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Spatial Distribution and Dominance of Nipa Palm (*Nypa fruticans* Wurmb) in Mandeh Mangrove Forests, West Sumatra, Indonesia

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Abstract

Background: *Mangrove ecosystems are shaped by environmental conditions and species-specific characteristics. In Nagari Mandeh, West Sumatra, nipa palm (Nypa fruticans Wurmb) is abundant, but information on its spatial distribution and relationship with river distance remains limited. This study quantified its density and frequency, examined spatial distribution, assessed its relationship with river distance, and mapped its occurrence.* **Methodology:** *The study was conducted from November to December 2024 using purposive sampling and a 10-m-wide × 200-m-long belt transect from the riverbank. Twenty 10 × 10 m plots were established. Spatial distribution was assessed using the Morisita index, the relationship between river distance and abundance using simple linear regression, and coordinates were mapped using QGIS. Environmental relationships were examined using Canonical Correspondence Analysis (CCA).* **Findings:** *A total of 568 individuals were recorded across 2,000 m^2, with a density of 0.284 individuals m^{-2} and a frequency of 95%. The Morisita index was 1.16, indicating a clustered distribution. Abundance decreased significantly with increasing river distance ($Y = -0.1829X + 47.6$; $R^2 = 0.7162$; $r = -0.846$; $p < 0.001$). Mapping showed concentration near the riverbank, occupying 1,630 m^2 (>75% of the sampled area). CCA indicated no strong association with measured environmental variables.* **Contributions:** *N. fruticans exhibited high abundance, frequent occurrence, and a clustered distribution. Its abundance decreased with increasing river distance, highlighting the importance of the river-to-inland gradient and providing a baseline for monitoring and site-specific management.*

Keywords: *Dominance; Morisita Index; Nagari Mandeh; Nypa fruticans; QGIS*

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INTRODUCTION

Mangrove forests are highly dynamic tropical and subtropical coastal ecosystems characterized by high productivity and complex interactions among physical, chemical, and biological components. The high productivity of mangrove vegetation contributes substantially to organic matter production, which serves as an important energy source for organisms inhabiting and utilizing these ecosystems (Pakaya et al., 2017). In addition to providing important ecological functions, mangrove vegetation plays a critical role in maintaining ecosystem structure and stability through coastal protection, carbon sequestration, habitat provision, and the maintenance of biodiversity (Anu et al., 2024). However, mangrove vegetation structure and composition are not static, but are shaped by interactions between environmental conditions and species-specific ecological characteristics, including tolerance, regeneration, dispersal, and resource utilization. Consequently, variation in the abundance and spatial distribution of plant species may influence vegetation structure and affect the establishment and persistence of other species through interspecific interactions and competition.

One important mangrove ecosystem in West Sumatra is located in the Nagari Mandeh area, Pesisir Selatan Regency, which covers approximately 896.73 ha (Rahmi, 2017). The area is ecologically important and has also been developed as a tourism destination emphasizing ecological and educational values while supporting biodiversity conservation and mangrove ecosystem management (Raynaldo et al., 2020). Within this ecosystem, the occurrence and dominance of particular plant species, particularly the nipa palm (*Nypa fruticans* Wurmb), are relevant to understanding local vegetation dynamics. High abundance and dominance of *N. fruticans* may influence the composition and spatial structure of mangrove vegetation by modifying the availability of space and resources for other plant species. Therefore, quantifying the density and spatial distribution of *N. fruticans* is important for understanding its occurrence, dominance, and potential influence on vegetation dynamics within the Nagari Mandeh mangrove ecosystem.

The ecological characteristics of *N. fruticans*, including its high reproductive capacity, seed dispersal through water, and ability to establish in riverine and brackish habitats, may contribute to its persistence and spatial distribution in mangrove environments (Numbere, 2019). These characteristics may result in heterogeneous patterns of abundance across different parts of the mangrove habitat. Understanding such variation is important because the spatial distribution of plant species reflects the interaction between species characteristics and environmental conditions. Previous studies have reported variation in the density and distribution of *N. fruticans* across mangrove habitats (Fithria et al., 2024). Consequently, assessing the spatial distribution of *N. fruticans* and its variation along environmental gradients can provide insights into the ecological factors associated with its occurrence and dominance.

