

**STUDYING THE FERTILITY OF THE SOIL SYSTEM USING THE ANALYSIS OF  
PHYSICAL AND CHEMICAL CHARACTERISTICS IN CA MAU PROVINCE,  
VIETNAM**

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**ABSTRACT**

This study investigates the current fertility status of soils in Ca Mau Province, Vietnam. Soil fertility is a complex result of various interactions, including physical and chemical properties. The study utilized soil samples collected from different districts and cities within Ca Mau Province. Physical properties such as mechanical composition and bulk density, as well as chemical properties including soil acidity, organic matter content, total nitrogen, phosphorus, potassium, and cation exchange capacity were analyzed. The results provide insights into the distribution of soil fertility levels across different land uses in the province. Overall, the findings contribute to a better understanding of soil fertility management in Ca Mau Province, which is essential for sustainable agricultural practices in the region.

**Keywords:** Soil Fertility , Physical Characteristics , Chemical Analysis , Ca Mau Province , Vietnam Soil Study , Soil System Analysis.

**1. INTRODUCTION**

Soil fertility is a critical factor influencing agricultural productivity and ecosystem sustainability. In Ca Mau province, located in the southernmost part of Vietnam, understanding the fertility status of soils is crucial for optimizing agricultural practices and ensuring food security. However, soil fertility is influenced by various factors, including physical and chemical properties, making its assessment complex.

This study aims to assess the current fertility status of soils in Ca Mau province by analyzing key physical and chemical properties. The findings will provide valuable information for soil management strategies tailored to the specific needs of different land use types in the region. By understanding the distribution of soil fertility levels and their influencing factors, stakeholders can make informed decisions to enhance agricultural productivity and environmental sustainability.

**2. RESEARCH METHODS**

The current soil fertility evaluation results for Ca Mau Province are based on the analysis of 238 soil samples collected from various districts within Ca Mau Province, Vietnam.

***Secondary Data Collection Methods***

Information, documents, land statistics, current land use maps, soil maps of Ca Mau Province, and specialized maps were collected from local specialized agencies and central ministries.

### ***Primary Data Collection Methods***

An investigation was conducted on 238 soil samples distributed evenly across the districts of Ca Mau Province, Vietnam.

### ***Soil Analysis Methods***

The physical and chemical properties of the 238 soil samples were analyzed using methods in accordance with Vietnamese Standards (Table 1).

[Table 1] **Methods for analyzing indicators to determine soil fertility**

<b>Targets</b>	<b>Method</b>	<b>Note</b>
Soil mechanical components	Pipette method	TCVN 8567:2010
Density	Cylindrical tube method	TCVN 6860:2001
pH	Measure with a pH meter	TCVN 5979:2007
OM total	Walkley-Black method	TCVN 8941:2011
N total	Kjeldahl method	TCVN 6498 : 1999
P <sub>2</sub> O <sub>5</sub> total	Color comparison method	TCVN 8940:2011
K <sub>2</sub> O total	Flame photometric method	TCVN 4053:1985
CEC	Amonacetate method pH = 7	TCVN 8568:2010

(TCVN : Vietnam standard)

### ***Mapping method***

Utilize MicroStation and Mapinfo software to overlay thematic maps within GIS for the creation of soil resource and fertility maps of Ca Mau province.

### ***Multi-Criteria evaluation (MCE) method***

Assess and classify soil fertility down to individual soil plots by constructing pairwise comparison matrices and determining weights. Specifically, this involves: pairwise comparison matrices for soil types and physical properties (priority order of soil type, texture, and bulk density); pairwise comparison matrices for soil chemical properties (priority order of pH, total organic matter, cation exchange capacity, total nitrogen, total phosphorus, and total potassium); and pairwise comparison matrices among indicator groups (priority order of indicators for soil types and physical properties, chemical properties).

***Data processing and synthesis method***

Use Excel software to process, analyze, and synthesize data and information relevant to the research topic.

**3. RESULTS AND DISCUSSION**

The soil texture reflects the proportion of particles of different sizes in the soil, including sand, silt, and clay. Based on this proportion, soil is classified into three main groups: light soil, medium soil, and heavy soil.

