus soils tend toward sandy loam, which supports drought-tolerant and fast-draining species such as *Casuarina equisetifolia*. Moisture conservation practices, including the application of mulch and frequent shallow irrigation during the establishment phase, are crucial for sustaining plant growth. On the other hand, Jeli campus soils exhibit a higher clay content, which favors moisture-retentive species like *Syzygium myrtifolium*. Implementing contour planting and incorporating raised planting beds enhances soil aeration and improves root zone condition. The outcome of this study provides practical and site-specific plant recommendations tailored to each campus's soil conditions, confined particularly to rapid textural-based analysis. By aligning planting design strategies with local soil conditions, this study implied the contribution to ecologically grounded planting practices and promoted greater awareness of soil-responsive design strategies in campus environments.

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1. INTRODUCTION

Sustainable campus development is increasingly prioritized, with landscape design playing a significant role in ecological, aesthetic, and human well-being, as well as resource management (Gomez & Derr, 2021). An effective campus landscape design must be grounded in a comprehensive understanding of the site-specific context, including the characteristics of local soil types. While past campus landscape studies have primarily focused on species composition to improve visual quality, few integrate soil texture as a design driver. For instance, Zhang (2022) stated that the role of soil analysis has received limited attention in informing and applying the landscape services concept for design decisions. As a fundamental characteristic influencing plant growth, Brady and Weil (2008) also noted that insufficient consideration is often given to understanding soil texture,

which affects water flow, aeration, moisture retention, and nutrient availability in the selection of planting designs.

Although numerous studies highlight the substantial selection of soft landscape elements and spatial layout strategies, such as the studies conducted by Akhir et al. (2023) and Xian and Du (2022), the foundational limited attention to soil characteristics, such as the soil texture and structure, remains underexplored in providing a strong basis for planting implementation in campus settings. This gap is particularly evident during the early stages of the landscape design process, specifically in the site inventory, analysis, and synthesis. These pre-design phases involve gathering, organizing, and evaluating vital information that will serve as the foundation for the subsequent design phases.

Nevertheless, insufficient consideration of soil analysis during the design process may adversely affect planting selection and overall landscape performance. Li and Lee (2025) noted that the personal aesthetic viewpoints and experiences of landscape designers often shape their design decisions, which may compromise the objectivity of the resulting designs. Unawareness of the importance of soil analysis not only affects plant health (Xing et al., 2025) but can also compromise the practicality of the intended landscape design concept, ultimately hindering the aesthetic, ecological, and functional goals of spatial planning. Therefore, while aesthetic judgment plays a role in landscape design, ecological compatibility remains the fundamental consideration. Healthy vegetative growth can only be achieved when plants are selected based on their adaptability to specific site conditions, ensuring balanced coexistence with other organisms and human activities (Uppala et al., 2025).

Generic assumptions about soil conditions often lead to mismatched planting schemes, higher maintenance demands, and compromised sustainability of the campus environment. Planting decisions that repeatedly default to generic, aesthetically driven species palettes or regional recommendations fail to account for significant micro-site soil variability across campus (Law et al., 2025; Bateman et al., 2023). This oversight often resulted in poor plant establishment, increased mortality rates, higher irrigation demands, and elevated reliance on fertilizers and pesticides, ultimately leading to unsustainable maintenance burdens and costs (Kjellgren et al., 2000). This situation compromises the ecological functionality and value of the landscape design, limiting opportunities to enhance plant performance and utilize resources efficiently, thereby promoting campus sustainability.

Addressing this deficiency requires a shift toward site-responsive planting strategies, grounded in specific local site conditions, by integrating practical soil analysis into the landscape design process. This study argues that integrating basic, cost-effective soil texture analysis into the early planning of design stages can significantly improve planting success and sustainability. Focusing on Universiti Malaysia Kelantan (UMK) campuses at Bachok and Jeli, this study aims to evaluate soil texture variability across UMK campuses using low-cost methods and translate the results into site-specific planting strategies for sustainable campus design.

2. LITERATURE REVIEW

2.1. Ecological Landscape Design and Sustainable Campus Planning

Sustainable campus landscape design emphasizes the creation of environments that are resource-efficient,

ecologically functional, and require minimal long-term maintenance inputs (Agraval & Yadav, 2021). Within this framework, site analysis forms a foundational principle that guides subsequent design decisions. However, the integration of soil characteristics remains limited in many planting design specifications. Sustainable campus design initiatives often prioritize spatial composition, green infrastructure, or user experience, yet the underlying biophysical context of soil conditions is frequently underexamined (Li & Lee, 2025). Recognizing soil as a living system that underpins plant health and ecosystem performance is crucial for achieving long-term sustainability and resilience in campus landscapes (Uppala et al., 2025).

2.2. Soil Texture and Its Functional Importance

Soil texture, defined by the relative proportions of sand, silt, and clay particles, determines the key physical and hydrological properties. Sandy soils drain rapidly, but retain limited water and nutrients. In contrast, clay soils have high water-holding capacity but poor drainage, while loam soils offer a balanced medium for plant growth (Brady & Weil., 2008). Texture is crucial in evaluating soil behavior and its implications for agriculture, environmental management, and landscape applications. It governs a range of interrelated properties, including drainage characteristics, aeration, nutrient availability, and overall soil fertility. Accurate texture classification is essential for land-use planning, ecological restoration, and planting design (Rajendra et al., 2025).

