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RESEARCH ARTICLE

Soil constraints and recommendations for improving major farming in Vinh Long province, Vietnam

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Abstract

This study aims to assess the potential of soil and its constraints for production to meet economic needs and diversify types of crop models of Vinh Long province in the Vietnamese Mekong Delta region. Identifying the main constraints of the soil is the basis for reasonable land arrangement and proposing measures to maintain and improve the soil characteristics suitable for each crop type and purpose of use. The study used survey methods, interviewed farmers about the current farming situation and collected soil samples to analyze physical and chemical properties. Research results show that in Vinh Long, for three main crops, namely rice, fruit trees (grapefruit trees) and sweet potatoes, the primary constraints are a potential and active acid sulfate and low pH soil. In addition, Al toxicity causes phosphorus fixation, the exchangeable K content is low and the organic matter is only moderate. These limitations have affected crop productivity, especially for fruit trees. The research results also recommended improving soil properties suitable for the cultivation of major crops, including controlling the water level so as not to oxidize the sulfidic material to active acid sulfate soils, draining the water at the beginning of the season rain to leach the toxicity in the soil and need to fertilize with nitrogen, phosphorus and potassium supplements for a long time, divided into several times of application.

Keywords

constraints; improvement; soil resources; sustainability

Introduction

In the Southern region of Vietnam (or the Vietnamese's Mekong Delta), crop cultivation is usually irrigated and highly productive, featuring multiple rice crops. However, it also faced severe problems, including the unsustainable exploitation of water and soils, inefficient use of chemical inputs and emerging or worsening disease and pest problems. The intensive cultivation that increased pressure on land led to the degradation and pollution of soils, which caused a partial or complete loss of its productive capacity (1). According to Xuan and Matsui (1998) (2), the area of acid-sulfate soil in Vietnam is 1,866,500 ha, accounting for 5.5% of the total land area in the country, occupying about 1.6 million ha (40%) distributed mainly in Dong Thap Muoi, Long Xuyen Quadrangle, Hau River and part of Ca Mau Peninsula of Mekong Delta. Besides, saline soil covers 0.74 million ha, accounting for about 19% of the total land area of the Mekong Delta. In which the group of saline soils is considered the most difficult in agricultural production in general and rice production in particular.

According to the Vinh Long Department of Natural Resources and Environment (3), Vinh Long is located in the central area of the Mekong Delta, not

bordering the sea, with many favorable conditions regarding nature, economy and society, creating favorable conditions for development. Vinh Long province has developed different farming models, especially for cultivation. In recent years, the province's exploitation of land resources has undergone many changes to maximize the land's potential, meet economic needs and diversify the types of crop models of the region. Promoting the exploitation of the potential of land for agricultural purposes has caused many problems with the land, the rotation of crops to increase crops, the introduction of crops into the field is encouraged to develop and some areas are specialized in cultivation. Continuous rice crops in the year and the farming regime of farmers using a lot of chemical fertilizers, pesticides in high doses, dried sowing, burning straw after harvesting, exploiting clay for raw materials, replacing change from rice-growing land to fruit-growing land. It has caused the soil to change the morphology of the soil profile, increasing the risk of soil degradation, decreasing fertility and appearing to be a constraint for plants.

Several studies support that the fundamental soil constraints limiting plant growth and development include high permeability, soil crusting, sub-surface mechanical impedance and soil hardening (4-6). Mitigating significant soil physical problems that limit crop growth and development is vital for enhancing agricultural production and maintaining soil health (7 -9). Incorporating organic amendments (*Sesbania spp*, farmyard manure, crop residue, etc.) reduced the N requirement and improved the soil sub-surface mechanical impedance under the rice-wheat cropping system (7, 10).

The study aims to evaluate and identify the main constraints of soil factors that affect the development of major crops, thereby proposing effective remedial measures for adequate and suitable soil improvement in Vinh Long province.

