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THE COMPARISON OF DIVERSITY OF GRASS SPECIES AND ITS PHYSIOLOGICAL PERFORMANCE ON SELECTED SLOPE AND FLAT AREAS IN UiTM KUALA PILAH

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Abstract

Landslides are natural disasters that cause a lot of damage towards both human and biodiversity on earth. The damage is significant enough to deplete nature's resources and claim human lives. Vegetation on slope play a crucial role in stabilizing them by strengthening the roots and influencing the saturated soil water cycle. The study investigates the morphology and physiological performance of different grass species in direct sunlight on selected slope and flat areas. Additionally, it compares the biodiversity of grass species between these two areas, providing insights into their adaptation and ecological roles. A comprehensive analysis of grass diversity and its physiology has been conducted. The diversity index of the data was analyzed using SPSS output to determine the diversity and evenness of the grass species. The data were collected from selected slope and flat areas in UiTM Kuala Pilah. A total of nine grass species from the Poaceae family were recorded in three plots on the slope and three plots on the flat area. The mean values of Shannon-Wiener diversity (H') indices for six plots were recorded at slope area as 0.67 (Plot 1), 0.68 (Plot 2), 0.68 (Plot 3) and 0.37 (Plot 1), 0.76 (Plot 2) and 0.69 (Plot 3) at flat area. Mean of Pielou's Evenness (J') reveal a higher value at slope (0.97 for Plot 1, 0.98 for Plot 2 and 0.98 for Plot 3) compared to plat areas where the values were 0.53 (Plot 1), 0.68 (Plot 2) and 0.99 (Plot 3). The value of the relative chlorophyll content on the slope was highest in *Sporobolus vaginiflorus* with a reading of 40.1 ± 2.4^a, and lowest in *Heteropogon contortus* with 23.2 ± 3.32^b. On the flat area, *Pennisetum clandestinum* with 37.8 ± 0.79^a as the highest and *Paspalum vaginatum* with 20.4 ± 6.26^b as the lowest reading. The pH of the soils ranged from 3.99 ± 0.08^b to $4.80a \pm 0.04^a$ in the sloping area, and from 5.83 ± 0.23^a to 6.21 ± 0.30^a in the flat area. The soil pH was measured to determine the stability of the slope, as it plays an important role in ensuring stability at different elevation. The relative chlorophyll content between different species of grass proving the physiological performance also contributes to maintaining the slope stability. The abundance of species diversity determines the overall diversity and ensures a balanced ecosystem.

Keywords: slope, diversity of plant species, plant physiology, relative chlorophyll content, soil pH

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Introduction

Grass, also known as *Poaceae* or *Gramineae* is one of the shrub species on the planet's that are undoubtly considered as the most prevalent and extensively distributed in the world (Soreng et al., 2015). Grass can be found on every continent regarding the surface that exists on earth, even in Antarctica. It needs enough water, sunlight, and nutrients like the other plant but can survive with the minimum amount of attention. Grass comes in a variety of forms with various structural and morphological characteristics. There is grass that does best in warmer climates and cooler climates. For instance, Bermuda grass (*Cynodon dactylon*) is suitable for full sun usage, but Augustine grass (*Stenotaphrum secundatum*) is extremely tolerant of the shady places. Due to their capacity to adapt to harsh climatic conditions, grasses are among the most prominent plant species in many environments (Fatima et al., 2022). Even on the slope, the grass is inhabiting abundantly. Plants on the slope are necessary to increase slope stability by draining the soil of water.

Slopes in open locations tend to retain less moisture because of direct sunlight and increased evaporation. Soil erosion and landslides are the common incidents that occur on the slope especially the slope beside the river or stream. Landslides are a natural hazard caused by the movement of soil, rock falls and debris flow that happen frequently especially during heavy rainfall or earthquakes (Marin and Velásquez, 2020). In 2021, there are 1 474 moderately to very risky slopes that might provide significant threats during the Northeast Monsoon season in Peninsular Malaysia (Babulal, 2021). On 16th December 2022, Malaysia was shocked by a deadly landslide that hit a camping site in Batang Kali, Selangor and killed at least 31 people due the heavy rain and underground water beneath the campground that resulted in high soil saturation and pressure (Shah, 2022). As Malaysia is categorized as tropical climate, there is a low chance for dry seasons as Malaysia has high annual rainfall. These demonstrate that Malaysia is at very high danger of a future landslide. The erosion process is intensified by the depletion of vegetative cover and the deterioration of soil structure due to compaction and the loss of organic matter. This frequently leads to a decrease in infiltration, causing an increase in runoff and the transportation of soil particles (JPS, 2010).

Vegetation on slopes is crucial for stabilizing the soil by reinforcing it with strong roots and modifying saturated soil conditions. This helps prevent erosion and slope instability. Plant roots create a network of interlocking fibers within the soil, anchoring it and strengthening areas prone to weakening (Saifuddin and Normaniza, 2016). The long-term stabilization of soil is achieved through the seeding of grasses and the planting of trees, shrubs, and ground covers (JPS, 2010). The National Slope Master Plan 2009-2023 highlights the lack of attention to hydrological conditions in mountainous terrain and the increased surface runoff due to vegetation clearance caused by development (JKR, 2009). The connection between plant diversity and physical performance is vital in understanding landslides. Diverse plant species, with various root structures, increase soil cohesion, lowering the risk of landslides. The diverse vegetation cover also aids in water absorption, reducing surface runoff and enhancing soil stability. Higher plant diversity improves the landscape's physical performance, contributing to its resilience against landslides (Zhu et al., 2015). There is no evidence of specific best grass for hillslopes as many factors need to be considered such as type of soil, soil pH, temperature, weather, and seasons that differ in different places. Therefore, this study is conducted to investigate the diversity of grass species on the selected slope and flat area in UiTM Kuala Pilah and its physiological performance to prevent landslides as there are few reports of the current research. In addition, the numerous grass species that grow on the selected slope were also examined and compared to define the best grass species at the that can support the hillslope.