Spatial distribution patterns can be quantitatively assessed using indices such as the Morisita index, which can characterize whether individuals exhibit random, uniform, or clustered distributions (Rani, 2003). In addition, spatial mapping based on the geographic coordinates of individual plants can provide a spatially explicit representation of species occurrence and distribution. Such approaches have been applied to characterize plant distribution and support spatial assessment using geographic information systems (Pasaribu et al., 2024; Solfiyeni & Nurmalasari, 2025). In the context of mangrove ecosystems, examining the relationship between habitat position and species density is also important because environmental gradients may influence vegetation distribution and structure (Yuvaraj et al., 2017). Distance from the river represents a readily measurable spatial gradient that may reflect variation in hydrological and environmental conditions within the mangrove habitat.

Building on the previous study by Putri (2025), which documented the composition and structure of invasive plants in the Nagari Mandeh mangrove area, a quantitative assessment of *N. fruticans* density, spatial distribution, and its relationship with river distance is warranted. Therefore, this study aimed to quantify the density of *N. fruticans*, examine its spatial distribution pattern, determine the relationship between distance from the river and *N. fruticans* density, and map its spatial distribution within the Nagari Mandeh mangrove tourism area. The findings are expected to provide a spatially explicit baseline for monitoring *N. fruticans* distribution and dominance and to support evidence-based management and conservation of the Nagari Mandeh mangrove ecosystem.

METHOD

The study was conducted in the Nagari Mandeh area, Koto XI Tarusan Subdistrict, Pesisir Selatan Regency. Data collection took place in a mangrove forest dominated by *Nypa fruticans*. Geographically, this area is located at 1°11'33'' S, 100°25'45'' E (Figure 1). In each plot, the number of nipa palm individuals was counted, and coordinates were recorded using a map marker application. Environmental factors recorded in the study area included sunlight intensity using a lux meter, as well as measurements of air and soil temperature, salinity, and soil pH.