Materials and Methods

Study area

Vinh Long has a total natural area of 1,525.73 km^2, accounting for 3.74% of the area of the Mekong Delta. Vinh Long province belongs to a plain topography that is relatively flat. The slope is less than 5°. The province's terrain is spread along the Tien, Co Chien and Hau Rivers. It is located in the central region of the Mekong Delta towards the lower reaches of the Mekong River and between the Tien and Hau Rivers. This province has an early and diversified agricultural development compared to other areas in the Mekong Delta. The province's total agricultural land area is 120490.1 ha, accounting for 78.97% of the province's total natural land area. According to land use type, the province's agricultural land is divided into rice, perennial, annual, aquaculture and other agricultural land. With nearly 50000 hectares of land for perennial crops, Vinh Long has much potential to develop fruit trees such as oranges, pomelos, longans and rambutans and bring high-income values to farmers in the province. However, in recent years, saline intrusion and excessive pesticide use have changed perennial crop soil properties (3). The study area location is shown in Fig. 1.

Methods of synthesizing secondary data:

Collecting data and maps on natural conditions, current status, the potential of resources and land distribution for agricultural development of the province at agencies. Vinh Long Department of Natural Resources and Environment, Vinh Long Department of Agriculture and Rural Development and Department of Land Resources, College of Environment and Natural Resources, Can Tho University.

Methods of soil sampling and analysis:

Collecting soil profile data and soil analysis results of survey sites from Vinh Long Provincial Technical Center for Natural Resources and Environment. Describe the soil profile morphology, take soil samples for analysis according to the survey manual (11) and combine them with documents describing field soils according to the Guidelines for Soil Profile description of FAO-UNESCO (12).

Soil survey was conducted according to the Soil Evaluation and Classification Manual and the Guidelines for Soil Profile Description (12). According to the instruction document, the profile was excavated and described in detail and soil samples were analyzed according to the generation layer. Soil samples were taken; bulk density samples were taken from the topsoil layer and the layer adjacent to the topsoil layer.