Landslide area at FT 1275 Section 2.7 Jalan Felda Kepis in Kuala Pilah has a 30m-long landslip area with an estimated 10m depth of debris (Bernama, 2022). More landslides are predicted to occur as a result of earthquake potential, deforestation, climate change and rising temperatures, particularly in mountainous regions covered in snow and ice (Tongkul, 2021). Vegetation enhance slope stability by absorbing water from the soil. Due to their need for water, plants absorb moisture via their roots, causing photosynthesis, a crucial metabolic activity that helps both plants and the ground at building sites (Saifuddin and Normaniza, 2016). This leads to safety issue towards human mankind and also the biodiversity as it can be really dangerous. Furthermore, the landslide rate can increase if the deforestation activity keeps happening as the plants that support the soil are removed.

Between 2002 and 2020, Malaysia lost 2.7 million hectares of humid primary forest, or 34% of the country's overall loss of tree cover (Malik, 2021). The richness of plant species in an ecosystem can be impacted which might result in certain plant species going extinct forever. There would be significant losses in biodiversity if plant species began to go endangered on a big scale. This also would lead to the climate change as plants is a major component in ecosystem in order to storing the carbon dioxide and releasing the oxygen in the atmosphere. In Malaysia, rainfall, storm water activities, and ineffective slope management were the major causes of slope collapse and landslides at several sites in hillside development. A decrease in the upper mineral soil due to deforestation can have cascading effects on the nutrient availability, water retention, root stability, microclimate, competition, and biodiversity of grasses in the affected area, subsequently influencing the composition and performance of grass species (Merino et al., 2023). Therefore, in this study, the benefit of grass species on the slope can be a factor that can prevent landslide and soil erosion as the physiology of the grass species will be studied.

The results of this study will be helpful, particularly in the planning for landslide safety and the planting of the ideal species of pioneer grass to minimize soil erosion. In the process, using natural slope supporters as an option to avoid soil erosion will increase awareness and enhance understanding of natural resources. The grass is a fantastic solution for areas that are prone to erosion because of its morphological characteristics. Through this study, the best grass species may be used as an alternative to the existing complicated way to sustain several weak slopes.

Methods

Study Area

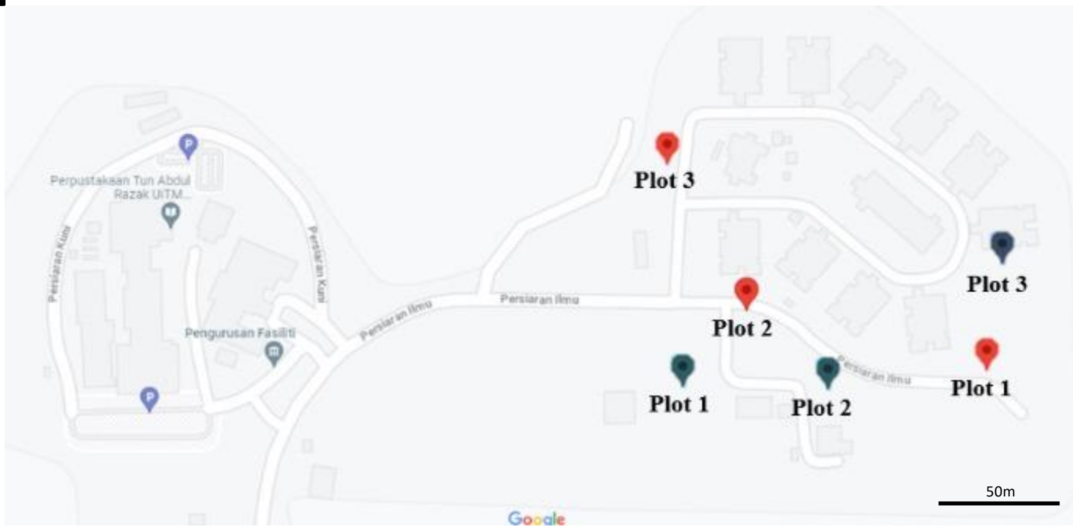
This study conducted at the selected slope area and flat area (Table 1) in UiTM Kuala Pilah (Figure 1) and continued in the Biology Research Laboratory (Plant) at UiTM Kuala Pilah from March until August 2023.