2.3. Plant Adaptation to Soil Conditions

Plant species exhibit specific physiological and morphological adaptations to soil moisture regimes, aeration, and mechanical resistance, all of which are controlled by soil texture (Larcher, 2003). The selection of plants that are mismatched to the underlying soil texture often results in physiological stress, poor growth, and greater susceptibility to pests and diseases. Consequently, an understanding of soil-plant interactions should form the foundation of planting design decisions, particularly within educational and campus settings where diverse soil conditions coexist. Despite this, detailed soil texture mapping at the micro-site level remains rare in campus landscape planning due to perceived cost and procedural complexity (Helfand et al., 2006).

3. METHODOLOGY

3.1. Site Study

The research was conducted at two campuses of Universiti Malaysia Kelantan. The Bachok campus (approximately 5.99698° N, 102.40338° E), located 8 km from the town of Bachok, is the largest and operates as the main

campus, covering a total area of 3,152,503.94 m² (779 acres). The site was a former paddy plantation before the construction of the Bachok campus started in 2007. 71% of the total area is encompassed by green, in which approximately 40% (1,270,000 m²) of this area is comprised by natural gelam forest (*Maleleuca cajaputi*). In addition, 31% (973,303 m²) of the area is covered with planted vegetation, and about 7% dedicated to water buffer zones (Sustainability Report UMK 2020/2021). The surrounding ecosystem comprises a mosaic of coastal vegetation, agricultural land, and patches of secondary forest, as illustrated in Figure 1. These diverse environmental conditions make the site ideal for exploring various soil textures, drainage capacities, and nutrient profiles, thereby supporting studies related to sustainable landscape and planting design.



Figure 1: Site study of UMK Bachok campus (Source: Google Map, 2025)

The Jeli campus (latitude 5°43'15" to 5°45'30" N and longitude 101°51'15" to 101°53'30" E), situated in Gemang, Jeli, Kelantan, operates as a science-based campus that comprises an area of about 5000 m² (270 acres). Formerly a rubber plantation, the campus area is located in an inland area within a more humid tropical forest biome. The campus features secondary tropical rainforest fragments, which are utilized for biodiversity conservation and resource studies, as illustrated in Figure 2. The managed landscape zones, featuring diverse vegetation types, recorded a wide variety of landscape plantings, comprising over 1,400 trees from 83 different species (Daliman et al., 2021). These multiple representatives of landscape zones within the Jeli campus contribute to spatial heterogeneity in soil layers, which is important for capturing potential variability in soil sampling.

3.2. Soil Sampling

The composite soil samples were collected during a two-day field survey conducted on 9-10 April 2025, coinciding with the end of the northeast monsoon period, to capture the stable soil moisture and texture characteristics for analysis. A

systematic approach was adopted to collect the soil sample that included the following considerations: (i) mapping the area for sampling locations; (ii) taking appropriate tools; (iii) collecting samples at the correct depth and procedures, and (iv) handling the samples properly. This ensures the sample accurately reflects the overall soil conditions for analysis (Schoeneberger et al., 2021).



Figure 2: Site study of UMK Jeli campus (Source: Google Map, 2025)

3.2.1 Sampling Sites

Soil samples were collected from representative zones based on land-use categories and vegetation cover. Each campus was divided into sub-zones based on visual vegetation patterns and topographical features. A total of 8 sampling plots (n=8) were selected, in which 5 soil samples were collected at Bachok campus, and 3 soil samples were collected at Jeli campus to ensure diverse representation of soil conditions as depicted in Table 1.

3.2.2 Sampling Collection Procedures

Soil samples were extracted at each sampling point, specifically for soil fertility assessment, using a trowel to a depth of 15–20 cm, corresponding to the primary root zone for most herbaceous and woody landscape plants (Abate, 2024). At each sampling point, soil was collected from 3 to 5 spots within a 1- to 2-meter radius, depending on the size of the designated zone. Each soil sample from a different location was thoroughly mixed to form a single composite sample. Mixing the multiple subsamples creates a more representative sample for the selected point, thereby increasing reliability (Brewer et al., 2016). Furthermore, able to prevent bias by avoiding anomalies due to local features (e.g., root clumps, stones, animal droppings). Approximately 500 grams of soil was collected per location and placed in labeled ziplock bags.