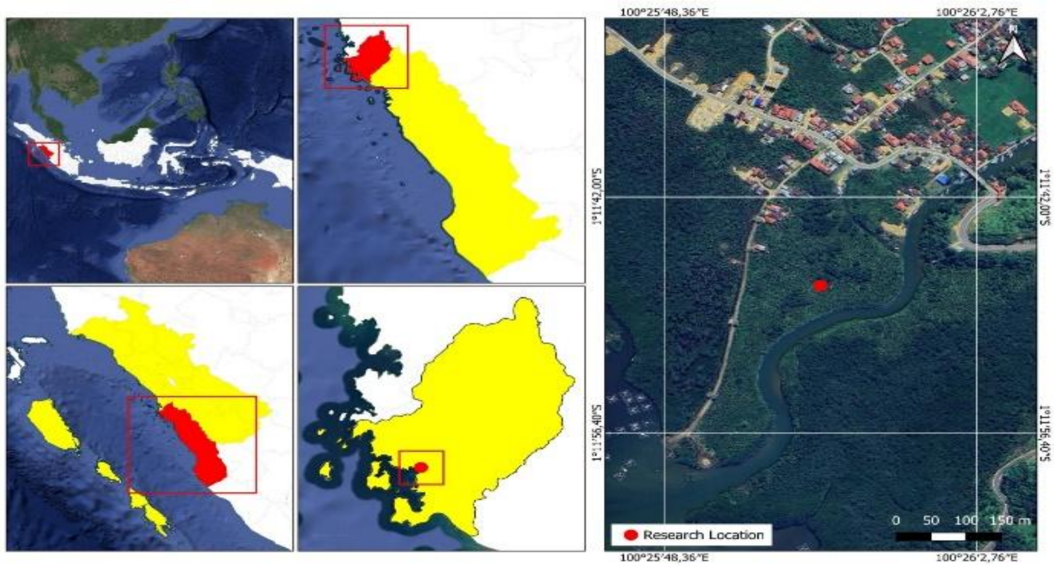

Figure 1. Map of research locations

Data collection

The study employed a field survey method, with the research site selected using purposive sampling based on predefined ecological criteria relevant to the objectives of the study. The study site was purposively selected because it represents a mangrove area in Nagari Mandeh, Koto XI Tarusan Subdistrict, Pesisir Selatan Regency, West Sumatra, where *N. fruticans* occurs abundantly and forms a dominant component of the mangrove vegetation. The selection criteria included: (1) the presence of *N. fruticans* populations; (2) relatively high density or apparent dominance of *N. fruticans* within the mangrove vegetation; (3) the presence of a habitat gradient extending from the riverbank toward inland areas, allowing spatial variation in *N. fruticans* density to be assessed; and (4) sufficient accessibility and habitat continuity to establish systematic observation plots and measure relevant environmental parameters. These criteria were established to ensure that the selected site was directly relevant to the assessment of the density, spatial distribution, and dominance of *N. fruticans* within the mangrove ecosystem. Purposive sampling is appropriate when research sites are deliberately selected according to predefined characteristics that are directly related to the research objectives (Campbell et al., 2020). At the designated location, a 10-m-wide belt transect was established and extended 200 m from the riverbank toward inland areas. The transect was divided into 20 consecutive 10 × 10 m observation plots, with adjacent plots arranged continuously without intervening gaps.

This design covered the entire transect and enabled the assessment of spatial variation in *N. fruticans* density along the river-to-inland gradient (Sidik et al., 2018) (Figure 2). The plots were used to examine the spatial distribution of nipa palms in the Nagari Mandeh tourism area. Additionally, linear regression analysis was performed using Microsoft Excel to evaluate the relationship between distance from the river and the density of *N. fruticans* individuals. The coefficient of determination (R^2) was used to assess the proportion of variation in *N. fruticans* density explained by distance from the river. Data analysis utilized the Morisita index to identify distribution patterns; Avenza software was used for mapping, and QGIS was employed for visualizing distribution points and the extent of dominant areas.

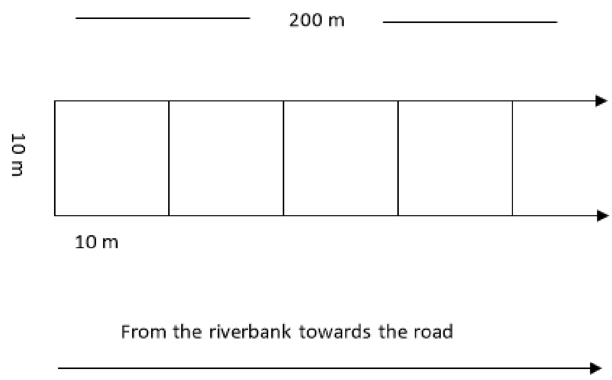

Figure 2. Plots of density observations, distribution patterns, and mapping
Density and frequency

Data analysis

Density (D)

$$\text{Density (D)} = \frac{\text{Total number of individuals}}{\text{Sample plot size}}$$

Frequency (F)

$$\text{Frequency (F)} = \frac{\sum \text{Subplots found a species}}{\sum \text{all sample subplots}}$$

The Effect of Distance from the River on Density

$$\boldsymbol{Y} = \alpha + \beta X$$

Where: Y = Dependent variable, X = Independent variable, α = Intercept, β = Slope.
Spatial Distribution Patterns (Krebs, 2014)

Indeks Morisita (id)

$$Id = n \left(\frac{(\sum x^2 - \sum x)}{((\sum x)^2 - \sum x)} \right)$$

Where,

Id : Morisita scatter index
n : Number of observation plots
Σx2 : The square of the number of individuals found in each plot (x12+x22+ …)
Σx : Total number of individuals found in each plot (x1+x2+ ………..)

The results of the Morisita index (Id) analysis can be defined as follows: Id=1: the distribution pattern is random; Id>1: the distribution pattern is clustered; Id<1, the distribution pattern is uniform or regular.

Mapping and Area Coverage of *Nypa fruticans*

During field research, data collection was carried out by recording the coordinates of each individual *Nypa fruticans* species found within the plot. The coordinates were collected using the Map Marker application. The data was then transferred in text form to the Excel application. Next, during the map creation stage, an analysis was first performed using the Excel application to input attributes in the form of a CSV file. After the coordinate data was analyzed, the data was input into the QGIS application. Once the analysis process was complete, the coordinate data entered into the QGIS application displayed the distribution points of *N. fruticans*.