Table 1. Coordinates for slope area and flat area

Plot Area	Coordinates (Slope)	Coordinates (Flat)
Plot 1	2.793617, 102.221342	2.793267, 102.221043
Plot 2	2.794454, 102.220907	2.793420, 102.222862
Plot 3	2.793901, 102.222860	2.793184, 102.221793

Sampling design and collecting sample

The sampling design adapted from Liu et al (2022) with some modification. Five plots, each measuring 2m x 2m, were established across the selected slopes covered by shrub species and grass species. Various grass species were chosen for investigation in the area exposed to direct sunlight (Osman et al., 2021). The grass from different species and the soil sample from the plot were collected. The grass was chosen because it was thriving compared to shrubs, which were less abundant in the selected area. Soil collection was performed using a soil auger, obtaining samples from 0 to 10 cm depth within the selected plot, in proximity to the collected grass for each grass species in the plot. Collecting soil at a 10 cm depth captures the roots of chosen plants without going too deep. The topsoil, usually in the first few centimeters, is where plant-microbe interactions, nutrient uptake, and physiological processes happen (Liu et al., 2022). The pH value can be measured from this depth.



(a) Plotting area on the map. Red pin represents slope area and blue pin represents flat area

(b) Slope area

(c) Flat area

Figure 1. Study site.

Herbarium for species identification

Herbarium technique adapted from Mengisu et al (2022). Healthy grass was chosen, preferably in reproductive stages like flowering or fruiting, although not all species were in these stages. A spade was used to obtain specimens with sufficient features for identification. The samples were placed in ziplock bags and labeled with habitat description, collection date, and plot number. Due to time constraints, the drying process was not completed, and the samples proceeded directly to species identification.The grasses placed on a white paper with the 20 cm ruler on the side as reference to the grass sizes.

Identification of grass species

The grass species determined using four different books and two reliable websites:

1. Upland Rice Weeds of South and Southeast Asia by Marita et al (1999)
2. A Practical Field Guide to Weeds of Rice in Asia by Caton et al (2004)
3. Tropical grasses by Riveros et al (1990)
4. Grasses: An Identification Guide by Brown L. (1979)
5. Malaysia Biodiversity Information System (MyBIS), Malaysia Biodiversity Cetre (MBC) by Azmi N., M. N. (2010)
6. PlantwisePlus Knowledge Bank, CABI Digital Library by Soa P. et al (2016)

From the structure of the grass, the grass species identified by referring the book and categorized by the species upon the determination of the species completed.

Analysis of soil pH using pH meter

Analyzation of soil pH adapted from Yamashita (2011) with some modification. After the soil sample were collected, the soil pH measured with filling the beaker of 250 mL with an equal mixture of distilled water and dry soil using ratio 1:1 accordingly. The soil and water combination stirred with a glass rod for 5–10 seconds before being left undisturbed for 15 minutes. The soil stirred once more for 5–10 seconds, then the pH meter used to record the value.

Measurement of relative chlorophyll content using SPAD-502 meter

Measurement of the relative chlorophyll content using SPAD-502 meter is adapted from Rodriguez & Miller (2000) with some modification. First, the grass leaf inserted in the measuring head of the SPAD-502 meter and the measuring head closed. The SPAD-502 meter showed the reading of the relative chlorophyll content of the grass. The reading of chlorophyll meter were recorded and the process repeated at different part of the grass which are tip of the leave, middle of the leave and bottom of the leave. The step was repeated on another species of the grass. The data of the chlorophyll content recorded before the harvesting process. Three replications of the measurements for each data set were used to establish the average readings.

Determination of species diversity of grass

Determination of species diversity of grass adapted from Zhang (2022) where using Shannon-Wiener index (1) was used to determine species diversity. The number of individuals in the species and the total individuals of all species need to be determined at the selected plot on the slope. The abundance of each species of grass that can be found in the selected plot on the slope in the table were recorded. From the recorded data, Shannon-Wiener index formula used to determine the species diversity value, where the higher the number of the diversity value, the more diverse ecosystem is. The formula used for calculating is:

$$H' = -\sum_{j=1}^{S} p_i \, In \, p_i \qquad (1)$$

Where, H' = the diversity index, Pi = the relative abundance (s/ N), s = the number of individuals of one species and N = the total number of individuals in the sample.

Pielou's evenness is an index which analyzes both species richness and diversity (Tikadar et al., 2021). Evenness refers to the number of individuals present in each species (2). The formula used for calculating is:

$$J' = \frac{H'}{In(S)} \qquad (2)$$

Where, J’ = the evenness index, H’ = the Shannon-Wiener index and S = the total number of species.

Result and Discussion

The purpose of grass species identification is to accurately classify and distinguish different species in the grass world. From the herbarium process, various of grass species were identified based on their characteristics and morphology features. A total of nine different expected grass species under seven genuses were recorded which are *Axonopus fissifolius*, *Axonopus compresus*, *Sporobolus vaginiflorus*, *Heteropogon contortus*, *Imperata cylindrica*, *Paspalum vaginatum*, *Paspalum conjugatum*, *Digitaria ciliaris* and *Pennisetum clandestinum* (Figure 2). In this study, the grass was identified by the examination of the leaf morphology, root type, habitat preference, inflorescence, spikelet characteristics and growth habit.

***Axonopus sp*.**

Common carpet grass, also known as *A. fissifolius* (Figure 2a) and *A. compresus* (2b), often known as tropical carpet grass, are the species of grass under the same genus and they have similar characteristic and morphology yet two distinct species within the *Axonopus* genus. Residential of these two grass species is naturalized that the grass has established and is growing in that area without direct human intervention or cultivation (Azmi et al., 2010). Alternate leaves appear on *Axonopus* species as they grow from stem (Lim et al., 2009). The leaves of *A. compressus* are broad and flat, ranging from 5 to 15 centimeters in length. They have prominent parallel veins and are typically hairless. In contrast, the leaves of *A. fissifolius* are narrower and longer, ranging from 10 to 30 centimeters. They also have parallel veins but may exhibit some hairiness along the leaf surface.