**Table 2. The mechanical composition of the soil system in Ca Mau Province, Vietnam**

<b>Classification of mechanical composition</b>	<b>Notation</b>	<b>Area (ha)</b>	<b>Ratio (%)</b>
Soil with medium mechanical composition	TPCG1	205	0,05
Soil with light mechanical composition	TPCG2	139.387	32,48
Soil with heavy mechanical composition	TPCG3	289.531	67,47
<b>Total</b>		<b>429.123</b>	<b>100</b>

The results of determining the soil texture composition in Ca Mau province show significant variability among different soil types:

- The area of soil with medium texture is 205 hectares, accounting for a very small proportion of the total surveyed area, primarily distributed in the aquaculture land of Nam Can district.

- Light-textured soil occupies the largest portion, with an area of 139,387 hectares, widely distributed in districts such as U Minh, Thoi Binh, and Dam Doi.

- Heavy-textured soil covers the largest area, with 289,531 hectares, mainly concentrated in the districts of Dam Doi, Tran Van Thoi, and U Minh.

- Light-textured soil is commonly found in aquaculture land, perennial crop land, and forestry land.

- Heavy-textured soil is mainly concentrated in rice cultivation land, forestry land, and aquaculture land.

- Medium-textured soil is typically found only in the aquaculture land of Nam Can district.

**Table 3 Bulk density of the soil system in Ca Mau Province, Vietnam**

<b>Classification of bulk density (g/cm<sup>3</sup>)</b>	<b>Evaluation</b>	<b>Notation</b>	<b>Area (ha)</b>	<b>Ratio (%)</b>
< 1,0	Soil with low bulk density (rich in organic matter)	DT1	230.131	53,63
1,0 - 1,2	Soil with medium bulk density (typical cultivated soil)	DT2	191.320	44,58
> 1,2	Soil with high bulk density (compacted soil)	DT3	7.672	1,79
<b>Total</b>			<b>429.123</b>	<b>100</b>

Soil bulk density, determined by the mass (grams) of a unit volume of soil (cm<sup>3</sup>) in its natural state after thorough drying, is a crucial indicator for assessing soil quality and physical properties. The results of this evaluation are presented as follows:

- The area of soil with low bulk density occupies a large proportion, reaching 230,131 hectares, accounting for 53.63% of the total surveyed area. The lowest measured bulk density value is 0.07 g/cm<sup>3</sup> in soil sample MD - 48, located in the saltwater shrimp farming area of Dam Doi district.

- The area of soil with medium bulk density covers 191,320 hectares, equivalent to 44.58% of the total surveyed area.

- The area of soil with high bulk density occupies a very small portion, only 7,672 hectares, representing 1.79% of the total surveyed area. The highest measured bulk density value is 1.34 g/cm<sup>3</sup> in soil samples MD - 1, MD - 13, and MD - 133.

The results of soil bulk density evaluation according to land use provide detailed insights into the variation of this index:

- Low bulk density (indicating high organic matter content) decreases progressively from aquaculture land to rice cultivation land, forestry land, perennial crop land, and other annual crop land. No low bulk density soil was recorded in salt-making land and other agricultural land.

- Medium bulk density (representing typical cultivated soil) increases progressively from salt-making land to aquaculture land.

- High bulk density (reflecting soil compaction) decreases progressively from aquaculture land to perennial crop land. No high bulk density soil was recorded in other annual crop land, forestry land, salt-making land, and other agricultural land.

**Table 4 pH of the soil system in Ca Mau Province, Vietnam**

<b>Classification of soil acidity</b>	<b>Evaluation</b>	<b>Notation</b>	<b>Area (ha)</b>	<b>Ratio (%)</b>
≥ 6.0 - ≤ 7.0	Neutral	pH1	161.497	37,63
≥ 4.0 - 5.0 and ≥ 5.0 - ≤ 6.0	Acidic and slightly acidic	pH2	188.304	43,88
< 4.0 and > 7.0	Alkaline, weakly alkaline, and very acidic	pH3	79.322	18,48
<b>Total</b>			<b>429.123</b>	<b>100</b>

The determination of pH<sub>KCl</sub> in the topsoil of Ca Mau province is a crucial indicator for assessing soil acidity. The following analysis elucidates the variability in soil acidity and the influence of specific geographical characteristics:

Soil acidity varies significantly, ranging from very acidic to alkaline levels, as illustrated by two specific soil samples:

- Soil sample MD - 227, currently used for wet rice cultivation on peat soil in U Minh district, has a very low pH<sub>KCl</sub> value of 2.79, indicating extremely high soil acidity in this area.