Next, the area invaded by the dominance nipa plant was calculated by connecting the outer points of the coordinates to form a polygon, which was then colored to distinguish the invaded area. After that, the total domination area was calculated to obtain the area in square meters. The data was visualized in the QGIS application and the results were obtained in the form of coordinate points and polygons of the nipa domination area at the research location. The mapping results were displayed on a Google Satellite base map and supplemented with photo documentation of the research location obtained from drone photos (Solfiyeni & Nurmalasari, 2025).

RESULT AND DISCUSSION

Density and Frequency

Based on the research conducted, the number of *Nypa fruticans* individuals varied in each observation plot. The number of N. fruticans individuals recorded in each plot is presented in Table 1.

Table 1. Density of *Nypa fruticans* in each plot

No. Plot	Distance (m)	Number of Individuals	Density (ind/m²)
1	0-10	54	0.54
2	11-20	47	0.47
3	21-30	36	0.36
4	31-40	42	0.42
5	41-50	30	0.3
6	51-60	37	0.37
7	61-70	36	0.36
8	71-80	34	0.34
9	81-90	38	0.38
10	91-100	15	0.15
11	101-110	20	0.2
12	111-120	31	0.31
13	121-130	29	0.29
14	131-140	25	0.25
15	141-150	23	0.23
16	151-160	18	0.18
17	161-170	16	0.16
18	171-180	14	0.14
19	181-190	0	0
20	191-200	23	0.23
Total Individuals		**568**	**0.284 ind/m²**

Based on Table 1, it can be seen that the number of *N. fruticans* individuals found in each plot varies. At the study site, which covered an area of 2,000 m² (0.2 ha), there were a total of 568 individuals (0.284 ind/m²). The higher number of individuals in plots adjacent to the river suggests that *N. fruticans* was more abundant in areas closer to the riverbank. In Figure 3, plots located near the river were found to have denser stands of *N. fruticans* in waterlogged areas, while plots toward inland areas were found to have sparser and less frequent nipa that were not waterlogged. This finding is in line with Kitamura et al., (1997), who stated that nipa is generally found along rivers affected by tides, forming a large community from the estuary to the brackish water upstream. According to Irsadi et al., (2019) and Ellison (2021), environmental conditions such as salinity greatly affect the distribution of nipa. In addition, the nutrient content or organic matter in the soil and water also contributes to vegetation growth and density (Pérez et al., 2018). Numbere (2019) adds that the level of sea tides also has the strongest correlation with nipa population density.

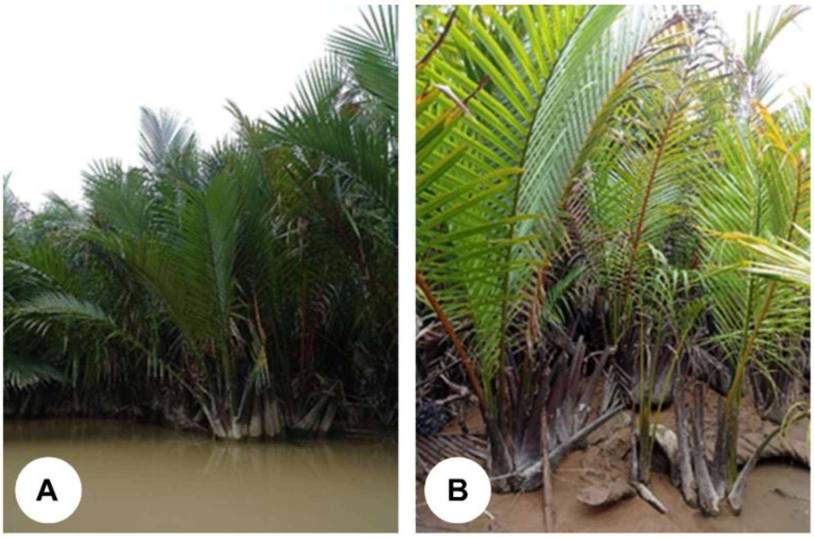

Figure 3. Conditions of *Nypa fruticans* observation plots: (A) plot adjacent to the riverbank and (B) plot located further inland

Table 2. Frequency of *Nypa fruticans*

Observation Plot	Total Number of plots where *Nypa fruticans* individuals were found	Frequency
20	19	95%