Both *A. compressus* and *A. fissifolius* have fibrous root systems, more robust and stoloniferous (Riveros et al., 1990). These roots help with nutrient absorption and anchoring the plants. *A. compressus* can survive in both wet and dry situations and is suited to a variety of soil types. It frequently grows on pastures, lawns, and other disturbed places. On the other hand, *A. fissifolius* favours moister settings including marshes, riverbanks, and wetlands.

Sporobolus vaginiflorus

Sporobolus vaginiflorus (Figure 2c) is a perennial grass that typically grows in clumps or tufts. Residential of this grass species is introduced from North America. It has a bunchgrass growth habit, meaning it forms dense clusters of stems rather than spreading by stolons or rhizomes. The leaves of *S. vaginiflorus* are narrow and linear in shape. They are typically long, ranging from 10 to 30 centimeters. The leaf blades have a prominent midrib and parallel veins running lengthwise. The margins of the leaves may be smooth or slightly serrated (Brown, 1979). The stems of *S. vaginiflorus* are slender and erect, reaching heights of up to 75 cm. They are usually smooth or slightly hairy and can vary in color from green to reddish-brown. Typically, the ligule is truncate or short and rounded in form. The spikelets of *S. vaginiflorus* are small and usually contain several florets. The spikelets hairy or have long bristles, particularly on the lemma. The fibrous root system of S. vaginiflorus is made up of several small and shallow root that easy to pull out. The plant uses these tiny, hair-like roots to collect water and nutrients from the earth

Heteropogon contortus

Residential of this grass species is native. *Heteropogon contortus* (2d) has alternating, linear-shaped leaves . They normally measure from 10 and 40 centimetres in length. The surfaces of the comparatively thin leaf blades are rough or hairy. The leaf edges are often rough and might include tiny teeth or serrations (Lim et al., 2009). *H. contortus* has upright stems that can grow as tall as 1.5 metres. The grass gets its popular name from its characteristic thin, inflexible, and frequently twisted or distorted appearance. At the junction of the leaf blade and the sheath, *H. contortus* has a membranous ligule. The ligule is short and often jagged or torn along the edges. *H. contortus* is a tufted grass, meaning it grows in dense clumps or tussocks rather than spreading through stolons or rhizomes (Riveros et al., 1990).

Imperata cylindrica

Imperata cylindrica (Figure 2e) is known as Lalang in Malaysia has alternating, often flat, and wide leaves. They often have parallel longitudinal veins and are lanceolate or ovate in form. The leaf blades often lack hair and have smooth borders. *I. cylindrica* has thin, creeping stalks. They often take root at the nodes, enabling vegetative growth and dispersion of the grass. The stems can grow up to one metre in length. *I. cylindrica* possesses a membrane ligule at the point where the leaf blade and sheath converge. Typically, the ligule is truncate or short and rounded in form. *I. cylindrica* often grows as a mat of thick, creeping grass. It grows prostrately, with stems that extend out horizontally across the surface (Caton et al, 2004).

Paspalum sp.

P. vaginatum (2f) and *P. conjugatum* (2g) are two separate species. Residential of these two grass species is native to tropics America and introduced to Southeast Asia (Manidool, 1980). Despite sharing the same genus, *P. vaginatum* and *P. conjugatum* vary in several of important ways. When compared to *P. conjugatum*, *P. vaginatum* leaves tend to be wider and wider. The lanceolate or ovate leaves of *P. vaginatum* have conspicuous parallel veins spanning the length of them. The leaves of *P. conjugatum* have parallel veins and are thinner and more linear. *P. vaginatum* has a stoloniferous growth habit. It spreads horizontally through above-ground stems called stolons, forming a dense mat. *P. conjugatum*, on the other hand, has a clump-forming growth habit and does not spread as aggressively through stolons (Caton et al., 2004).

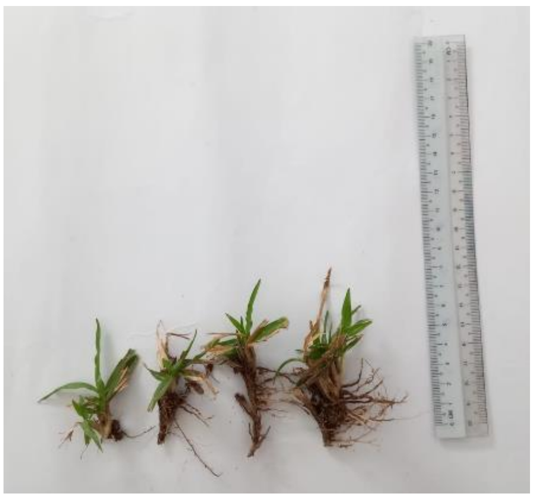
Digitaria ciliaris

The leaves of *Digitaria ciliaris* (Figure 2h) are alternate and linear in shape. Residential of this grass species is native (Lim et al., 2009). The lowest portion of the leaves and leaf sheaths are hairy, and the leaves can go up to 25 cm long and 1 cm broad (Soa et al., 2016). The leaf blades are typically green but may develop purplish tones as they mature. The culms of *D. ciliaris* are slender, wiry, and often slightly flattened. They can be smooth or have short hairs. The stems may branch near the base and root at the lower nodes, allowing the grass to spread and form new plants. A membranous ligule is present at the point where the leaf blade and sheath meet in *D. ciliaris*. The ligule often has a jagged or toothed look and is short and truncate. *D. ciliaris* has a prostrate to ascending growth habit (Marita et al, 1999). It typically forms low-growing, spreading clumps or mats, with stems that may reach heights of up to 1 meter (3 feet).