- Soil sample MD - 36, currently used for shrimp farming on highly saline soil in Dam Doi district, has a higher pH<sub>KCl</sub> value of 7.81, indicating the alkalinity of the soil in this area.

This analysis highlights the diversity of soil acidity in Ca Mau province, from the very acidic environment of peat soil in U Minh district to the alkaline environment of highly saline soil in Dam Doi district. The significant variability in soil acidity can affect the growth potential of plants and animals and have substantial impacts on the local ecosystem.

**Table 5 CEC content of the soil system in Ca Mau Province, Vietnam**

<b>Classification of cation exchange capacity (CEC)</b>	<b>Evaluation</b>	<b>Notation</b>	<b>Area (ha)</b>	<b>Ratio (%)</b>
≥ 25	Moderate and high	CEC1	68.877	16,05
≥ 10 - 25	Medium	CEC2	353.851	82,46
< 10	Low and very low	CEC3	6.395	1,49
<b>Total</b>			<b>429.123</b>	<b>100,00</b>

Soil cation exchange capacity (CEC) is considered a crucial indicator in soil evaluation, especially for determining fertilization regimes and soil improvement measures. High CEC levels are often associated with better soil fertility.

The determination of soil CEC levels in Ca Mau province shows notable variation, ranging from very poor to rich. For example, soil sample MD - 25, currently used for forestry combined with aquaculture on potential acid sulfate soil in Nam Can district, has a CEC value of only 4.74 cmol/kg soil. In contrast, soil sample MD - 163, currently used for aquaculture on potential acid sulfate soil in Thoi Binh district, has a CEC value of 36.10 cmol/kg soil.

The data in the table indicate that the majority of the soil area in Ca Mau province has a medium CEC level, accounting for 82.46% of the total surveyed area. Meanwhile, the area with high CEC levels only represents 16.05% of the total surveyed area in the province. This variation in soil CEC levels highlights the diversity of soil fertility in Ca Mau, providing important information for effective land management and use.

**Table 6 Total organic matter content of the soil system in Ca Mau Province, Vietnam**

<b>Classification of total organic matter content</b>	<b>Evaluation</b>	<b>Notation</b>	<b>Area (ha)</b>	<b>Ratio (%)</b>
≥ 4,0	Rich	OM1	415.273	96,77
≥ 2,0 - 4,0	Medium	OM2	13.274	3,09
< 2,0	Poor	OM3	576	0,13
<b>Total</b>			<b>429.123</b>	<b>100</b>

The total organic matter content (OM%) is an important indicator in evaluating soil fertility, as it reflects the overall organic matter present in the soil. Higher total organic matter content indicates better soil fertility, which is crucial for determining plant growth potential and supporting soil management in agriculture.

Based on field survey results and sampling, the following observations were made:

- The area with the lowest total organic matter content was recorded in the aquaculture zone on highly saline soil in Cai Nuoc district, with soil sample MD - 101 having an OM% of only 0.70%.

- Conversely, the area specialized in wet rice cultivation on peat soil in U Minh district was identified as having the highest total organic matter content, with soil sample MD - 227 showing an OM% of 11.81%.

The evaluation results of total organic matter content reveal the diverse distribution of soil fertility in Ca Mau province:

- Soil with rich total organic matter content occupies a large proportion, reaching 415,273 hectares, corresponding to 96.77% of the total surveyed area, primarily distributed in districts such as Dam Doi, Thoi Binh, and U Minh.

- Soil with medium and poor total organic matter content occupies a small proportion, accounting for 3.09% and 0.13% of the total surveyed area, respectively. These are distributed in districts such as U Minh, Dam Doi, Tran Van Thoi, Phu Tan, and Ca Mau city.

These results provide important information on the status and diversity of total organic matter content in the soil of Ca Mau province, thereby supporting sustainable and effective land management and use in agriculture and local ecosystems.

**Table 7 Total nitrogen content of the soil system in Ca Mau Province, Vietnam**

<b>Classification of total nitrogen content</b>	<b>Evaluation</b>	<b>Notation</b>	<b>Area (ha)</b>	<b>Ratio (%)</b>
≥ 0,15	Rich	N1	338.665	78,92
≥ 0,08 - 0,15	Medium	N2	89.882	20,95
< 0,08	Poor	N3	576	0,13
<b>Total</b>			<b>429.123</b>	<b>100</b>

The total nitrogen content (N%) in the soil is a crucial indicator for assessing the availability of the most essential nutrient for crops—nitrogen. However, excessively high nitrogen content in the soil can harm plants and cause soil pollution.