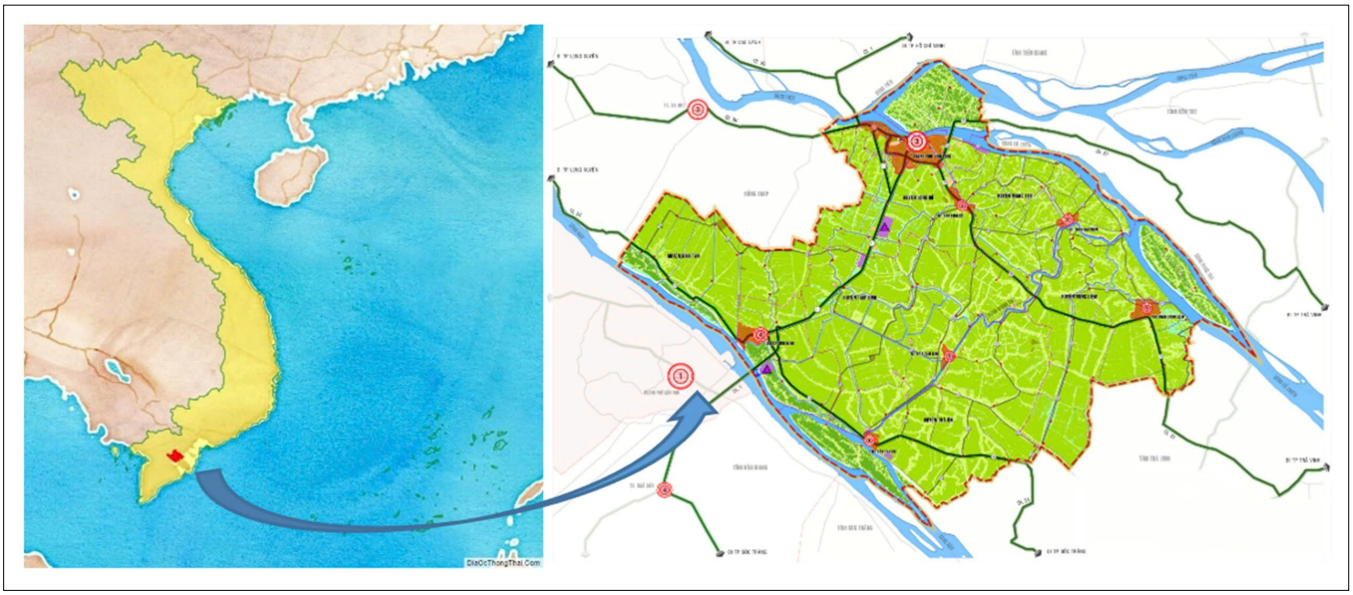

Fig. 1. Map of the study area (Vinh Long province) in Viet Nam.

A total of 20 major profiles were taken according to the phylogenetic layer and 120 profiles were sampled from 0 to 20 cm deep, from 20 to 50 cm below the soil surface.

Accordiing the Vietnamese standard (TCVN 8567:2010). Soil samples were taken to analyze the electrical conductivity (EC); pH_{H2O}, pH_{KCl}; organic matter (OM); Cation Exchangeable Capacity (CEC); total nitrogen (N); phosphorus (P); Potassium (K); and exchange K^+. The soil was analyzed at the laboratory of Can Tho University.

Three main crops were identified, including rice, fruit trees (grapefruit) and sweet potatoes, to assess soil constraints based on the soil data collected and analyzed.

Data processing

The collected soil's physical and chemical properties data were analyzed, synthesized, compared and evaluated about crops, identifying the soil's hindering factors and proposing recommendations to improve crop cultivation. Descriptive statistical analysis was applied.

Results and Discussion

Status of major crops in Vinh Long province

The results in Fig. 2 show that the largest rice land area is 69255 ha (accounting for 45.4%), with 2 or 3 crops per year. They were mainly concentrated in low-lying, flooded and embanked areas. The sowing time is relatively uniform. Rice cultivation is concentrated in the Tam Binh, Tra On, Vung Liem, Long Ho, Mang Thit and Binh Minh districts. As a result, productivity and output increased significantly, meeting the province's food demand and ensuring national food security.

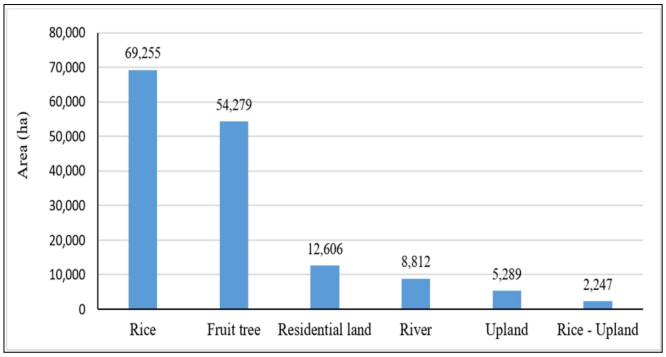

Fig. 2. Land uses map distribution in Vinh Long province *(Source: Vinh Long Department of Natural Resources and Environment, 2021).*

Meanwhile, the area of fruit trees is 54279 ha (accounting for 35.6%), such as mangosteen, green-skinned pomelo, earthen orange, durian, pomelo, mango, rambutan, longan pepper, distributed in the region. It is located along the Tien and Hau rivers, a small part of Binh Tan and Binh Minh districts and other main rivers, canals and waterways with home gardens. For crops, the main crops are sweet potatoes, watermelons, soybeans, broccoli, okra, spinach, peppers, etc. Because different plants' growth times differ, the cropping pattern is unstable. After harvesting, leave the soil to rest for about 5-10 days, then continue sowing. Concentrate on scattered districts where there is enough water for irrigation and crops.

Table 1 shows that rice changes in both area, output and yield, but only a little between seasons of the year due to favorable weather conditions, less waterlogging and less rain and storms; rice is highly suitable.

