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Wind-Resistant Plants: Assessing the Efficacy of Vegetation in Kampung Wai, Kuala Perlis

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ABSTRACT. Storms often cause trees to topple and uproot, resulting in damage to the settlement's infrastructure. During periods of intense rainfall, the water content of the soil at shallow depths is typically high, which reduces the anchoring resistance of tree roots in the soil. The root systems of plants play an important role in anchoring against strong winds during the windy season. The aim of this study is to identify the types of plants that have high wind resistance and to observe the effectiveness of wind-resistant plants in the settlement area of Kampung Wai, Perlis. Kampung Wai, a coastal village surrounded by paddy fields in Kuala Perlis, was chosen as the study area. Due to its coastal location, it is very likely to be exposed to varying wind conditions, making it an ideal place to study how wind-resistant vegetation can reduce potential damage from strong winds. The efficiency of wind resistant plants was investigated to determine the types and effectiveness of wind resistant plants in blocking the wind during the windy season to safeguard the settlement area from the threat of severe winds. A qualitative multi-method approach comprised of field observations, wind speed measurements and random interviews with the villagers was used in this study. This study conclusively demonstrates that the strategic use of wind-resistant plants—such as *Tamarindus indica* and *Cocos nucifera*—in settlement areas significantly reduces the impact of strong winds. By acting as natural barriers, these species effectively mitigate storm damage, as evidenced by the lower wind velocities measured in the safe zone compared to the affected area. Future studies should focus on the arrangement and selection of these plants to improve wind protection and storm preparedness.

Key words: Wind-resistant plants, Storm protection, Settlement area, Coastal village

INTRODUCTION

In rural landscapes, where the connection between communities and the natural environment are closely connected, the importance of wind-resistant plants is becoming increasingly apparent. Rural areas often must deal with distinct challenges from the patterns of unpredictable wind. The buildings and structures in coastal villages, though typically modest and essential, are more vulnerable to the whims of nature than in the urban area due to its proximity to the open sea waters, making it experience greater risk of unpredictable winds from the sea. This is why wind-resistant plants play a crucial role in mitigating these challenges, acting as natural shields against the potential damage caused by varying wind intensities. The weather in Malaysia is characterised by two types of monsoons, the southwest monsoon, which occurs from the end of May to September, and the northeast monsoon from November to March. The northeast monsoon brings heavy rainfall mainly to the states on the east coast of Peninsular Malaysia, West Sarawak and East Sabah, while the southwest monsoon relatively dry weather. The transition period between these two monsoons is known as the monsoon transition phase. Stronger winds occur in some parts of Peninsular Malaysia's

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east coast. During the northeast monsoon, winds can reach up to 54 km/h, especially along the coast of Peninsular Malaysia. During the southwest monsoon, wind speeds are usually below 25.2 km/h. It is evident that Malaysia generally has low wind speeds, but some areas experience stronger winds at certain times of the year.

Over the years, several storms, including severe storms and tropical cyclones, have affected the northern states of Malaysia. Storms that hit the northern states of Malaysia usually occur at the end of the year. Perlis, the northernmost state in Malaysia, is one of the states affected by the storm. Storms that occurred during the monsoon season have reportedly damaged numerous houses in the settlement area. The storm damaged numerous houses to such an extent that their roofs were blown off and trees fell, highlighting the need for effective measures to mitigate wind damage. Therefore, the use of plants that are suitable for the settlement area and have a high resistance is very important to prevent strong winds from damaging the structure of the house. The use of wind-resistant plants is an important consideration in settlement areas to minimise potential damage from strong winds. Several tree species have been identified as being resistant to wind-induced stresses. These trees are also known as storm-resistant plants. They are characterised by their ability to withstand strong winds, heavy rainfall and other forms of extreme weather conditions. These trees are not only visually appealing but offer several advantages that make them effective in settlement areas. While some tree species have been identified as resistant to wind-induced stresses, there is limited research on the specific use and effectiveness of these wind-resistant plants in settlement areas to minimize damage from strong winds. This lack of knowledge hampers the implementation of strategic landscaping to protect settlements from severe storm impacts.