The frequency of a species indicates its distribution level in an area. The more evenly a species is distributed, the higher its frequency value. *N. fruticans* individuals were found in 19 of 20 observation plots, giving this species a frequency value of 95%. No nipa palm individuals were found in plot 19 because other mangrove individuals were growing there. At the study site, nipa palm individuals were found to be more numerous than other mangrove species. This is thought to be because the biotic and abiotic environmental conditions are optimal for the growth and development of nipa palm individuals. According to Bengen (2000), nipa dominates the transition zone between mangrove forests and lowland forests, but this dominance is very dangerous for the balance of the mangrove ecosystem because this species is highly proliferative, adapts quickly, and is classified as an invasive species in some regions of North Africa (Numbere, 2019). This concern is supported by a recent study in the same Nagari Mandeh mangrove ecosystem, where *N. fruticans* dominance was associated with high carbon storage but low diversity of native mangrove species (Fikri et al., 2026).

The dominance of nipa in this location is thought to be due to its adaptability. This adaptability is supported by several factors, including tolerance to changes in salinity, the ability to grow on muddy substrates, and resistance to dynamic environmental changes such as sea level rise and tidal fluctuations (Björn et al., 2022). In addition, nipa reproduction is also more efficient through the production of large numbers of seeds, where in one bunch there can be 30-50 fruits that are tightly packed together, forming a cluster of round fruits as shown in Figure 4. After ripening, the fallen fruit floats in the water, following the tidal currents or river flow until it gets stuck where it grows (Radam et al., 2018).

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Figure 4. Reproductive organs of *Nypa fruticans.* Male (A); Female (B)

The Effect of Distance from Rivers on the Density of *Nypa fruticans* Individuals

The results of the regression analysis to determine the effect of distance from the rivers on the density of nipa palm individuals are shown in Figure 5. The equation model obtained from the linear regression analysis is y = -0.1829x + 47.6 with R2 equal to 0.7162. This equation shows that the effect of distance on individual density is 71.62%, while 28.38% of individual density is influenced by other factors. This indicates that the distance from the river to the mainland affects the individual density of *N. fruticans*.

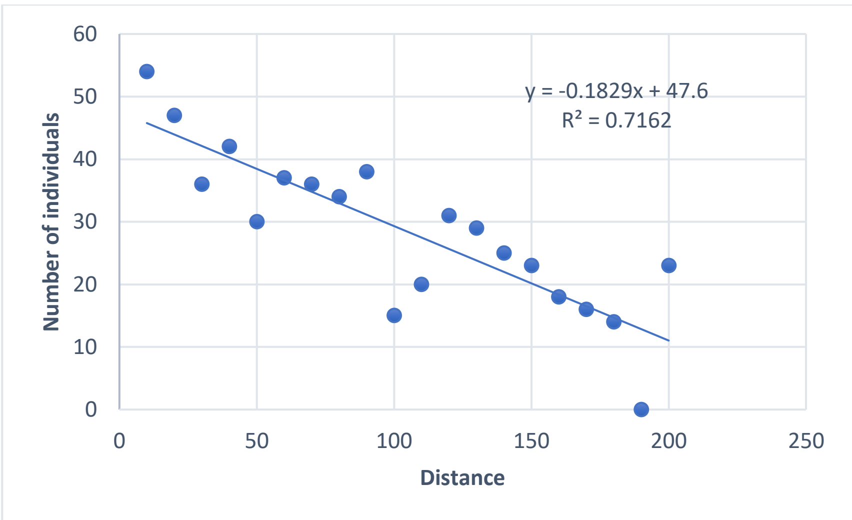

Figure 5. Effect of distance from the river on the density of *Nypa fruticans* individuals (linear regression)

Based on the figure, it can be seen that the number of nipa palm individuals decreases as the distance from the river increases. Nipa tends to grow more abundantly on the edges of mangrove forests along river channels. This indicates that *N. fruticans* tends to grow more optimally in areas close to waterways. Widodo et al., (2020) stated that nipa grows abundantly along riverbanks, canals, and tributaries in mangrove ecosystems, forming pure stands or mixed stands with other mangroves. According to Radam et al., (2018), nipa stands in mangrove areas generally grow behind the main mangrove forest with lower salinity conditions. Its ability to grow in brackish or almost fresh water zones reinforces the evidence that distance from the river is one of the key factors in determining the distribution of this species.