Table 1: Selection of sampling plots at Bachok Campus and Jeli Campus

Sampling Area / Plot	Site Description (Vegetation Characteristics and Topographical Features)	Ecological and Design Rationale for Site-specific Sampling
Bachok Campus		
1. Dewan Tunku Canselor:	Formal landscape design with ornamental shrubs, structured street planting. Flat to slightly elevated area with artificial hardscape.	Represents constructed landscapes with compacted soil due to pedestrian traffic and structural proximity. Soil analysis is crucial for evaluating drainage performance, compaction levels, and suitability for ornamental species in high-traffic areas.
2. Lake	Mix of aquatic-edge species, grasses, and riparian buffer plants. Some areas are planted with native wetland-adapted species. Depressed, low-lying basin with natural water catchment.	As a hydrologically sensitive area, this site is characterized by poorly drained or silty soils, which are typically found near lake edges. The soil data are important for selecting species with high water tolerance and designing buffer planting zones to manage erosion.
3. Student Residential Area (IBS)	Semi-formal planting with street trees, shrubs, and turf; mixed sunlight and shade conditions. Mildly undulating terrain around built structures with moderate drainage.	Reflects residential landscaping under partially shaded conditions. Soil samples here help assess texture variability due to human-modified ground layers, guiding low-maintenance, shade-tolerant planting strategies near student accommodations.
4. Sport Complex	Predominantly turfgrass with scattered shade trees, especially along the perimeter; open field conditions. Broad, level to gently sloped area designed for surface water runoff.	Represents intensively maintained open green spaces. Soil texture analysis informs surface drainage, root zone suitability for turf, and compaction risks due to recreational use, supporting sustainable turf management strategies.
5. Veterinary Farm / Agro-Techno Park	Open agricultural plots with forage crops, pasture grasses, and animal-grazed areas. Gently sloping land with evidence of historical paddy uses and managed agricultural fields.	Implies the agricultural and agro-ecological contexts. Soil texture data are key to evaluating the suitability of soils for food crops, forage, and tree planting, as well as for comparing managed versus natural soil conditions in ecological design integration.
Jeli Campus		
1. Dewan Utama	Formal campus landscaping with ornamental shrubs, flowering plants, palm trees, and maintained lawn areas surrounding the hall. Slightly elevated and flat terrain with paved surroundings and drainage channels.	Typifies a high-activity zone with artificial soil modifications and compaction resulting from pedestrian traffic and proximity to hardscape. Supports the evaluation of planting conditions under managed and built environments, where texture affects drainage and influences the selection of planting palettes for institutional landscapes.
2. Tengku Muhammad Fa-iz Petra Mosque	Mixed shade trees, palms, ornamental shrubs, turfgrass, and flowering species in formal planting beds, with shaded and semi-open conditions. Moderately sloped terrain with landscaped embankments and water flow paths around built structures.	Reflects a semi-formal landscape with partial canopy cover and structured plantings that experience periodic foot traffic. Soil texture data from this site help inform plant choices for shaded, moderately sloped areas and guide maintenance practices in religious and communal spaces, where both aesthetics and function are important.
3. Lake near to Faculty of Agro-based Industry (FIAT)	Naturalized vegetation near the lake edge, including grasses, sedges, riparian plants, and scattered trees; minimal human intervention in some parts. Low-lying depression forming a natural catchment area; often seasonally waterlogged or saturated.	An example of a naturalized ecological buffer zone. Soil texture analysis is crucial for assessing hydrological response, such as water retention and permeability, which directly influence the selection of wetland-adapted or flood-tolerant species. The findings support the use of ecologically sensitive planting layouts for erosion control and biodiversity enhancement near water bodies.

**Figure 3:** Procedures taking the soil samples – digging, measuring depth, mixing, and labelling

All soil samples were air-dried at room temperature (approximately 27°C) for 48 to 72 hours before analysis. This process ensured uniform moisture conditions, prevented microbial alteration, and improved sample handling. Following air-drying, soil samples were gently crushed using a mortar and pestle to disaggregate clumps and release individual particles. The crushed soil was then passed through a 2 mm sieve to remove gravel, roots, and other coarse materials. This process ensured that only the fine earth fraction (<2 mm) was used for subsequent soil texture analyses, in accordance with standard soil testing protocols.

3.3. Soil Texture Analysis

Two low-cost and accessible soil texture analysis techniques namely the soil jar test and the ribbon method was employed to investigate textural variation in each sampling point collected. These techniques were selected for their practicality where rapid, field-based assessments are often needed as an expeditious test being conducted as part of the

experimental program (Saliba et al., 2025) in landscape design settings to support ecological planting design decisions. This soil jar test was employed for the sedimentation-based analysis, while the ribbon method was employed for tactile-based assessment. These accessible techniques provide complementary visual and tactile assessments of soil texture. The methodological accessibility supports replicability in pedagogically resource-constrained academic settings while maintaining relevance for professional applications, such as rapid soil-based site assessments.

3.3.1 Soil Jar Test

The soil jar test was employed to quantitatively classify soil texture by estimating the relative proportions of sand, silt, and clay based on particle-size distribution and sedimentation rates. This method followed a simplified sedimentation protocol adapted from the United States Department of Agriculture (USDA NRCS, 1993). While this technique is commonly used in introductory soil science, its application in this study was intentionally adapted to suit educational and resource-limited contexts. Instead of relying on laboratory-based hydrometer analyses, the method utilized readily available glass jars and household detergents as dispersing agents, allowing for rapid, low-cost, and replicable assessments. This adaptation supports experiential learning in landscape architecture education and provides meaningful data for the early stages of the landscape design process, particularly in analyzing soil attributes that inform planting decisions.

