Nutrient dynamic in sediment and organs of the mangrove *Avicennia marina* (Forsk.) Vierh

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Abstract. *Avicennia marina* is a mangrove species that can be found on the coast of Indonesia, specifically in Lampung province. The aim of this study was to investigate the relationship between *Avicennia marina* nutrients in natural mangroves. This study was conducted in the coast of Pesawaran, Lampung, Indonesia in December 2023. Nutrient sampling included leaves, roots, and sediment in the *Avicennia marina* mangrove area. The statistical analysis used the principal component analysis (PCA) approach. The nutrients analyzed were nitrogen (N), phosphorus (P), zinc (Z), magnesium (Mg), and iron (Fe) in the leaves, roots, and sediment. The results of this study revealed the eigenvalues and loading factors of the nutrient variables. The main factor (F1) presented 99.78% of the variable data where each variables contributed not significantly different. The main to the least variables were Mg (0.47), Fe (-0.46), N (0.43), Zn (-0.43), and P (0.42). The negative values of Fe and Zn variables indicated a negative correlation with Mg, N, and P. If the Fe and Zn values increase, then the Mg, N, and P values will be the opposite.

1 Introduction

Mangroves are coastal plants that have important roles and can be easily found along the coast of Indonesia, one of which is in the Pesawaran area, Lampung Province. Mangroves also provide various benefits, including serving as a food source for marine biota, carbon storage [1-3], and climate change mitigation [4]. Mangroves can optimally grow and develop with the support of soil conditions that are influenced by the frequency of inundation of the mangrove ecosystem from the ebb and flow of sea water [5]. The high nutrients found in sediment can also affect the growth and productivity of mangroves [6]. Limited nutrients also have an impact and influence the height and productivity of mangroves [7].

The presence of nitrogen and phosphorus can be beneficial and stimulate primary productivity in the mangrove ecosystem [8]. Important nutrient elements consisting of N, P, and K can also be utilized by organisms in the mangrove ecosystem for growth and

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reproduction [9]. Therefore, the limited content of N and P entering the mangrove ecosystem causes mangroves to become stressed [10]. The hydrological process in the mangrove ecosystem is very necessary to maintain the sustainability and effectiveness of the N, P and K cycles in the mangrove area.

The nutrient content value is influenced by key factors, both biotic and abiotic, and these two factors affect the availability of N in sediment [5]. Leaf litter decomposition has a key factor in contributing to nutrient distribution with the support of microbial activity [11] and tannin content [12,13]. N and P have an impact on the quality of mangrove litter [14], and nutrient accumulation also has an impact on ecosystem services [15,16]. The aim of this study was to determine the relationship between nutrients in leaves, roots, and sediment in the mangrove *Avicennia marina*.

2 Materials and methods

2.1 Location and time of research

This research was conducted in the mangrove area in Pesawaran subdistrict, Lampung, Indonesia. Field data collection was conducted on the *Avicennia marina* mangrove in December 2023. The research site was geographically located at 5° 20' 0'' – 5° 50' 0'' South latitude and 104° 55' 0'' – 105° 20' 0'' East longitude.

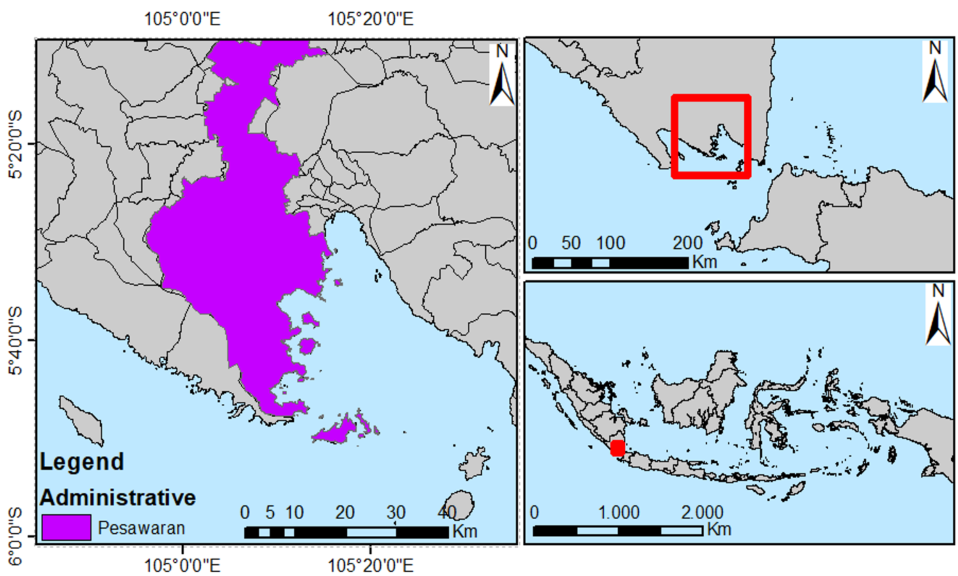

Fig. 1. Research location in Pesawaran, Lampung Province, Indonesia.