Pennisetum clandestinum

Warm-season perennial grass *Pennisetum clandestinum* (Figure 2i), sometimes referred to as Kikuyu grass, is a favourite for usage in lawns, sports fields, and grazing regions. Residential of this grass species is native (Lim et al., 2009). *P. clandestinum* has alternating leaves that are typically thin and lanceolate in form. They feature longitudinally parallel veins and a prominent midrib. Usually brilliant green in colour and with a slightly rough surface, the leaf blades are. The leaf edges can be either smooth or slightly serrated.The *P. clandestinum* has thin, somewhat flattened culms, or stems. They may grow up to one metre (3 feet) in length and are typically smooth. Nodes, from which leaves and branches arise, may be present on the stems at regular intervals.The growth habit of *P. clandestinum* is prostrate or creeping. It spreads horizontally by stolons (above-ground stems) that root at the nodes and create new plants, forming thick, low-growing mats or sods (Riveros et al., 1990).

(a) *Axonopus fissifolius*



(b) *Axonopus compressus*

(c) *Sporobolus vaginiflorus*

(d) *Heteropogon contortus*

(e) *Imperata cylindrica*

(f) *Paspalum vaginatum*

(g) *Paspalum conjugatum*

(h) *Digitaria ciliaris*

(i) *Pennisetum clandestinum*

Figure 2: The images of grass species

Grass species

Among the grass species on the slope, *H. contortus* recorded the highest numbers of individuals which is 122 (Table 2). *Heteropogon contortus*, also known as Black speargrass, is a species of grass that is typically found on hillsides and slopes in tropical and subtropical climates. It has a deep root system that can help to stabilize the soil and prevent erosion. The root system also allows the grass to access water and nutrients that may be deeper in the soil. *A. compresus* has the highest numbers of individuals which is 320. *A. compressus* thrives in low-lying, frequently flat, poorly drained environments. Water stagnated if it rains but not cause flooding in selected research area. Periods of floods and waterlogging, which are frequent in these places, are not harmful to the grass (Arunbabu et al., 2015). It has less number on the slope as it has shallow root system which is not suitable for erosion control. From the result of grass identification, *P. vaginatum* is one the best grass for drought season. It is well-known for its excellent drought tolerance and salt tolerance (Soa P. et al., 2016). It is frequently observed in coastal regions or locations characterized by suboptimal water quality, such as the chosen research area.

Table 2. The number of individuals on slope area and flat area

No.	**Grass species**	**Number of individuals**	
		Slope area	**Flat area**
1.	*Axonopus compressus*	0	320
2.	*Axonopus fissifolius*	68	87
3.	*Digitaria ciliaris*	0	5
4.	*Heteropogon contortus*	122	0

5.	*Imperata cylindrica*	77	65
6.	*Paspalum conjugatum*	82	0
7.	*Paspalum vaginatum*	0	118
8.	*Pennisetum clandestinum*	0	113
9.	*Sporobolus vaginiflorus*	102	44

From Figure 3 below, there are three species of grass can be found in both slope and flat area. *A. fissifolius*, *S. vaginiflorus*, and *I. cylindrica* are grass species that can be found in both slope and flat areas due to their adaptability and ecologic (Wang et al., 2016). The distribution of grass species across the specified areas not only highlights ecological preferences but also underscores the adaptability of these grass types to varying moisture conditions. In slope areas, *H. contortus* and *P. conjugatum* dominate, constituting 22.2% of the grass distribution. Their inclination towards slope environments may be influenced by specific soil or microclimatic conditions. *A. fissifolius*, *S. vaginiflorus*, and *I. cylindrica* exhibit versatility across both slope and flat areas, representing 33.3% of the overall grass composition. These grass types demonstrate the ability to handle a range of moisture levels, with *A. fissifolius* particularly noted for its tolerance of wet or poorly drained soils. This adaptability makes it well-suited for both wetter locations on slopes and flat areas with increased water retention. Similarly, *S. vaginiflorus* and I. cylindrica show adaptability to conditions ranging from moderately damp to dry, indicating some moisture tolerance and enabling their survival in both slope and flat habitats. In flat areas, *A. compressus, P. vaginatum*, *D. ciliaris*, and *P. clandestinum* thrive, collectively comprising 44.4% of the grass community. Their prevalence in flat regions may be influenced by factors such as soil type, water availability, and sunlight exposure. This breakdown, coupled with the moisture adaptability of these grass types, enhances our understanding of the complex interplay between environmental factors and grass species distribution in diverse landscapes.