Based on the analysis results of total nitrogen content in the soil of Ca Mau province, the following observations were made:

- The entire area of Ca Mau province has total nitrogen content in the soil ranging from medium to rich. Soil sample MD - 234, currently used for production forestry on active acid sulfate soil in U Minh district, has a very rich total nitrogen content, with an N% value of 1.12%.

- Conversely, soil samples MD - 225, currently used for production forestry on active acid sulfate soil in U Minh district, and MD - 101, currently used for aquaculture on highly saline soil in Cai Nuoc district, have the lowest total nitrogen content, with an N% value of only 0.08%.

This result reflects the diversity and variability of nitrogen content in the soil of Ca Mau province, providing important information for sustainable land management and use in agriculture and local ecosystems.

The evaluation results of total nitrogen content in the soil offer an overview of the soil nutrient status in Ca Mau province, Vietnam. Based on specific data collected from field surveys, the following conclusions can be drawn:

- Soil with rich total nitrogen content occupies the majority of the surveyed area, with 338,665 hectares, accounting for 78.92% of the total area. This distribution is mainly concentrated in the districts of Dam Doi, Thoi Binh, and Tran Van Thoi, each with a significantly large area.

- Soil with medium total nitrogen content also occupies a considerable proportion, with 89,882 hectares, corresponding to 20.95% of the total surveyed area. The distribution of this area is mostly concentrated in the districts of U Minh, Cai Nuoc, and Dam Doi, with U Minh having the largest share.

- Although the area of soil with poor total nitrogen content is not large, only 576 hectares, it is primarily distributed in the aquaculture areas of Cai Nuoc district, indicating some limitations in nutrient supply for crops in this region.

**Table 8 Total phosphorus content of the soil system in Ca Mau Province, Vietnam**

<b>Classification of total phosphorus content</b>	<b>Evaluation</b>	<b>Notation</b>	<b>Area (ha)</b>	<b>Ratio (%)</b>
≥ 0,10	Rich	P1	211.658	49,32
≥ 0,06 - 0,10	Medium	P2	183.873	42,85
< 0,06	Poor	P3	33.592	7,83
<b>Total</b>			<b>429.123</b>	<b>100,00</b>

The total phosphorus content in the soil plays a crucial role in providing nutrients for crops, particularly for biological growth and development. The analysis results of total phosphorus content in the soil of Ca Mau province show the variation and diverse distribution of this nutrient across the topsoil area:

Considering the entire topsoil layer of Ca Mau province, the total phosphorus content ranges from poor to rich. This reflects the diversity of geographical conditions and nutritional characteristics of the province's soil.

Soil sample MD - 200, currently used for wet rice cultivation on slightly saline soil in Tran Van Thoi district, was found to have the lowest total phosphorus content, with a P2O5% value of only 0.01%. Conversely, soil sample MD - 220, currently used for Melaleuca forestry on active acid sulfate soil in U Minh district, has the highest total phosphorus content, with a P2O5% value of 0.39%.



The evaluation results of total phosphorus content in the soil provide deeper insights into the distribution and nutritional status of the soil in Ca Mau province:

- Soil with rich total phosphorus content occupies a large portion, covering 211,658 hectares, accounting for 49.32% of the total surveyed area. This is primarily distributed in districts such as Dam Doi, Ngoc Hien, Nam Can, and Tran Van Thoi.

- Soil with medium total phosphorus content also occupies a significant proportion, covering 183,873 hectares, equivalent to 42.85% of the total surveyed area. This is mainly distributed in districts such as U Minh, Tran Van Thoi, and Thoi Binh.

- Soil with low total phosphorus content is primarily concentrated in Thoi Binh district, covering 33,592 hectares.

These results highlight the diversity and distribution of phosphorus content in the soil of Ca Mau province, Vietnam, providing important information for sustainable and effective land management and agricultural practices.