The textural analysis from the soil jar test served as a preliminary assessment of the soil's particle size distribution, which can be more accurately determined through laboratory tests (Changyi Meng et al., 2018). While it is suitable for site-level comparative analysis, the method generally yields an accuracy within $\pm 10\%$ compared to laboratory-based hydrometer analysis (Gee & Bauder, 1986). This field texture analysis approach is further reinforced by Rajendra et al. (2025), who emphasized that its particular strengths and applicability are influenced by considerations such as the required level of accuracy, ease of implementation, available expertise, cost constraints, and the specific objectives of the study. This level of precision is considered acceptable in landscape design applications where relative soil conditions are sufficient to inform the site suitability for ecological decision-making. The procedure consisted of the following five key steps:

(i) Sample preparation: Approximately 250 to 300 g of air-dried, crushed, and sieved (<2 mm) soil was placed into a

clean 750 mL transparent jar. This amount allows enough volume to create a distinct sedimentation profile.

(ii) Addition of water and dispersing agent: Distilled water was added to the jar up to 500 to 600 mL, leaving 5 to 6 cm of headspace to allow effective shaking. This ensured a soil-to-water ratio of approximately 1:2 to 1:3 by volume. Consequently, 5 to 10 drops of liquid dish detergent, serving as a dispersing agent (e.g., sodium hexametaphosphate), were added to disaggregate soil particles and maintain suspension during sedimentation.

(iii) Shaking: The jar was tightly sealed and shaken vigorously for 1 to 2 minutes to fully disaggregate the soil particles and create a homogeneous suspension.

(iv) Sedimentation: The jar was placed undisturbed for 48 hours on a flat surface. Sand particles settled within 1 to 2 minutes, silt particles within 1 to 2 hours, and clay particles within 24 to 48 hours. Particles settled over time based on their size and weight.

(v) Layer measurement and texture determination: After 48 hours of sedimentation, the thickness of each soil layer formed was measured using a ruler. The percentage of each particle size fraction was calculated relative to the total depth of the soil. To quantify the relative proportion of an individual layer within a stratified profile, the percentage of a specific fraction is calculated by dividing the height of the selected layer (in cm) by the cumulative height of all layers (in cm) and then multiplying the result by 100. This normalization enables a standardized assessment of the vertical distribution of fractions within the profile, facilitating comparative analysis across samples and study sites. The soil textural class is further classified using the USDA soil texture triangle (Soil Survey Staff, 2024).



Figure 4: Steps conducting soil jar test for sedimentation analysis

3.3.2 Ribbon Method

Complementing the soil jar test, the ribbon method served as an empirical approach, utilizing qualitative evaluation of physical-based properties to classify soil texture based on feel standards. This standard is guided by the feel method flowcharts developed by Thien (1979) to interpret

tactile assessment of soil according to ribbon length and surface texture characteristics. The tactile field technique estimates soil texture based on plasticity and cohesion. In the context of the study, the approach was modified to emphasize hands-on interpretation and collaborative learning among students. Participants compared tactile observations across multiple landscape zones, thereby enhancing their ability to relate soil feel with environmental variation across campus sites. This pedagogical adaptation reinforces critical observation and decision-making skills essential for landscape design education, particularly in settings where access to advanced analytical tools is limited. The procedure generally involves four key steps:

(i) Sample Preparation: A small amount, approximately 25 to 30 grams (heaping tablespoon) of air-dried, sieved soil was moistened gradually with water on the palm until it reached a pliable and workable consistency for feel assessment.

(ii) Ball and Ribbon Formation: The moistened soil was kneaded thoroughly by hand to achieve a uniform, plastic consistency, ensuring even distribution of moisture throughout the particles. Then, the soil was molded into a cohesive ball to assess stickiness and cohesion. The ball was subsequently rolled and pressed between the thumb and forefinger to form a flat ribbon.

(iii) Ribbon Length Measurement: The maximum length and the stability of the ribbon could be extended before breaking was observed and measured. Ribbon length was used to estimate the clay content, thus reflecting the soil's plasticity.

(iv) Texture Estimation: The soil's feel or tactile characteristics, including grittiness, smoothness, and stickiness, as well as the ribbon length, were interpreted using standard field texture keys. Classification into soil texture groups (e.g., sandy loam, clay loam) was guided by Thien's (1979) feel method flowchart, which provides a systematic framework for qualitative texture estimation.



Figure 5: Steps for conducting the ribbon method for tactile assessment

4. RESULT

The results of the soil analysis, performed using both the soil jar test and the ribbon method, were compared and synthesized across the designated sampling area within the Bachok and Jeli campuses to determine the definitive textural class for each sample according to the USDA classification system. To ensure reliability and consistency between the jar test and ribbon method, each composite soil sample was analyzed using both techniques under the same environmental conditions. The outcomes were cross-validated by comparing the textural classifications derived from both methods to identify any discrepancies and confirm agreement in texture categories. The findings are organized by sampling location and interpreted to inform site-specific planting design strategies.

4.1 Soil Texture Characterization

The sedimentation result obtained from the soil jar test calculated the relative percentages of sand, silt, and clay, enabling textural classification using the USDA soil texture triangle, as presented in Table 2. These classifications were subsequently interpreted to infer drainage potential and water nutrient retention capacities. These two key parameters are crucial for informing site-specific ecological planting design strategies.