In settlement areas, wind-resistant trees can have a major influence on air flow and wind speed. An observation by Li et al. (2024) found that trees that block the airflow create a sheltered area downstream, which reduces wind speed. The impact of strong winds on settlements can be mitigated by this reduction in wind speed. There can be ecological impacts when wind-resistant trees are located in areas where people live. Research by Ollerton (2017) has shown a negative relationship between annual rainfall and the proportion of tree canopy dispersed by wind. This means that areas with less annual precipitation have a higher concentration of wind-resistant trees. The effectiveness of wind-resistant plants in settlement areas is influenced by various factors. It has been shown that the increasing height and slenderness of trees reduces the stability of individual trees to wind-induced stresses (Ancelin, 2004). The composition and configuration of tree stands, including species composition and distribution, can also enhance the resilience of individual tree stands to wind damage (Zong, 2019). In addition, asymmetric root distribution has been found to destabilise standing trees and reduce their ability to withstand strong winds (Messerschmidt et al., 2021). The arrangement and coordination of trees in windbreaks can create protected areas that reduce wind speed and provide effective wind resistance. It has been found that trees with high wood density and low microfibril angle are more wind resistant (Shang, 2022). This means that the density of the wood is a factor that contributes to its ability to provide stability and structural strength in strong winds. Another aspect of wind resistance in populated areas that needs to be considered is the spacing between trees. Both at the level of individual trees and at the level of the entire forest stand, the degree of support from neighbouring trees can change the effective "tensile strength" against the wind (Kamimura, 2022). Table 1 lists various types of wind resistant tree species that are commonly used in settlement areas in Malaysia and have good wind resistance properties.

Table 1. Type of plants species that have good wind resistance characteristics

Plant Species		Characteristics	Roots	Trunks	Leaves	Canopy
	*Bursera simaruba* (Gumbo Limbo) Becerra & Yetman (2024)	Flexible branches that can bend without breaking with deep root system	Deep and extensive	Straight and cylindrical	Alternate, simple, and oval-shaped	Rounded and symmetrical
	*Sweitenia macrophylla* (Mahagony) Sinaga (2023)	Deep root system,strong wood that can resist strong winds	Deep and extensive	Straight and cylindrical	Alternate, compound, and feather-shaped	Rounded and symmetrical
	*Lagerstroemia indica* (Crape Myrtle) Duryea & Kampf (2007)	Robust root and pliable branches that can flex without breaking	Deep and spreading	Multiple trunks with smooth bark	Alternate, simple, and oval-shaped	Rounded and symmetrical
	*Magnolia grandiflora* (Southern Magnolia) Li et al. (2013)	Strong wood withdeep roots that can withstand strong winds	Deep and extensive	Straight and cylindrical	Alternate, simple, and oval-shaped	Rounded and symmetrical
	*Polyalthia longifolia* (Ashoka Tree) Tembe et al. (2020)	Strong root system, flexible branches that canbend without breaking	Deep and extensive	Straight and cylindrical	Deep green leaves growing in dense clusters.	Conical and pyramidal
	*Cocos nucifera* (Coconut) Chan & Elevitch (2006)	Durable root system, able to withstand powerful winds without breaking	Deep and extensive	Straight and cylindrical	Sheathed by an erect long petiole	Rounded and symmetrical
	*Tamarindus indica* (Asam Jawa) Naeem et al. (2017)	Massive, wind-resistant wood with deep roots	Deep and extensive	Slender, upright trunk	Compound leaves that are feathery	Broad, spreading crown
	*Tabebuia rosea* (Tecoma) Natalia et al. (2023)	Flexible brancheswith a deep root system that can bend without breaking	Deep and extensive	Straight and cylindrical	Leaves are compound, digitate and deciduous	Rounded and symmetrical

Trees provide more than just a visual appeal; they offer several benefits that make them effective in settlement areas. The aim of this study is to identify specific plant species with high wind resistance and evaluate their effectiveness in protecting the settlement area, especially in Kampung Wai, Perlis. The research focus on how these plants can contribute to serve as natural windbreaks to minimise the impact of wind damage. The importance lies in creating more sustainable and resilient communities by incorporating nature-based solutions that work in harmony with the local climate and ultimately reduce the vulnerability of structures and landscapes to the challenges of the seasonal monsoon.

METHODOLOGY

This study employed a multi-method qualitative approach. The study uses field observation, measurement of wind speed with an anemometer from 13 to 19 November 2023 and a random interview with the villagers as instruments for data collection. Two primary data sources were used for the analysis, resulting from the field observation and measurements and interviews with the villagers. Both types of data support the objectives and provide suggestions and insights. Kampung Wai, which lies on the coast and is surrounded by rice fields, was chosen as the study area. The village is located in Kuala Perlis and is likely to be exposed to the effects of varying wind conditions due to its coastal location. This makes it an ideal location to study the effectiveness of wind-resistant vegetation in mitigating potential damage from strong winds. Field observation is one of the methods used in this study that aims to identify areas affected by the storm and areas that are safe from the storm. The field observation was carried out by observing the characteristics and types of plants found in these two areas and the characteristics of the plants that have an impact on the affected area and the safe area in order to determine the differences between these two areas.