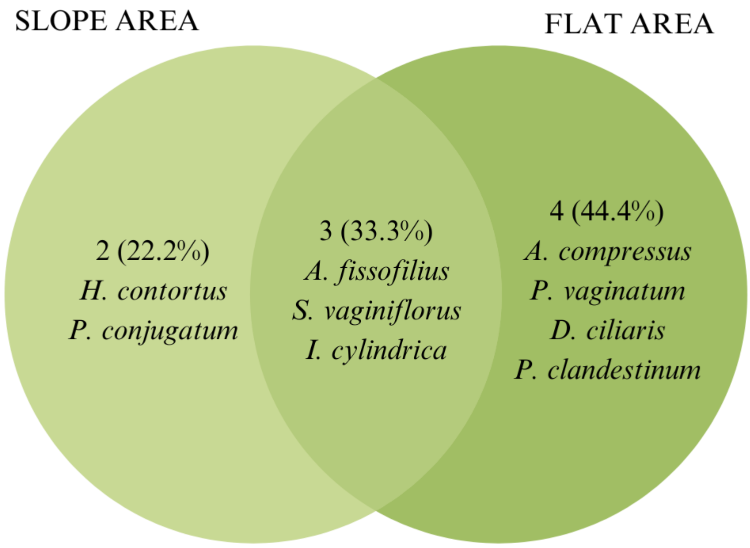


Figure 3. Venn diagram showing the distribution of grass species at UiTM Kuala Pilah

The root systems of grasses in slope areas and flat areas exhibit distinct adaptations corresponding to the specific challenges posed by their respective terrains. In slope areas, grasses develop fibrous and extensive root systems that serve as a resilient defense against soil erosion and gravitational forces (Li et al., 2021). These roots create a dense network, effectively binding soil particles together, and may even follow the natural contours of the slope, forming a terracing effect. A study's findings indicate a negative correlation between the tensile strength of thicker roots and their diameter while the tensile strength of fine roots and their diameter shows a positive correlation (Zhang et al., 2014). This adaptation is crucial for stability on inclined surfaces and prevents the loss of soil due to water runoff. In flat areas, where soil stability is less of a concern, grasses tend to favor horizontally spreading root systems. These shallow and spreading roots allow grasses to efficiently exploit the available resources, such as nutrients, water, and oxygen in the surrounding soil. While slope-dwelling grasses prioritize anchoring and erosion control, those in flat areas optimize their root systems for resource uptake, emphasizing the versatility of grasses in adapting to the unique demands of diverse landscapes (Li et al., 2021).

The abundance of plant life differs between slope and flat terrains. Slope areas exhibit diverse species adapted to variable conditions, including erosion challenges (Zhang et al., 2022). In contrast, flat terrains offer stable conditions, promoting a high abundance of various plant species, with larger plants potentially dominating due to reduced slope-related constraints. Biodiversity is influenced by factors like climate and soil type in each landscape, shaping the overall distribution of organisms.

Soil pH

From the research, soil pH on the slope area is highly acidic compare to soil pH on the flat area (Figure 3). The lowest value of soil pH at slope area is from Plot 3 with 3.99 ± 0.08^{b} and the highest value of pH is from Plot 1 with 4.80 ± 0.04^{a} (Table 4). The percentage different of soil pH on the slope area between Plot 1 and Plot 3 is 18.43%. The lowest value of soil pH at flat area is from Plot 1 with 5.83 ± 0.23^{a} and the highest is from Plot 2 with 6.21 ± 0.30^{a} (Table 5). The percentage different of soil pH on flat area between Plot 1 and Plot 2 is 6.31%. The most acidic soil pH is soil of the slope area from Plot 3 with 3.99 ± 0.08^{b} and the weak acidic soil of the flat area from Plot 2 with 6.21 ± 0.30^{a} (Figure 4). The values (mean ± SD) followed by dissimilar letters in each row are significantly different at $p \leq 0.05$.

Table 3. Soil pH on the slope area and flat area

Slope area	Soil pH	Soil pH
Plot 1	4.80 ± 0.04^{a}	5.83 ± 0.23^{a}
Plot 2	4.41 ± 0.45^{a}	6.21 ± 0.30^{a}
Plot 3	3.99 ± 0.08^{b}	5.96 ± 0.17^{ab}

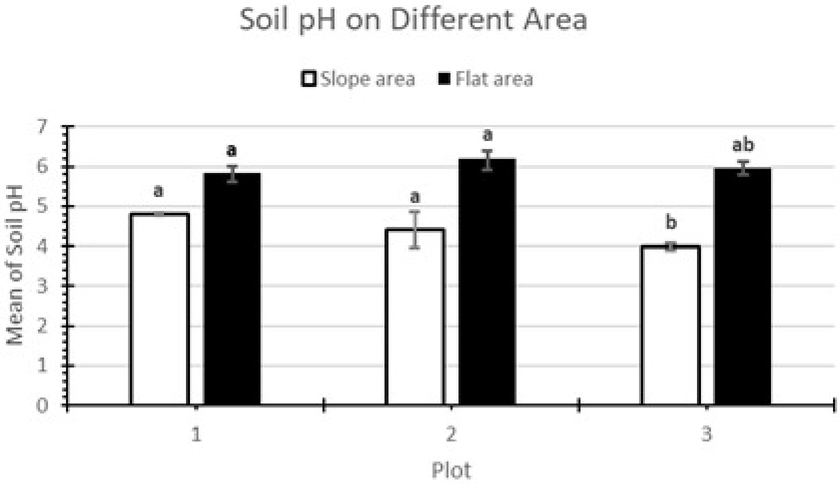


Figure 4. Soil pH on Different Area. Vertical bars represent standard deviation. Different letter indicates a significant difference between different area at $p < 0.05$.