Table 2: Soil texture characterization at Bachok Campus and Jeli Campus obtained from the soil jar test

Sampling Area / Plot	Soil Height (cm)			Soil Percentage (%)			Soil Textural Types
	Sand	Silt	Clay	Sand	Silt	Clay	
Bachok Campus							
Dewan Tunku Canselor	6	1.5	0.5	75	18	7	Sandy Loam
Lake	4.5	1	1.5	64.3	14.3	21.4	Sandy Clay Loam
Student Residential Area (IBS)	2.4	0.2	0	92.3	7.7	0	Sand
Sport Complex	3.2	0.3	0	91.4	8.6	0	Sand
Veterinary Farm / Agro Techno Park	4	1.5	2.5	50	31	19	Sandy Loam
Jeli Campus							
Dewan Utama	1.5	2	3.2	31	4	65	Clay
Tg Muhammad Faiz Petra Mosque	1.8	1.2	1.3	42	28	30	Clay Loam
Lake near FIAT	1.5	2.3	1	38	59	3	Silt Loam

The result revealed distinct and consistent differences in soil texture between the two campuses. The Bachok campus revealed a predominant soil texture identified as sandy loam. This texture indicates a high proportion of sand particles, resulting in rapid drainage, low inherent water-

holding capacity, and lower natural fertility. The proximity to the coast contributes to the prevalence of sandy and alluvial soil types, while inland areas may exhibit variations, such as loamy or clayey soils, depending on topography and historical land use. The secondary rainforest fragments and managed landscape zones, with diverse vegetation types present, contributed to spatial heterogeneity in soil layers.

For instance, the organic-rich topsoil layers formed in the landscaped area of the Agro-Techno Park, where the decomposition of plant litter contributes to a high organic matter content that helps retain moisture and enhances soil structure. These conditions create fertile and well-structured soils, which are highly suitable for ecologically based landscape design and site-specific selection of plant species that require adequate nutrient and water retention. Thus, the Gelam forest area not only plays an ecological role but also offers practical value in informing sustainable planting strategies across the campus.

On the other hand, the soil texture analyzed in Jeli campus is predominantly identified as clay loam to silty clay loam, indicating a significantly higher proportion of fine clay and silt particles. This fine-textured soil is closely linked to the campus's upland hilly terrain, and the surrounding Gemang Forest encloses the campus. The deposition of finer particles, such as silt and clay, results in slower drainage, a higher water-holding capacity, a potential for compaction, and increased natural fertility; however, it also carries the risk of waterlogging. These environmental factors collectively influence the formation of moisture-retentive soils, which are beneficial for forest-adapted plant species. Indirectly, it indicates the careful consideration of drainage, root aeration, and plant adaptability in landscape planting strategies. Figure 6 illustrates the comparative distribution of soil texture classifications between UMK Bachok and UMK Jeli campuses.

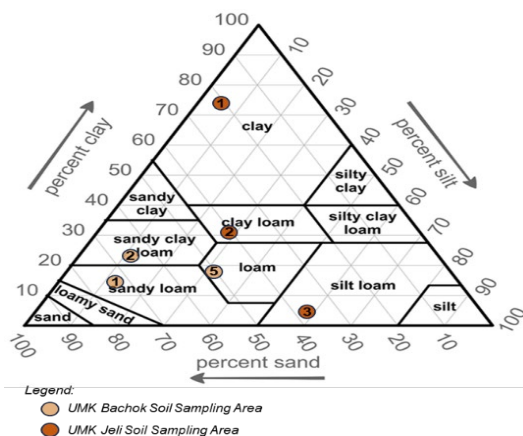


Figure 6: Soil texture triangle plot for eight composite samples collected at Bachok Campus and Jeli Campus (Source: Author, 2025, and diagram adapted from Groenendyk et al. (2015) according to USDA Soil Textural Triangle)

Table 3: Differentiation of soil texture characterization interpreted to inform site-specific planting strategy

UMK Campus	Soil Textural Class	Soil Properties (Drainage Potential and Nutrient Retention)	Planting Design Strategy
Bachok	Sandy Loam (Coarse-textured)	Fast drainage, Low water holding, Low fertility, Less compaction	Drought tolerance Avoid water-intensive
Jeli	Clay Loam to Silty Clay Loam (Medium to fine-textured)	Slow drainage, High water holding, Higher fertility, Prone to compaction	Moisture retention tolerance Deep-rooting plants

4.2 Soil Physical Properties

The tactile assessment of the ribbon method revealed the tactile properties analyzed from the ribbon length and feel characteristics, which were then used to determine the textural classes according to the feel method flowchart, as presented in Table 4. The result was further interpreted to infer the associated physical properties, including plasticity, cohesion, and workability, that are relevant to understanding how soil behaves during handling and root penetration. Such understanding is crucial to inform suitable planting design, species selection, and strategies.

Tactile analysis of soil samples from Bachok revealed the dominant texture class to be sandy loam. These soils exhibited low plasticity and weak cohesion as the moistened samples readily crumbled under slight pressure. The feel was noticeably gritty, indicating a higher sand content. These characteristics indicate excellent workability, with good friability and ease of cultivation, which supports effective root penetration and minimizes compaction risks. The well-drained nature of the sandy loam in the Bachok campus is advantageous for species that require rapid water infiltration and low root zone saturation. However, due to the limited water- and nutrient-retention capacity, planting strategies should incorporate soil amendments, such as compost or biochar, to enhance moisture retention.