In order to record different wind conditions, locations with different vegetation such as open fields, settlement areas and coastal areas were selected for wind velocity measurements (refer Figure 1). Wind speed and direction were recorded with anemometers at different times of the day to understand temporal variations. The wind velocity in the study areas were measured at 1.5m to 2m above ground. Measuring wind speed velocity in the morning at 8.00 a.m, noon at 12.00 p.m, and evening at 5.00 p.m provides a comprehensive assessment of how wind conditions develop throughout the day, helping to identify potential hazards and assess the safety of the area. A representative group of villagers with different demographics were selected for the interviews. The villagers were selected randomly based on their availability to be interviewed especially those affected by strong winds. Random interviews with villagers are used to gain valuable insights into the people's experience, the impact on the community and the environmental consequences of the storm. The interview questions are designed to encourage open and detailed responses, allowing for a nuanced understanding of the situation (Creswell & Creswell, 2018). The first set of questions aims to capture the people's personal experiences during the storm. This information is crucial to understand the emotional and practical challenges faced by the villagers. Questions about the impact of the storm on the surrounding area provide a comprehensive overview of the consequences of the storms. This information helps to prioritize immediate intervention, allocate resources effectively and plan for long-term recovery and reconstruction. These interviews serve to gather diverse perspectives, local knowledge and qualitative data that contribute to a comprehensive understanding of the storm's impact on the human and environmental aspects of the affected community.

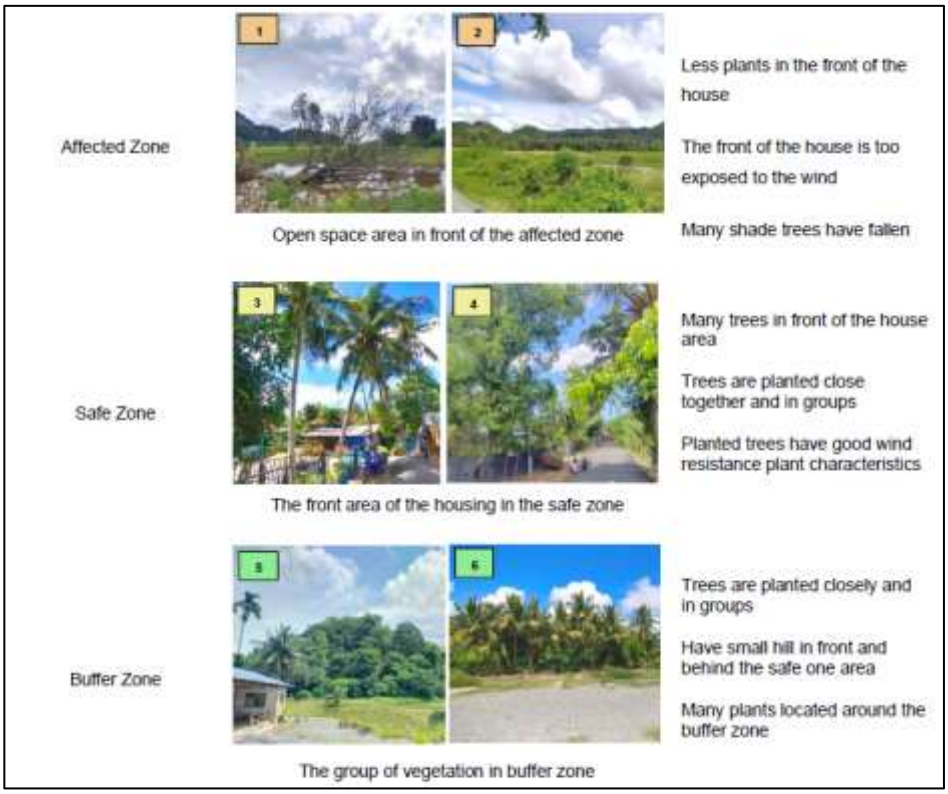

Figure 1. The measurement locations and their environmental characteristics

This study was guided by three main types of analyses. The first is an analysis of efficiency of different vegetation types in providing wind resistance, the second is an analysis of wind velocity trends across the safe and affected zones, and the third is an analysis of qualitative data from interviews with residents in Kampung Wai, Kuala Perlis.