**Table 9 Total potassium content of the soil system in Ca Mau Province, Vietnam**

<b>Classification of total potassium content</b>	<b>Evaluation</b>	<b>Notation</b>	<b>Area (ha)</b>	<b>Ratio (%)</b>
≥ 2,0	Rich	K1	143.634	33,47
≥ 1,0 - 2,0	Medium	K2	277.781	64,73
< 1,0	Poor	K3	7.708	1,80
<b>Total</b>			<b>429.123</b>	<b>100</b>

The total potassium content in the soil is an important indicator for evaluating the soil's ability to supply minerals to crops, particularly for resistance and development. The analysis results of total potassium content in the soil of Ca Mau province have provided diverse information and distribution across the topsoil area as follows:

- The topsoil layer of Ca Mau province shows significant variation in total potassium content, ranging from poor to rich. For instance, soil sample MD - 4, currently used for rice cultivation on active acid sulfate soil in Ca Mau city, has a poor total potassium content (K<sub>2</sub>O% = 0.75%), whereas soil sample MD - 108, currently used for perennial crops on acid sulfate soil in Cai Nuoc district, has a rich total potassium content (K<sub>2</sub>O% = 2.85%).

The evaluation results of total potassium content in the soil continue to provide a clear view of the mineral supply status for crops in Ca Mau province:

- Soil with rich total potassium content occupies a significant portion, covering 143,634 hectares, accounting for 33.47% of the total surveyed area. This is primarily distributed in districts such as Dam Doi, Cai Nuoc, Ngoc Hien, and several other areas.

- Soil with medium total potassium content also occupies a large proportion, covering 277,781 hectares, equivalent to 64.73% of the total surveyed area. This is mainly distributed in districts such as U Minh, Thoi Binh, Tran Van Thoi, and neighboring regions.

- Soil with poor total potassium content is relatively small, only 7,708 hectares, accounting for 1.80% of the total surveyed area. It is primarily found in districts such as Nam Can, Thoi Binh, U Minh, and Ca Mau city.

These results highlight the diversity and distribution of potassium content in the soil of Ca Mau province, providing important information for sustainable and effective land management and agricultural practices.

**Table 10 Soil fertility classification in the soil system of Ca Mau Province, Vietnam**

**Unit of measurement: hectares**

Types of soil	Classification of soil fertility assessment			Surveyed area
	High	Medium	Low	
Agricultural land	77.13	27.418	42.352	146.9
Forest land	16.691	40.835	635	58.161
Aquaculture land	51.132	170.783	1.949	223.864
Salt production land		80		80
Other agricultural land		118		118
<b>Total (hectares)</b>	<b>144.953</b>	<b>239.234</b>	<b>44.936</b>	429.123
<b>Composition (% of surveyed area)</b>	<b>33,78</b>	<b>55,75</b>	<b>10,47</b>	<b>100,00</b>

According to the survey data, the area of low pH soil in Ca Mau province is 44,936 hectares, accounting for 10.47% of the total surveyed land area. Districts with low pH soil include Tran Van Thoi (8,158 hectares), Phu Tan (5,695 hectares), U Minh (5,431 hectares), and Thoi Binh (5,532 hectares).

- Saline Intrusion Subzone: The area of low pH soil is 29,789 hectares, primarily consisting of various types of saline soil (11,170 hectares), slightly saline soil (7,812 hectares), and potential acid sulfate soil (7,331 hectares). These types of soil are mainly used for perennial crops and agroforestry.

- Freshwater Intrusion Subzone: The area of low pH soil is 10,963 hectares, mainly comprising deep acid sulfate soil (5,532 hectares) and slightly saline soil (4,250 hectares). These types of soil are primarily used for perennial industrial crops and other perennial crops.

- Freshwater Swamp Subzone: The area of low pH soil is 4,184 hectares, all concentrated

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on deep acid sulfate soil, scattered in distribution, and primarily used for perennial industrial crops and other perennial crops.

***Characteristics and Classification of Land Resources***

The land resources of Ca Mau province are divided into 6 groups comprising 12 types of land. Within the scope of the project, there are 4 groups of land with 10 types, wherein saline land and saline-affected land occupy the majority of the area (over 90% of the province's natural area).

- Alluvial Land Group: There is only 1 unit of land, distributed in strips parallel to the western coast and the Cape of Ca Mau (Nam Can and Ngoc Hien districts).

- Saline Land Group: Consists of 4 units including submangrove saline land, highly saline land, moderately saline land, and slightly saline land.

- Submangrove saline land is distributed along the western coastline in U Minh, Tran Van Thoi, and Phu Tan districts.

- Highly saline land is most prevalent in the shrimp farming transition zone in Dam Doi, Cai Nuoc, Phu Tan, Thoi Binh, Cà Mau City, and along the narrow strip adjacent to the Cua Lon River in Nam Can and Ngoc Hien districts.