In contrast, the tactile analysis of soil samples from Jeli campus predominantly fell within the clay loam to silty clay loam categories. These fine-textured soils exhibited high plasticity and strong cohesion, evidenced by their ability to retain shape under moderate pressure. Workability was moderate to low, signaling limited friability under field conditions. This implies that the soils have a substantial water and nutrient-holding capacity but may present resistance to root penetration, requiring pre-planting soil amelioration (e.g., organic amendments or mechanical loosening). Consequently, the site-specific planting designs on the Jeli campus should prioritize deep-rooted or moisture-tolerant species and incorporate aeration strategies (e.g., raised beds) to accommodate the soil's plastic and cohesive behavior.

Overall, the Bachok campus soils, characterized by higher sand content, demonstrated low plasticity and cohesion but high workability, making them more suitable for well-drained planting zones. In contrast, the Jeli campus soils, which contained greater proportions of clay and silt, exhibited higher plasticity and cohesion yet lower workability, indicating the need for careful drainage and species selection in planting design. Table 5 shows the differentiation of these soil properties.

The soil texture analyses provided essential insights into the different physical characteristics of soils. Coarse soils

at the Bachok campus favor drought-tolerant plants, while the finer soils at the Jeli campus accommodate species adapted to higher moisture levels. The observed textural variations correspond with the principles outlined by Brady and Weil (2008), who emphasized that sandy soils typically enhance drainage and aeration but limit nutrient and water retention, whereas clayey soils demonstrate greater cohesion and water-holding capacity. By linking the identified soil types, the discussion further elaborates on how these characteristics inform the selection of appropriate planting species and functional design strategies, with ecological considerations tailored to each site's environmental context.

Table 4: Soil textural characterization at Bachok Campus and Jeli Campus obtained from the ribbon method

Sampling Area / Plot	Tactile Assessment (Ribbon Length and Feel Characteristics)	Soil Textural Types
Bachok Campus		
Dewan Tunku Canselor	Form a weak ribbon of <2.5 cm long. It does not hold its shape well and breaks easily. Feels very gritty and non-sticky.	Sandy Loam
Lake	Form a medium ribbon that is approximately 3cm in length. Feels gritty with slight stickiness. Able to hold the ribbon, but breaks with bending.	Sandy Clay Loam
Student Residential Area (IBS)	No ribbon can be formed at all. Feels very gritty, coarse, and non-sticky. Does not hold together when squeezed and falls apart easily, and cannot form a ball.	Sand
Sport Complex	Soil makes a weak ribbon of <2.5cm long, or specifically 1.25cm. Breaks almost immediately after squeezing. Feel a slightly gritty texture and stickiness when moist.	Loamy Sand
Veterinary Farm / Agro Techno Park	Form a weak ribbon of <2.5 cm long. Feels very gritty and slightly crumbly with low stickiness when wet.	Sandy Loam
Jeli Campus		
Dewan Utama	Form a strong ribbon of >5cm long, or specifically 6.5cm, before breaking with a flexible and durable ribbon. Feel neither grittiness nor smoothness predominate when moist. It can be molded easily without breaking and holds its shape well in the hand.	Clay
Tengku Muhammad Fa-iz Petra Mosque	Form a medium ribbon of 2.5-5 cm, or specifically 4cm long, before breaking. Feel neither grittiness nor smoothness predominate when excessively wet.	Clay Loam
Lake near FIAT	Form a medium ribbon of 2.5-5cm, or approximately 4.5cm long before breaking, that holds briefly. Feels very smooth and silky when moist, as well as soft and slippery between fingers. Does not mold easily into stable shapes	Silty Clay Loam

Table 5: Differentiation of soil texture characterization interpreted to inform site-specific planting strategy

UMK Campus	Soil Class	Textural	Soil Properties (Plasticity, Cohesion, and Workability)	Planting Design Strategy
Bachok	Sandy (Coarse-textured)	Loam	-Plasticity: Low with little to no plasticity; does not hold shape easily -Cohesion: Low with particles that are loose and non-sticky -Workability: High with easy to dig, good drainage, but poor moisture retention	-Drought tolerance -Apply mulch to conserve moisture -Frequent, shallow watering -Good for quick establishment species
Jeli	Clay Loam to Silty Clay Loam (Medium to fine-textured)		-Plasticity: Moderate to High in which holds shape well when moist -Cohesion: High, sticky, and cohesive; resists crumbling -Workability: Low to Moderate in which is hard when dry, sticky when wet	-Suitable for deep-rooted and moisture-dependent plants -Use terracing or contour planting to reduce runoff and control slope or erosion -Consider raised beds for zone aeration

Note: (i) Plasticity: Soil's ability to be shaped when moist, (ii) Cohesion: Force holding soil particles together, (iii) Workability: Ease of tilling or handling soil for planting.