RESULTS AND DISCUSSION

Distribution of Wind Velocity and Vegetation Efficiency

The outcome of analysis based on site observation on the efficiency of the vegetation is summarised in Figure 2. In settlement areas, wind-resistant trees can have a big impact on airflow and wind speed. Previous study by Lai et al. (2018) observed that when trees block airflow, they form a sheltered area downstream, which lowers wind speed. The effects of strong winds on settlements may be lessened by this decrease in wind speed. There may be ecological repercussions when wind resistant trees are present in areas where people live. Certain wind-resistant trees created a buffer zone within the safe area. In order to determine the trend of the wind velocity passing through this village area, anemometer measurements were made for five days in the morning, noon, and evening. Figure 3 displays the wind velocity measured in the affected zone and the safe zone.

Figure 2. The distribution of wind velocity zones in Kampung Wai, Kuala Perlis

Figure 3. The wind velocity in affected zone and safe zone

Based on the wind measurements in the safe zone, the wind is not too strong in the morning and is between 2 m/s and 3.5 m/s. At midday and in the evening, it can reach up to 3.5 m/s. At noon and in the evening, it can reach up to 4 m/s to 5 m/s, compared to the affected area where the wind speed is higher than in the safe zone. By comparison, it can be observed that the impacted area has more wind than the safe zone, and that severe winds occur more frequently in the afternoon and evening. This is also plausible given the meteorological elements that influence wind speed, as the study was carried out during the northeast monsoon season, when nighttime rain is widespread.

There is a stark contrast of vegetation characteristics between these zones, particularly in terms of their vulnerability to strong winds. Starting with the affected area, it is evident that the vegetation in this zone is less resistant to strong winds. The limited presence of wind-resistant plants in this area exposes it to a higher risk of damage from strong winds. Insufficient natural barriers contribute to the increased vulnerability of this zone to the negative effects of wind. In contrast, the safe area provides a more secure environment against the threat of strong winds. In addition, the presence of a significant number of wind-resistant plants in the safe zone plays a crucial role in strengthening this zone against the effects of strong winds. The buffer zones, as shown in the table, represent an important line of defence against the threat of strong winds. These zones feature a small hill that is strategically positioned to act as a natural barrier. In addition, the arrangement of the plants in these buffer zones is remarkable. The grouping of plants, especially those located in front of and around the houses, creates an effective buffer that can resist and mitigate the effects of strong winds. This strategic placement serves to protect the safe area from potential damage. Table 2 tabulates the characteristics of the vegetation in each zone in relation to their influence on the wind velocity.

Table 2. Characteristics of the vegetation in each zone

Zone	Area	Observation
Affected Zone	 	• Less plants in the front of the house • The front of the house is too exposed to the wind • Many shade trees have fallen
Safe Zone	 	• Located in front of the house area • Trees are planted close together and in groups • Planted trees have good wind resistance plant characteristics
Buffer Zone	 	• Trees are planted closely and in groups • Have small hill in front and behind the safe one area • Trees surrounded the settlements

Wind Velocity and Vegetation Efficiency toward Storm Protection in Kg. Wai

Based on the observation in both zones, this study compared plant species and their effectiveness in protecting against strong winds in the safe and affected zones of the village. Table 3 shows the plants in the safe zone, including *Peltophorum pterocarpum* (Batai laut), *Tamarindus indica* (Asam Jawa), *Cocos nucifera* (Kelapa), *Ceiba pentandra* (Kekabu), *Musa paradisiaca* (Pisang) and *Mangifera indica* (Mangga). These plants, especially *Tamarindus indica*, *Cocos nucifera* and *Mangifera indica*, are planted closely around houses and provide strong wind protection due to their high wind resistance (Naeem et al., 2017; Sinaga, 2023).

Table 3. Plant species observed in safe zone

Zone	Average Velocity	Plants Species	Characteristics	Wind Resistance	Plants Density	Remarks
Safe Zone	3.47 m/s	*Peltophorum pterocarpum (Batai laut)*	Multi-trunked Umbrella-domed canopy Deep root system	High Durability	Low Density	Most of the plants in the safe zone have the characteristics of good wind resistance plants, as there is a lot of density in this area, making it safe from the threat of strong winds.
		Tamarindus indica (Asam Jawa)	Straight trunk Broad, spreading crown Deep and extensive	High Durability	High Density	
		Cocos nucifera (Coconut)	Straight and cylindrical Rounded and symmetrical Deep and extensive	High Durability	High Density	
		Ceiba pentandra (Kekabu)	Huge straight trunk Pagoda-shaped, thin crown Large buttress roots	High Durability	Low Density	
		Musa paradisiaca (Pisang)	Rigid pseudostem Open symmetry crown Fibrous Root	Low Durability	High Density	
		Mangifera indica (Mangga)	Single Trunk Dome-shaped crown Tap root system	High Durability	High Density	