Spatial distribution pattern of *Nypa fruticans*

The spatial distribution pattern of *Nypa fruticans* was calculated using the Morisita index. This distribution pattern is known to be the tendency of plants to form a specific distribution within their community. The spatial distribution pattern of *N. fruticans* in the Nagari Mandeh mangrove area is presented in Table 3.

Table 3. Distribution pattern of the *Nypa fruticans* species based on the Morisita Index

n	$\sum x$	$\sum x^2$	*id*	Distribution pattern
20	568	19236	1.16	Clustered

Table 3 shows that there are 568 individuals of *N. fruticans* with a Morisita index (Id) >1, namely 1.16. Based on the Id value, the distribution pattern of nipa in this location is categorized as clustered. This is consistent with Sidik et al., (2018), who found that *N. fruticans* plants grow in clusters on sandy and muddy substrates along the water's edge. Nipa trees also generally grow close together and in clusters, forming pure communities.

Clumped distribution patterns are commonly found in nature because the environmental factors required by a particular species are relatively similar (Ludwig & Reynolds, 1988). The occurrence of clumped distribution patterns is due to the uneven distribution of resources required for life in the habitat environment (Sulistiyowati et al., 2021; Solfiyeni et al., 2024). According to Rofi'i et al., (2021), the distribution of a species is often influenced by environmental heterogeneity, even on a small scale, as well as by the species' adaptation strategy, so that a species has a clumped distribution pattern only in suitable environments.

Mapping and area coverage of *Nypa fruticans* in Nagari Mandeh

The distribution of *Nypa fruticans* individuals at the 2000 m^2 research site was mapped using GPS coordinates and visualized using the QGIS application. The mapping results are shown in Figure 6. Based on the distribution map, it can be seen that *N. fruticans* individuals grow more densely and in large numbers in areas directly adjacent to the riverbank. Conversely, further inland, the number of individuals found decreased and their distribution became sparser (Figure 7b). This is in line with the habitat characteristics of *N. fruticans*, which generally live in colonies and groups in brackish water zones, especially along rivers or estuaries.

The area where nipa palm individuals were found in the transect shows the observation area boundary in the form of an orange polygon analyzed using the QGIS application, which is 1630 m^2. This value shows that more than 75% of the research area is dominated by the *N. fruticans* species (Figure 7). According to Barbour (1987),

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the distribution pattern of plant species tends to be clustered, because reproduction methods such as seeds falling close to the parent plant or rhizomes producing vegetative offspring remain close to the parent plant. This pattern is commonly found in wild plants, especially in ecosystems with unevenly distributed environmental nutrients (Indriyanto, 2006).

Figure 6. Area polygon (a) and distribution points of *N. fruticans* individuals in each observation plot (b)

Species diversity will gradually decline if the dominant local plant species in a given area are not managed. In the long term, this situation can lead to changes in vegetation structure and composition, organism communities, and energy flow, ultimately reducing the function and quality of available ecosystem services (Solfiyeni et al., 2022). Comparable evidence from West Sumatra shows that species dominance can alter vegetation structure and reduce native species richness and ecosystem carbon storage capacity (Solfiyeni et al., 2025).

Relationship between environmental factors and the distribution of *Nypa fruticans* individuals

Environmental parameters measured at the research site in Nagari Mandeh were analyzed for their relationship with the number of *Nypa fruticans* individuals and distance from the river using Canonical Correspondence Analysis (CCA). The results of the analysis can be seen in Figure 7. The CCA analysis results provide a visual representation of the relationship between plant species and environmental factors at the research site. The combination of the two main axes explains the greatest variation in species composition influenced by the environment. The influence of environmental factors on the *N. fruticans* species shows the position of the *N. fruticans* species (labeled blue) in the ordinal space located near the center (negative Axis 1 and negative Axis 2). The *N. fruticans* species is close to the center point of the coordinates, indicating that this species does not have a strong association with any particular environmental variable. This indicates that *N. fruticans* has broad ecological tolerance and is able to adapt to various environmental conditions, or is referred to as a generalist species (Alongi, 2002).