The significant differences in soil pH between slope and flat areas, as indicated by the calculated percentage differences, offer valuable insights into the environmental conditions influencing grass species distribution. In the slope area, the soil is notably more acidic than in the flat area, with a substantial percentage difference of 18.43% observed between the most acidic (Plot 3) and least acidic (Plot 1) sites. This disparity can be attributed to the higher rates of water runoff experienced on slopes, which, according to Zhang et al. (2020), can result in the leaching of acidic substances from the soil, contributing to increased soil acidity.

Conversely, the flat area exhibits a more modest percentage difference of 6.31% in soil pH between the most acidic (Plot 1) and least acidic (Plot 2) sites. This difference is linked to the better water retention capabilities of flat areas, which accumulate sediments and materials rich in alkaline substances, influencing soil alkalinity (Li et al., 2021).

The observed percentage differences in soil pH between these distinct topographical areas highlight the dynamic nature of soil characteristics and their impact on vegetation. Such variations can influence the distribution and adaptability of grass species, as demonstrated by the specific grasses thriving in either acidic or alkaline conditions.

These findings align with existing literature, emphasizing the importance of soil pH as a determinant for vegetation composition. The work of Zhang et al. (2020) emphasizes the role of water runoff in influencing soil acidity, while Li et al. (2021) discuss the alkaline influence of sediment accumulation in flat areas. Understanding these relationships is crucial for predicting and managing vegetation patterns in diverse landscapes, particularly in the context of environmental changes or land use planning.

Relative chlorophyll content using SPAD-502 meter

Both on slope area and flat area have significantly high relative chlorophyll content except *S. vaginiflorus, H. contortus and P. vaginatum* (Figure 5). The highest average of relative chlorophyll content recorded on the slope area is *S. vaginiflorus* with 40.1 ± 2.4^{a} and the lowest is *H. contortus* with 23.2 ± 3.32^{b} (Table 4). The difference percentage of relative chlorophyll content between *S. vaginiflorus* and *H. contortus* is 53.4 % . On the flat area, the highest average of relative chlorophyll content recorded is *P. clandestinum* with 37.8 ± 0.79^{a} and the lowest is *P. vaginatum* with 20.4 ± 6.26^{b} (Table 4). The difference percentage of relative chlorophyll content between *P. clandestinum* and *P. vaginatum* is 59.8 %. The values (mean ± SD) followed by dissimilar letters in each row are significantly different at $p \leq 0.05$.

Table 4. Relative chlorophyll content of grass on different area

No.	Grass species	Relative chlorophyll content	
		Slope area	Flat area
1.	*Axonopus compressus*	-	35.9 ± 0.93^{a}
2.	*Axonopus fissifolius*	39.1 ± 2.69^{a}	34.6 ± 3.84^{a}
3.	*Digitaria ciliaris*	-	36.6 ± 1.21^{a}
4.	*Heteropogon contortus*	23.2 ± 3.32^{b}	-
5.	*Imperata cylindrica*	37.1 ± 1.15^{a}	34.0 ± 0.66^{a}
5.	*Paspalum conjugatum*	37.8 ± 0.79^{a}	-
7.	*Paspalum vaginatum*	-	20.4 ± 6.26^{b}
8.	*Pennisetum clandestinum*	-	37.8 ± 0.79^{a}
9.	*Sporobolus vaginiflorus*	40.1 ± 2.40^{a}	24.4 ± 1.87^{b}

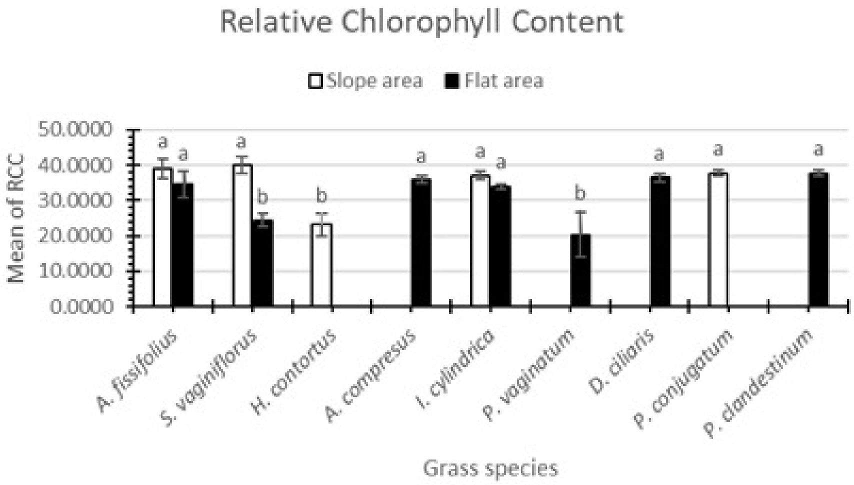


Figure 5. Relative Chlorophyll Content on Different Area. Vertical bars represent standard deviation. Different letter indicates a significant difference between different area at $p < 0.05$.