As for sweet potato, which belongs to the group of crops in the division of crops of the province, it is the second largest crop in the group of crops (25% with 13744.8 ha) and is the province's main crop. Binh Tan district is home to the largest sweet potato area, accounting for 94.84% of the whole province, mainly the area of purple sweet potato. On the other hand, only the Mang Thit district has no sweet potato growing region in the entire province (Table 2).

Besides, citrus fruit trees, due to their many advantages in soil and weather, are the main perennial crops of the province, typically pomelos. It concentrated mainly in Binh Minh, with 5 Roi pomelo as the main variety, accounting for 23% of the area compared to other districts in the province (Table 3).

Soil properties of the major crops in Vinh Long Province

The results of soil chemical analysis for the three main crops of Vinh Long province are presented in Table 4.

For rice: The appropriate range of variation for rice to grow in each evaluation criterion has been determined based on the analysis results and the adaptation requirements. The results of assessing the adaptability or suitability requirements of rice are presented in Table 4. It shows that most of the soil in Vinh Long has many constraints for rice, such as low pH, low OM, P and K^+

Table 1. Area (ha), yield (ton/ha) and production (ton) of Dong Xuan rice by District in Vinh Long province *(Source: Vinh Long Statistical Office. 2017)*

		Vinh Long city	Long Ho	Mang Thit	Binh Minh	Binh Tan	Tam Binh	Tra On	Vung Liem	total
Winter Spring	Area (ha)	379.0	6,455.0	6,673.0	3,130.0	3,758.0	15,443.0	10,026.0	13,124.0	*58,988.0*
	Yield (t/ha)	4.8	5.8	5.9	6.0	6.4	6.1	5.9	6.0	*47.0*
	Production (ton)	1,834.4	37,697.2	39,637.6	18,748.7	23,976.0	93,739.0	59,053.1	79,269.0	*353,955.0*
Summer Autumn	Area (ha)	312.0	6,230.0	6,553.0	2,876.0	2,879.0	14,766.0	9,467.0	12,754.0	*55,837.0*
	Yield (t/ha)	4.5	5.4	5.3	4.2	5.4	5.9	5.5	5.6	*41.7*
	Production (ton)	1,407.1	3,370.4	34,534.3	12,136.7	15,402.7	869,717.0	51,595.2	71,167.3	*276,585.4*
Autumn Winter	Area (ha)	317.0	5,923.0	6,079.0	2,545.0	3,803.0	14,376.0	9,181.0	12,346.0	*54,570.0*
	Yield (t/ha)	4.7	5.1	5.0	5.1	5.2	5.5	5.0	5.0	*40.6*
	Production (ton)	1,493.1	30,266.5	30,455.8	13,030.4	19,813.6	78,493.0	45,721.4	61,976.9	*281,250.7*

Table 2. Area (ha), yield (ton/ha), production (ton) of sweet potato by the district in Vinh Long province *(Source: Vinh Long Statistical Office. 2017)*

	Vinh long city	Long Ho	Mang Thit	Binh Minh	Binh Tan	Tam Binh	Tra On	Vung Liem	total
Area (ha)	16.2	2.5	_	430.5	13,063.9	236.6	22.2	2.9	*13,774.8*
Yield (t/ha)	242.4	246.2	_	262.5	259.7	265.7	268.9	241.2	*1,786.5*
Production (ton)	3,926.9	615.5	_	113,006.3	3,392,694.8	62,864.6	5,969.6	699.5	*3,579,777.1*

Table 3. Area (ha), yield (ton/ha) and production (ton) of pomelo trees by District in Vinh Long province (*Source: Vinh Long Statistical Office. 2017)*

	Vinh Long city	Long Ho	Mang Thit	Binh Mnh	Binh Tan	Tam Binh	Tra On	Vung Liem	Total
Area (ha)	170.9	430.4	872.8	2,029.7	541.6	1,681.7	1,263.0	1,989.7	8,979.8
Yield (t/ha)	10.12	9.9	9.2	10.8	9.6	8.7	10.0	8.2	76.6
Production (ton)	1,729.5	4,278.2	8,055.9	21,859.9	5,215.6	14,681.2	12,604.7	16,295.6	84,720.7