Table 4 lists the plants in the affected zone such as *Tamarindus indica, Terminalia catappa* (Ketapang), *Cocos nucifera*, M*usa paradisiaca, Mangifera indica* and *Rhizophora Sp.* (Bakau). Although these plants also have wind-resistant properties, their lower density and scattered planting make the area more susceptible to strong winds. The large crown canopy, strong trunk and deep roots of the trees enable them to withstand strong winds, but the lower density in the affected zone reduces their effectiveness in completely shielding strong winds, resulting in more storm damage.

Table 4. Plant species observed in an affected zone

Zone	Average Velocity	Plants Species	Characteristics	Wind Resistance	Plants Density	Remarks
Affected Zone	4.45 m/s	*Tamarindus indica* (Asam Jawa)	Straight trunk Broad, spreading crown Deep and extensive	High Durability	Low Density	Majority of the plants in the safe zone have good wind resistance characteristics as well, but the average planting distance is about 10 meters. This wide gap reduces their effectiveness in blocking strong winds. Thus, spaced plants 5 meters apart or increasing more trees from the
		Terminalia catappa (Ketapang)	Straight and cylindrica Pagoda-like shape Spreading, fibrous root system	High Durability	Low Density	
		Cocos nucifera (Coconut)	Straight and cylindrical Rounded and symmetrical Deep and extensive	High Durability	Low Density	
		Musa paradisiaca (Pisang)	Rigid pseudo stem Open symmetry crown Fibrous Root	Low Durability	High Density	
		Mangifera indica (Mangga)	Single Trunk Dome-shaped crown Tap root system	High Durability	Low Density	

		Rhizophora Sp. (Bakau)	Branching sympodial Dense canopy Stilt-like roots	High Durability	High Density	same plant community could enhance stronger natural barrier.

Insights from Villagers on Storm Impact and Environmental Resilience

Random interviews with nine available villagers who has been impacted by the wind damage in Kampung Wai provided important insights into the emotional and practical challenges faced by the community during and after the storm.

Villagers expressed feelings of shock, fear and trauma due to widespread damage to homes, farms and infrastructure, with low-lying areas near the riverbanks particularly affected. They emphasised the severe impact of the storm and highlighted the need for extensive recovery efforts. Many villagers recognised the protective role of trees and pointed out that certain tree species act as natural barriers that reduce wind force and provide important protection. This awareness emphasised the importance of wind-resistant plants in protecting the community. However, the interviews also revealed a gap in understanding among some villagers who were considering cutting down large trees near their homes as they were unaware of the protective effect of these trees.

"A key lesson from the storm was the importance of plants as windbreaks. Villagers now understand the need for large trees for their homes that they previously considered useless and want to cut them down. (Interviewee 9)

The storm was a significant lesson, emphasising the importance of pre-emptive measures, better planning, and enhanced awareness. Villagers understood the value of environmental resilience and the role of plants in minimising storm damage, and they advocated for preventive measures and future conservation plans. Despite this growing awareness, continuous education is needed to ensure that all community members understand plants' crucial role in storm mitigation and environmental protection. These findings highlight the importance of integrating ecological knowledge into disaster preparedness and recovery planning to create a more resilient and educated community.

CONCLUSION

The strategic use of wind-resistant plants near settlements is crucial for strengthening resistance to storms. These plants act as nature's shields, providing a crucial defence mechanism against the relentless effects of strong winds and reducing the risk of structural damage during storm. Our findings show just how crucial wind-resistant plants like Tamarindus indica and Cocos nucifera are for protecting settlements from storms. These plants act as natural shields, reducing the impact of strong winds. The data clearly shows that in areas where these plants are used, wind speeds were much lower, meaning less damage from storms. Going forward, it's important to figure out the best way to arrange these plants to offer even more protection. Future studies can investigate how the placement of wind-resistant plants affects wind intensity and its impact on the environment. Future research on plants with excellent wind-resistant properties for safe settlement areas and can protect the area and the most effective arrangement of plants to protect against wind.

AUTHOR CONTRIBUTIONS

Yussyamil Faiz is the main researcher of the study that conducted the data collection, analysis and draft write-up. Sharifah Khalizah is the co-author who supervised the study and revised the manuscript.

COMPETING INTEREST

The authors declare that there are no competing interests.

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