5. DISCUSSION

5.1 Site-Specific Planting Selection

The identification of specific soil texture classifications informed the development of tailored plant lists, grouped into four common planting types: trees,

palms/cycads, shrubs, and groundcovers. Accordingly, the plant species were selected using established horticultural and ecological principles as outlined in Garis Panduan

Landskap Negara Edisi 2 (2008) and several other planting design guidelines published by the National Landscape Department (i.e., Panduan Penanaman Pokok Teduhan (2008), Pokok Utama Berbunga (2008). Additionally, other related guidelines are considered, for instance, the Guidelines for Erosion and Sediment Control in Malaysia, to identify specific recommendations for erosion control facilities using seedling and planting strategies. The criteria prioritized native or well-adapted species known for their tolerance to specific soil moisture and drainage conditions (e.g., drought tolerance for sandy soils, tolerance to periodic saturation for clay soils).

These species selections were then integrated to guide in functional design strategy, particularly for site-responsive and sustainable campus landscape design. The findings tabulated species selection in accordance with planting design criteria, as emphasized by Akhir et al. (2021), to enhance the visual landscape quality in the campus environment. These criteria lie in eight attributes that influence preferences for planting composition, namely size, colour, texture, shape, density, arrangement, vividness, and naturalness.

Table 6: Planting characteristics and functional design strategies at UMK Bachok campus

Planting Types	Ecological Characteristics	Functional Design Strategy
Trees		
<i>Casuarina equisetifolia</i> (Rhu/ Whistling Pine)	- Tolerant of sandy, saline, and nutrient-poor soils; exclusion and vascular sequestration mechanisms that enable salt stress adaptation (Ribeiro-Barros et al., 2022). - Fast-growing; deep-rooted; good wind tolerance for windbreak supports its use in coastal and exposed sites (Miah et al., 2013; Zhang et al., 2023)	Coastal windbreak, boundary planting, and erosion control along exposed coastal edges
<i>Terminalia catappa</i> (Ketapang/Sea Almond)	- Thrives in sandy coastal soils and exhibits high tolerance to salt spray, making it suitable for areas with moderate salinity and low organic matter (Ramanan et al., 2025). - Wide canopy provides shade; deciduous habit improves soil organic matter through leaf litter - thrives in sandy and rocky coastal soils.	Street tree planting, open plaza shading, and linear pocket space composition
Palms/Cycads		
<i>Livistona chinensis</i> (Chinese Fan Palm)	- Adaptable to sandy, well-drained soils; significant drought resistance under water stress, which allows its establishment in well-drained clay loam areas with low soil moisture retention (Deng et al., 2024). - Provide large, fan-shaped fronds.	Accent planting at focal points, courtyards, or entry plazas; vertical visual contrast.
Shrubs		
<i>Tecoma stans</i> (Yellow Bells / Yellow Elder)	- Tolerates sandy, dry, and nutrient-poor soils; drought-resistant, which complements xeric planting zones (Singh et al., 2024). - Fast-growing; bright yellow flowers.	Ornamental flowering shrub for borders, pollinator-friendly, tropical landscapes
<i>Calliandra haematocephala</i> (Powder Puff)	- Adapted to sandy or well-drained soils; moderately drought-tolerant; ability to tolerate mild salinity stress (Ashour et al., 2023). - Attractive red puffball flowers.	Aesthetic shrub for visual interest, or informal hedging along pedestrian pathways
Groundcovers		
<i>Ipomoea pes-caprae</i> (Beach Morning Glory)	- Fast-spreading, sand-binder; salt-tolerant; attributed to osmotic adjustment and ion regulation mechanisms that facilitate survival in nutrient-poor, saline sandy soils (Zheng et al., 2018)	Soil stabilization on coastal slopes or road shoulders; erosion control planting
<i>Centella asiatica</i> (Pegaga)	- Favors moist soil but tolerates sandy mix with irrigation; medicinal value (Hoang & Rehman, 2023)	Understory herbal garden, shaded courtyard planting, or rain garden fringe species

The sandy loam of the Bachok campus should be considered for its moisture retention, drainage, heat, and salt tolerance (due to the coastal influence), as well as its low maintenance needs, which are appropriate for a tropical campus environment. Poor drainage in some areas, occasional waterlogging, and full-sun exposure in open spaces pose design challenges for creating an open plaza, particularly when planning the educational zone. Planting design guidelines emphasized drought-tolerant species adapted to fast-draining and lower nutrient conditions. Table 6 identifies several highly suitable species for optimizing functional design strategies.

The clayey loam soil at Jeli campus is characterized

by moderately fertile and moisture-retentive, but it can become compacted. Planting recommendations focused on species tolerant to heavier soils and periodic moisture, including those benefiting from higher natural fertility. Therefore, functional design needs and considerations require, among others are low maintenance, soil erosion control, as well as enhancing the aesthetics and walkability in selected zones. Table 7 identifies highly suitable species recommendations for optimizing functional design strategies.

Overall, the species composition reflects a functional planting design that integrates evidence-based selection, taking into account soil texture compatibility and salinity thresholds. Considering the sandy coastal setting at the

Bachok campus, the combination of drought-tolerant, salt-tolerant, and moisture-tolerant species ensures a sustainable vegetative cover and landscape resilience against environmental stressors. In contrast, the finer-textured, clay-rich soils and higher rainfall regime at Jeli campus favor the

integration of moisture-tolerant and shade-adapted species that can withstand reduced aeration and periodic water saturation, thus promoting stable vegetative growth within the campus landscape.