2.2 Data collection

The collected data in this study were trace elements (N, P, Mg, Fe, and Zn) and environmental parameters. Nutrient sample such as nitrogen and phosphorus were determined using UV-Vis spectrophotometer (Brand: Perkin Elmer). Meanwhile zinc, magnesium, and iron contents were determined using Atomic absorption spectroscopy (AAS, Brand: Perkin Elmer). Nutrient samples collection was carried out on sediment, roots, and leaves of *Avicennia marina* mangrove. Nutrients in sediment were obtained by using a 47.46 mm wide

PVC pipe with a depth of 30 cm. Root samples were taken close to the sediment, and leaf samples were taken on green leaves (medium).

2.3 Data analysis

The method used to analyze nutrient data in mangrove sediment, roots, and leaves was principal component analysis (PCA). PCA shows the variability of nutrient data.

3 Results and discussion

Fig. 2 shows the N and P contents found in leaves, roots, and sediment. The N and P contents showed that leaves had a higher content than roots and sediment. The highest N content was leaves > roots > sediment, the same as P content that leaves > roots and sediment. These findings indicated that the N and P contents found in leaves play important roles in supporting the growth sustainability and development of the mangrove ecosystem in the supply of nutrients. Total N can increase due to environmental factors such as rainfall and water movement cycles [17]. Previous research also reported that the higher rate of decomposition resulted in the higher N content in *A. marina* mangrove [18].

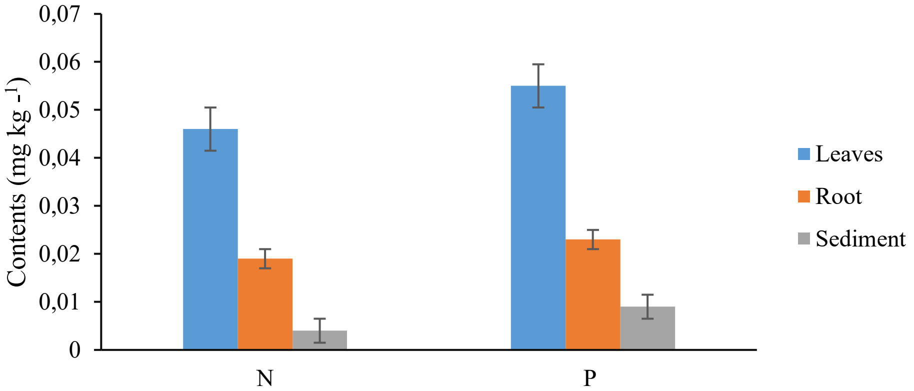

Fig. 2. N and P contents in leaves, roots, and sediment of the *A. marina*.

Fig. 3 shows the Mg content in leaves, roots, and sediment of *A. marina*. The highest Mg content was found in the leaves of *A. marina* mangrove compared to roots and sediment. The Mg content was highest in leaves, followed by roots and sediment. These results indicated that leaves have an important role in the Mg cycle in *A. marina* mangrove.

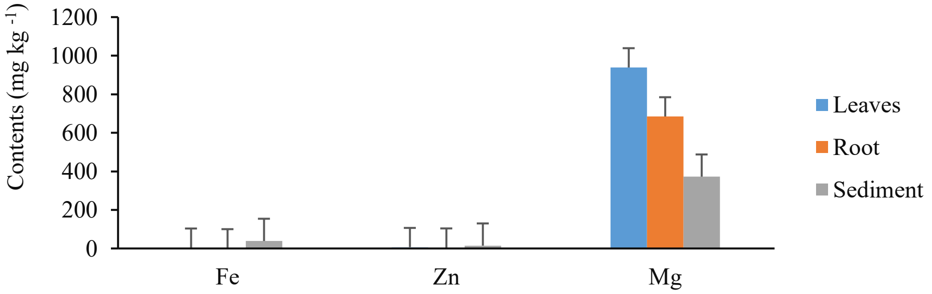

Fig. 3. Fe, Zn, and Mg contents in the leaves, roots and sediment of *A. marina*.