- Moderately saline land is concentrated in the southern region of the Doi River; most abundant in Tran Van Thoi, Cai Nuoc, and the southern part of Cà Mau City, and less abundant in Thoi Binh.

- Slightly saline land is mainly distributed in elevated terrain from Thoi Binh district to Cà Mau City, in high bank arcuate shapes in Tran Van Thoi district, or in natural levees along the Cai Tau and Trem rivers.

- Acid Sulfate Soil Group: Divided into 2 subgroups: potential acid sulfate soil and active acid sulfate soil, with 4 detailed units: potential acid sulfate non-agricultural land, potential acid sulfate deep land, active acid sulfate non-agricultural land, and active acid sulfate deep land.

- Potential acid sulfate non-agricultural land is most abundant in Ngoc Hien, Nam Can, and Phu Tan.

- Potential acid sulfate deep land is most abundant in Thoi Binh, Nam Can, and Dam Doi.

- Active acid sulfate non-agricultural land is most abundant in U Minh, Thoi Binh, scattered in Tran Van Thoi, Cà Mau City, Phu Tan, Dam Doi, and Cai Nuoc.

- Active acid sulfate deep land is most abundant in Thoi Binh, U Minh, Cà Mau City, scattered in Tran Van Thoi, and Dam Doi.

- Peat Soil Group: There is only 1 unit, which is peat mud soil, mainly distributed in the mangrove forest area in the southern part of U Minh district and the northern part of Tran Van Thoi district.

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***Soil Characteristics and Fertility Levels***

Soils in Ca Mau exhibit acidity, with the surface soil layer having a heavy mechanical composition, accounting for 67.47% of the surveyed area. Areas with high fertility levels are primarily concentrated in deeply buried potential acid sulfate soil, actively acidic sulfate soil, and moderately saline land, mainly utilized for mangrove forestry, rice-shrimp farming, and partially for rice cultivation, predominantly found in Thoi Binh, U Minh, and Tran Van Thoi.

Areas with medium fertility levels are mostly found on highly saline land, potential acid sulfate non-agricultural land, and active acid sulfate non-agricultural land, mainly used for forestry, aquaculture, rice-shrimp farming, and located in Dam Doi, Ngoc Hien, Cai Nuoc, and Phu Tan.

Areas with low fertility levels are predominantly found on slightly saline land, potential acid sulfate non-agricultural land, and active acid sulfate non-agricultural land, mainly utilized for mangrove forestry, afforestation, and distributed in Tran Van Thoi, Phu Tan, U Minh, and Thoi Binh.

**4. CONCLUSION**

The comprehensive analysis of physical and chemical characteristics undertaken in this study provides valuable insights into the fertility status of the soil system in Ca Mau Province, Vietnam. Through meticulous examination of soil texture composition, bulk density, pHKCl, cation exchange capacity (CEC), total organic matter content, and concentrations of essential nutrients such as nitrogen, phosphorus, and potassium, a detailed picture of soil fertility and variability across different land use types emerges.

The findings underscore the diverse nature of soil fertility within Ca Mau Province, reflecting the intricate interplay between geological, geographical, and anthropogenic factors. The predominance of medium-textured soil and low bulk density, particularly in aquaculture areas, indicates favorable conditions for agricultural productivity in these regions. Conversely, the presence of heavy-textured soil and high bulk density in rice cultivation areas suggests potential challenges in soil management and crop production.

The variation in soil acidity levels, from very acidic to alkaline, highlights the need for targeted soil amendment strategies to optimize agricultural productivity while mitigating environmental risks. Furthermore, the significant differences in CEC levels and total organic matter content underscore the importance of soil management practices aimed at enhancing soil fertility and sustainability.

By elucidating the distribution and characteristics of essential nutrients such as nitrogen, phosphorus, and potassium, this study provides valuable guidance for informed decision-making in agricultural practices, land management, and ecosystem conservation efforts. The identification of areas with nutrient deficiencies or imbalances serves as a basis for implementing targeted fertilization regimes and soil improvement measures to enhance agricultural productivity and promote sustainable land use practices.

Overall, the findings presented in this study contribute to a deeper understanding of soil fertility dynamics in Ca Mau Province and provide a scientific basis for the development of

evidence-based soil management strategies tailored to the diverse agricultural landscapes of the region. Through continued research and collaborative efforts between scientists, policymakers, and local stakeholders, it is possible to foster resilient agricultural systems that support food security, environmental sustainability, and socio-economic development in Ca Mau Province and beyond.

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