The central position of *N. fruticans* in Figure 7 shows that its existence is not greatly determined by fluctuations in temperature, salinity, or soil pH. The Soil pH and salinity arrows point to the upper right (positive Axis 1 and Axis 2), The ordination pattern suggests a weak association between N. fruticans occurrence and the measured salinity and soil pH gradients. Bawaihi et al., (2020) state that nipa plants are mostly found in brackish environments with low to moderate salinity levels. In addition, the optimal soil pH required for nipa to grow is neutral to slightly acidic, which comes from the decomposition of litter in mangrove forests (Mangwa & Fuashi, 2021).

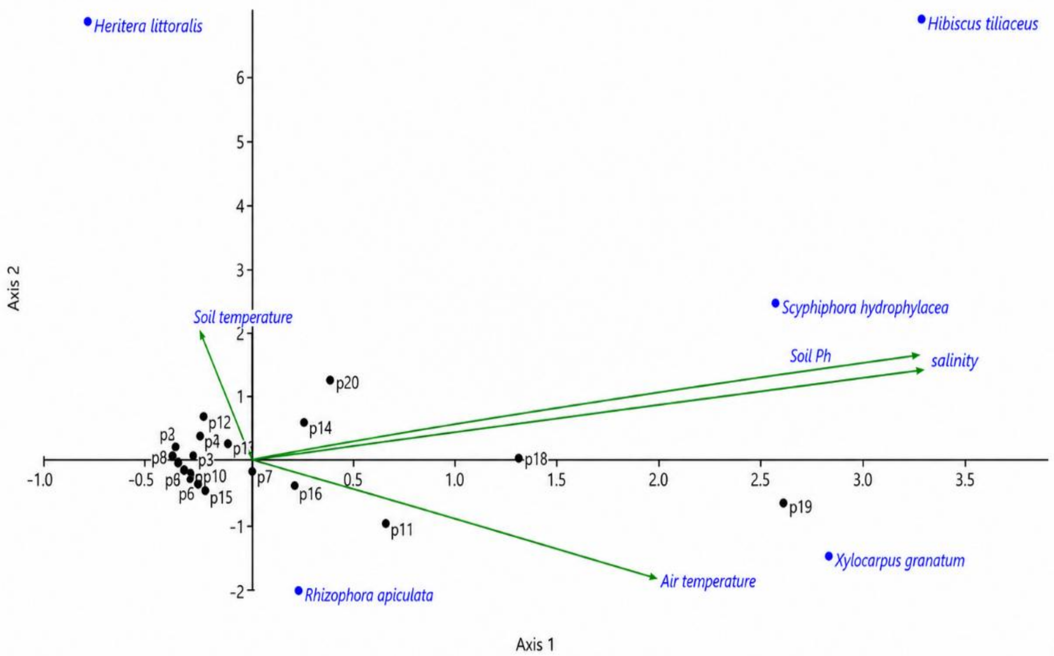

Figure 7. Results of Canonical Correspondence Analysis (CCA) of the relationship between environmental factors and the number of individuals and distance in the Mandeh area

Furthermore, the air temperature parameter is in the opposite direction, indicating that *N. fruticans* is not greatly affected by high temperatures. Meanwhile, *N. fruticans* is also far from the soil temperature arrow, so the presence of nipa is not greatly affected by soil temperature. Environmental temperature plays a role in the growth rate and photosynthesis of nipa. The optimal temperature for *N. fruticans* is in the range of 25–32 °C. From another study by Emoyama et al., (2019), the optimal temperature in mangrove areas dominated by nipa is 28 °C, so the air temperature in the study area is optimal for the existence and growth of nipa.

CONCLUSION

This study demonstrated that distance from the river significantly influenced the density of *Nypa fruticans*, with density decreasing as distance from the river increased. The species exhibited a clustered spatial distribution (Morisita Index = 1.16) and high local dominance, occurring in 19 of 20 observation plots and covering more than 75% of the sampled area. These findings highlight the importance of periodic monitoring and spatial mapping of *N. fruticans*, particularly in river-adjacent areas where its density was highest, to provide a basis for detecting future changes in its distribution and dominance. The study provides a spatially explicit baseline for monitoring vegetation dynamics and supporting site-specific management of *N. fruticans* within the Nagari Mandeh mangrove ecosystem.

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