Fig. 3 shows the Fe and Zn contents in leaves, roots and sediment of *A. marina*. The content of both Fe and Zn in the sediment was higher than in the leaves and roots. The highest contents of both Fe and Zn were the same, i.e., in sediment > leaves > roots. The highest ratio of Fe content was found in the sediment compared to Zn. The highest nutrient content was found in Zn compared to Fe, and this also had similarities with the Zn content in the roots which was also higher than Fe in the roots. Stem and leaf transport systems as central to understanding the integrated growth responses to variation in salinity from fresh- to seawater condition [19].The high content of Fe and Zn in sediment of *A. marina* in this study is in agreement with the highest content found in the Red Sea, i.e., Fe in sediment (8939.38 ± 312.63 mg/kg) and in leaves (1464.55 ± 1.05 mg/kg) of *A. marina* in Read Sea [20]. The differences in nutrient composition and dynamics are not only influenced by the plant's ability to absorb nutrients but are also affected by the abiotic components of the environment or habitat of the mangrove *A. marina* such as salinity, sediment size, tidal, ph, and mangrove location. In this study, the abiotic conditions during nutrient measurement included pH (6.2±0.6), salinity (21.3 ±0 PSU), temperature (31±0 ^{0}C), and total dissolved sediment (283 ±129 ppm) (Fig. 4).

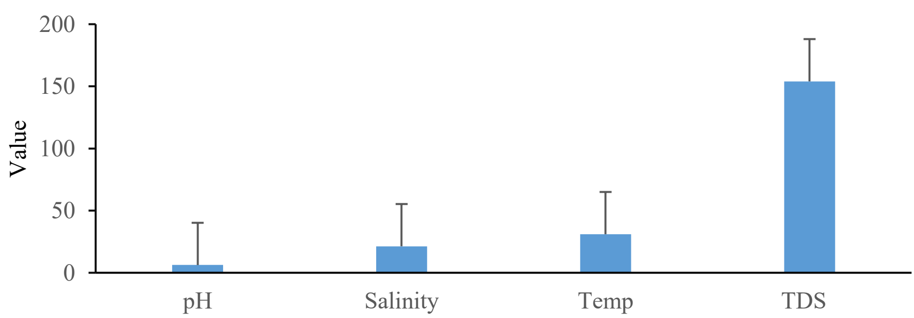

Fig. 4. Water quality in mangrove condition.

Fig. 5 shows the correlation of each variable. The matrix shows that Mg, N, and P, as well as Fe and Zn, are positively correlated. However, Mg, N, and P are negatively correlated with Fe and Zn, in which Mg and Fe show the highest negative correlation value that means an inverse relationship.

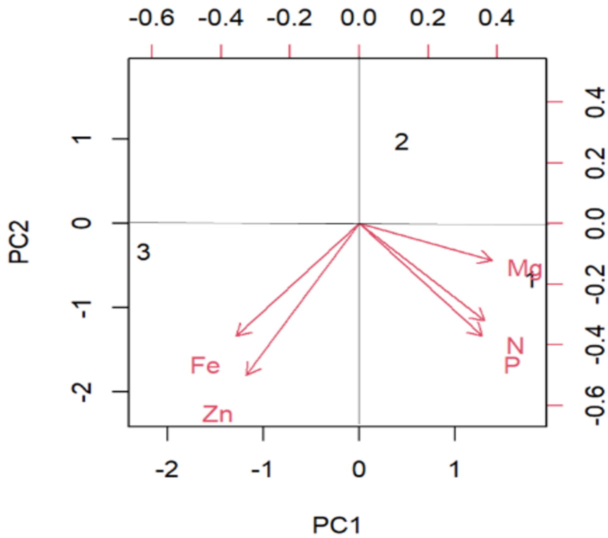

Fig. 5. Distribution of variables in the leaves (1), roots (2), and sediment (3) of *A. marina*.

Table 1. Results of eigenvalues PCA factor of variables.