Table 7: Planting characteristics and functional design strategies at UMK Jeli campus

Planting Types	Ecological Characteristics	Functional Design Strategy
Trees		
<i>Syzygium myrtifolium</i> (Kelat Oil/Red Lip)	- Tolerates heavy clay soils; adaptability to poorly drained and compacted substrates; tolerance to periodic wetness which are common in urban and campus landscapes - Physiological resilience suitable for roadside and open-space planting where pH variability and temporary saturation are likely to occur (National Parks Board, 2025).	Suitable for street tree planting, hedgerows, and buffer strips along built edges
<i>Ficus</i> spp. (Fig trees)	- Metabolic adaptation to poor, moderate drought and salinity; support capacity to establish deep root systems; wide canopies spread even in nutrient-limited substrates (Yuan et al., 2024).	Used for continuous tree planting, large feature trees in courtyards, and gathering zones
Palms/Cycads		
<i>Licuala grandis</i> (Ruffled Fan Palm)	- Prefers moist, fertile clay loam soils; shade-tolerance to low-light conditions; slow-growing and compact form (National Parks Board, 2025).	Suitable for mosque courtyard as focal points, shaded trails, or transitional zones between built and planted spaces
<i>Cycas revoluta</i> (Sago Palm)	- Tolerates compacted, heavy clay soils; drought-tolerant once established; symmetrical form	Suitable for structured planting beds, formal entrance zones, or low-maintenance tropical landscapes
Shrubs		
<i>Ixora</i> spp. (Jungle Geranium/Siantan)	- Prefers fertile, well-drained to moist clay soils; attracts local pollinators promoting campus biodiversity (Kamaruddin & Nor Zalipah, 2020).	Applied as aesthetic hedges, accent planting in formal beds
<i>Murraya paniculata</i> (Jasmine)	- Thrives in moist, well-drained clay loam; moderate tolerance to shade. - Fragrant white flowers enhance the sensory appeal of the campus landscape (Dosoky et al., 2016).	Scent-buffering hedge or screen in semi-public or transitional spaces; adds sensory value
Groundcovers		
<i>Wedelia trilobata</i> (Singapore Daisy)	- Thrives in clay loam; performs well in bio-swales, demonstrating its superior growth and nutrient uptake in different phosphorus conditions (Hu et al., 2023). - Slope stabilizing; fast-growing with aggressive spread; yellow bright flowers	Recommended for erosion control in bio-swales, roadsides; the use is restricted to functional and non-decorative areas due to invasive potential.
<i>Alternanthera</i> spp. (Alternanthera)	- Grows well in well-drained clay loam, particularly in moderately acidic soils with good organic matter content (Hu et al., 2023). - Attractive, colourful foliage offers a stable yet visually appealing option	Visual interest, ornamental and patterns beds or borders for planting displays

6. CONCLUSION

The distinct variation in soil texture between the Bachok campus and Jeli campuses underscores the limitations of a 'one-size-fits-all' planting approach, reinforcing the principle of 'the right tree in the right place'. Applying a uniform plant palette across both sites would result in suboptimal ecological performance. The sandy loam soils of the Bachok campus require drought-tolerant species that can adapt to rapid drainage and limited moisture availability. Conversely, the heavier, moisture-retentive soils of the Jeli campus favour species that can utilize the higher water-holding capacity and tolerate lower aeration typical of clay-rich substrates.

This study demonstrates the practicality and accessibility of basic soil texture analysis for ecological

planting design in landscape architectural education. The combined use of the jar test and ribbon method provided reliable texture classifications adequate for landscape-scale decision-making at minimal cost. The complementary application of both methods also enabled cross-verification, enhancing the accuracy of soil interpretation and, consequently, plant selection. Such clarity in results, as observed through field assessment, will facilitate the development of structured learning experiences that connect data collection, analysis, and design translation within the landscape design process.

Such experiential learning fosters critical skills in reading landscape and interpreting landscape conditions. By engaging directly with the physical characteristics of the site, students learn to bridge ecological processes, cultural context, and spatial form through observation, interpretation, and

critical reflection by understanding plant-soil relationships for evidence-based design. Integrating soil texture analysis into the design process is, therefore, not merely a technical necessity. The outcomes extend beyond producing a planting list; they offer a replicable methodology for achieving site-responsive design without prohibitive expense. Translating soil data into practical planting recommendations and design strategies contributes to a framework for ecologically informed and cost-effective landscape planning. Moreover, the methodological integration of soil analysis within landscape architecture education establishes a pedagogical model that cultivates critical skills in site diagnosis, ecological reasoning, and adaptive design thinking.

However, while the study provides valuable insights, it is constrained by the limited number of sampling zones and the absence of seasonal monitoring. Future research should incorporate multi-seasonal sampling and complementary assessments such as nutrient profiling and infiltration rate tests to provide a more comprehensive understanding of soil functionality in ecological planting contexts. Ultimately, this study makes a significant contribution to both professional and educational domains. It introduces a practical framework for site-specific planting design and establishes an experiential learning model that bridges scientific soil assessment with design pedagogy.

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