The chlorophyll content observed in *S. vaginiflorus* on slope areas is the highest can be attributed to several factor. Slope areas have less competition from other plant species, allowing *S. vaginiflorus* to receive a greater share of available resources, including sunlight (Rana et al., 2012).With reduced shading from neighboring plants, *S. vaginiflorus* can maximize its exposure to sunlight and enhance chlorophyll production. The angle of the sun's beams causes slope regions to frequently get more direct sunlight than level places. On the flat area, the grass averagely has lower content of chlorophyll compare to grass on the slope area. Particularly in sites with high traffic or extensive use, flat terrain is more susceptible to soil compaction (Saifuddin & Normaniza, 2016). *P. vaginatum* ability to absorb nutrients and water is hampered by compacted soil. Compared to hills, flat regions frequently contain a higher species density of plants.

The flat terrain may have different soil moisture levels and nutrient availability compared to slopes. In addition, excessive moisture or poor drainage in flat areas can hinder nutrient uptake and negatively impact chlorophyll production in *P. vaginatum*.

Diversity of grass species

The highest diversity of the grass species on the slope area is plot 2 and plot 3 with 0.68 while plot 1 is 0.67, the lowest diversity of grass species (Table 7). The highest diversity of the grass species on the flat area is plot 2 with 0.76 while plot 1 is 0.37, the lowest diversity of grass species (Table 5). Based on the Pielou's evenness index, on the slope area plot 2 and plot 3 with 0.98 have the highest evenness index than plot 1 with 0.97 while on the flat area the highest evenness is plot 3 with 0.99 and the lowest is plot 1 with 0.53 (Table 6).

Table 5. Diversity and evenness of grass species on slope area

Plot region (Slope Area)	Grass species	Number of individuals	Diversity, H'	Pielou's evenness, J'
Plot 1	*A. fissifolius*	68	0.67	0.97
	S. vaginiflorus	102		
Plot 2	*H. contortus*	60	0.68	0.98
	I. cylindrica	77		
Plot 3	*P. conjugatum*	82	0.68	0.98
	H. contortus	62		

Table 6. Diversity and evenness of grass species on flat area

Plot Region (Flat Area)	Grass species	Number of individuals	Diversity, H'	Pielou's evenness, J'
Plot 1	*A. compressus*	320	0.37	0.53
	S. vaginiflorus	44		
Plot 2	*D. ciliaris*	5	0.76	0.68
	I. cylindrica	65		
	P. vaginatum	118		
Plot 3	*A. fissifolius*	87	0.69	0.99
	P. clandedstinum	113		

The assessment of grass species diversity across slope and flat areas is complemented by statistical analyses that provide insights into the significance of the observed differences. The t-test analysis indicates a significant value of 0.591, surpassing the 0.05 threshold, suggesting that there is no statistically significant difference in diversity indices between the slope and flat areas. This result is further supported by the means, as the null hypothesis cannot be rejected, indicating that the diversity indices are not significantly different between the two topographical regions. Similarly, the evenness index and plot region exhibit a significance value of 0.147, above the 0.05 threshold, reinforcing the conclusion that there is no statistically significant difference in evenness indices between the slope and flat areas. The means further support this finding, emphasizing that the null hypothesis cannot be rejected.

Comparing these results with a previous study by Zhu et al. (2015), which demonstrated a negative correlation between functional diversity of grass species and soil erosion rates, the current research findings indicate a relatively lower diversity index in both slope and flat areas. This lower diversity index suggests less overlap of grass species within communities, potentially resulting in a more thorough utilization of both above- and below-ground areas (Zhu et al., 2015). While the diversity indices observed in the present study may not be high, the implications for soil erosion control are

complex, as a higher diversity index is generally associated with more adaptable root systems and increased plant resilience against soil erosion. The observed diversity and evenness align with the concept that nutrient-rich conditions in flat areas foster a broader variety of grass species, while human-induced disturbances in flat terrain, such as grazing and mowing, contribute to a balanced and diverse grass community (Zhang et al., 2022). Flat regions can maintain nutrient-rich conditions, supporting a diverse range of grass species. Even without disturbances, the stable environment in flat sites fosters favorable conditions for grass communities to thrive and establish diverse ecosystems.

The diversity index of grasses is vital for soil erosion prevention. A rich variety of grass species contributes to a complex and robust root system, stabilizing the soil and reducing erosion risk. Different grass types with diverse root structures provide comprehensive soil coverage, preventing erosion from water runoff. Studies, like Zhu et al. (2015), emphasize the negative correlation between grass diversity and soil erosion rates. Therefore, maintaining high grass diversity is a sustainable approach to enhance soil stability and prevent erosion.

Conclusion

In conclusion, this study evaluates the morphological and physiological performance of different grass species that grow in direct sunshine on both sloped and flat terrains. Through a comparative analysis of biodiversity, valuable insights into the adaptation mechanisms and ecological roles of these grass species have been uncovered. The investigation has highlighted the nuanced responses of different grass species to varying topographical conditions, shedding light on their ability to thrive in direct sunlight. By exploring both slope and flat areas, this research enhances our understanding of the diverse ecological roles these grass species play in different landscapes, contributing to the broader discourse on plant adaptation and ecosystem dynamics. The findings underscore the importance of considering both morphological and physiological attributes, as well as biodiversity, when assessing the ecological functions and roles of grass species in distinct environmental contexts.

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Author Contribution

Nurul Nasriah – carried out experimental work; and contributed in discussion and paper writing: Lili Syahani – conceptualizing, supervision on this work and contributed significantly in discussion and paper writing; Nor'aishah – review and editing

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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