	F1	F2	F3	F4	F5
Standard deviation	1.8475448	0.086054185	1.651983e-08	9.856010e-09	0
Proportion of Variance	0.9978352	0.002164776	7.977741e-17	2.839692e-17	0
Cumulative Proportion	0.9978352	1.000000000	1.000000e+00	1.000000e+00	1

The main factor (F1) presents 99.78% of the variable data where each variable provides a contribution that is not significantly different (Table 1). The main variables to the least are shown by Mg (0.47), Fe (-0.46), N (0.43), Zn (-0.43), and P (0.42) (Table 2). The negative values of P and Zn variables indicated a negative correlation with Mg, N, and P. When the values of Fe and Zn increase, the values of Mg, N, and P will be the opposite. Meanwhile, N, Mg, Zn are negatively correlated with P and Fe.The PCA results revealed that the main factor 1 is able to describe the data diversity. The contribution of each variable to the main factor (F1). The results showed that variables with the largest to smallest contributions to F1 are Mg, Fe, N, Zn, and P, respectively.

The PCA results of variables in leaves, roots, and sediment showed that leaves were influenced by Mg, N, P, Fe, and Zn. Mangrove roots were affected by Mg, N, P, while sediment was influenced by Fe, Zn, Mg, N, and P. The leaf organ of the mangrove has the highest contribution to the soil. Nitrogen is also found as the highest content in *A. marina* [28]. *A. marina* has the ability to have excess nitrogen in the growth process compared to other mangroves such as *Ceriops tagal* [7].

Table 2. Results of loading factor of variables.

Variables	F1	F2	F3	F4	F5
N	0.4380436	0.4184226	0.79563830	0.00000000	0.00000000
P	0.4247835	0.4806870	-0.48665836	-0.55658167	-0.20464466
Mg	0.4742825	0.1711890	-0.35114675	0.78382196	0.08983038
Fe	-0.4632119	0.4444311	0.02129988	0.27476425	-0.71551846
Zn	-0.4337829	0.6058365	-0.07978481	0.01856291	0.66187944

Fig. 6 showed the correlation every nutrient. The result showed that N, P and Mg had high correlation (value = 1). The presence of N and P content in the roots decreases with increasing soil depth [21]. The concentration of N in the mangrove ecosystem has different values due to the presence of different mangrove species, ages, nutrients, and sediment characteristics [22]. Phosphorus also describes the reflection of the influence of roots and soil [23]. Phosphorus availability can be significantly increased in mangrove forests by the presence of arbuscular mycorrhizal fungi and phosphate-solubilizing bacteria [24, 25]. *A. marina* provides high P and shows a high presence of bacteria with a strong root-soil-phosphobacterial association [26].

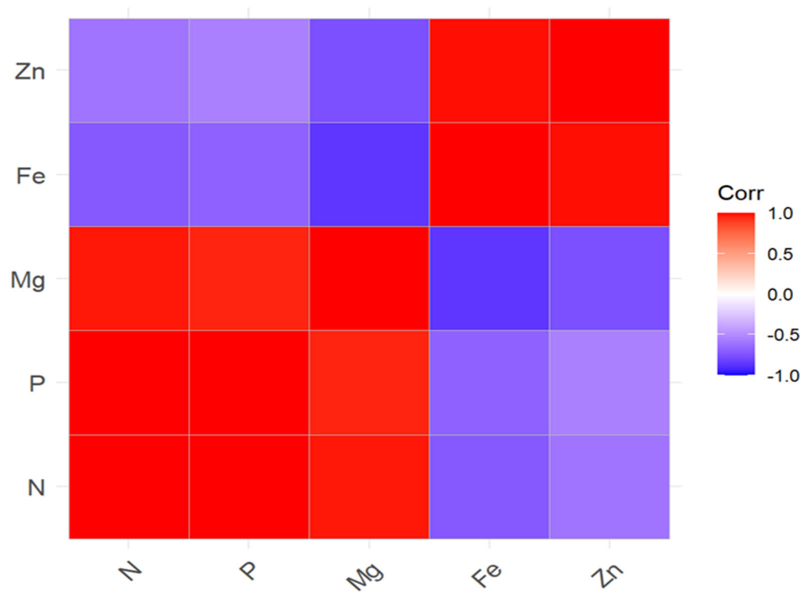

Fig. 6. Correlation matrix of nutrient variables.

The understanding of nutrients dynamics influenced by abiotic components has not been discussed in this study and will be analyzed further in the future. Related studies have been conducted by several researchers [27,28 ,29]. However, they have not specifically focused on a particular species, especially *A. marina*, at the root, sediment, and leaf levels. This topic can serve as an interesting area for future research to gain a comprehensive understanding of nutrient dynamics in mangroves.

4 Conclusion

The PCA results in this study revealed that *A. marina* leaves were affected by Mg, N, P, Fe, and Zn. The *A. marina* roots were affected by Mg, N, P, while sediment was affected by Fe, Zn, Mg, N, and P.

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