Table 4. Analytical results of chemical parameters of different major crops in Vinh Long province (Source: Vinh Long Department of Natural Resources and Environment, 2021)

Crops		Soil properties							
		$pH_{(H20)}$	EC	CEC	OM	N	P	K	K^+
			ms/cm	meq/100g	%	%	%	%	meq/100g
Paddy	Average	4.64	0.93	18.30	6.18	0.40	0.05	2.28	0.04
	Suitability requirements	*5.5-7.5*	*<2*	*7 - 30*	*>4*	*0.1-0.5*	*>0.1*	*>1.5*	*0.25-1.3*
Fruit crops	Average	4.89	0.18	13.13	2.42	0.23	0.05	1.89	0.05
	Suitability requirements	*5.5-7.0*	*<0.4*	*5-30*	*>3*	*0.1-0.5*	*>0.1*	*>1.5*	*0.23-1.3*
Sweet Potatoes	Average	4.64	0.67	13.31	2.61	0.26	0.03	2.03	0.05
	Suitability requirements	*4.5-7.5*	*<05*	*5-30*	*>3*	*0.1-0.2*	*>0.1*	*>1.5*	*0.3-1.3*

composition. Therefore, although rice plants can still grow and develop, it will limit microbial activity and the availability of nutrients will be low.

For fruit trees: As for the soil for growing fruit trees in Vinh Long province, mixed root crops are mainly grown. The results of soil characterization with soil characterization constraints showed that most of the soil properties such as pH, OM, N, P and K^+ have limited values for the growth of fruit trees, especially soil with low pH, low content of P, K, organic matter, N. However plants can still grow well. Still, they must invest in providing more nutrients (13).

For sweet potatoes: The survey data found that most of the soil for growing Sweet potatoes in Vinh Long had low OM, P and K content and similarly low for N. When the content was If OM is low, nutrients such as N, phosphorus and potassium will also be low (14).

Recommendation for suitable major crop development

Based on the results of determining soil chemical constraints for main crops in Vinh Long province, appropriate measures are proposed to improve soil properties and serve better in farming on the main soil groups in the province.

Improve acidity problems: Acidic soils with low pH often contain many toxic substances, such as Fe and Al. Therefore, it is necessary to apply measures to wash the soil with fresh water and apply lime to increase pH (15).

Improve phosphorus deficiency (P): This problem often occurs in active acid sulfate soils. Al, Fe and low pH quickly fix phosphorus. Therefore, it is necessary to provide phosphorus in the form of phosphate and super phosphorus, fertilize in rows or holes, mix with the soil and apply fertilizer for a long time, maintain annual fertilization and choose rice varieties with short growth time (16).

Improve the soil with low exchangeable potassium (K): Additional potassium from plant residues, organic fertilizers and chemical fertilizers is needed to provide the soil with low exchangeable potassium (K). Among them, chemical fertilizers provide the most considerable amount of potassium. For rice, many experiments with K fertilizer application on soil in the Mekong Delta showed that K fertilizer has little effect on increasing yield. Still, each harvest of 5 tons/ha, rice plants absorb from the soil, on average, about 150 kgK_2O/ha. The soil will likely be degraded if additional K fertilizer is not provided to compensate for this deficiency (17). For rice, adequate K fertilizer application will reduce the possibility of rice fell down, creating conditions for less nitrogen fertilizer (15).

Improve the soil with low organic matter: Apply organic fertilizers to enhance nutrients (18, 19). Combined with balanced NPK fertilizer application in each area based on experimental practice. The fertilizer should be divided several times to avoid leaching. The CEC of the soils was closely related to their organic C contents (20). Additional organic fertilizers should be applied to increase soil CEC (21).

Improve the soil with low N content: can be supplemented with chemical and organic fertilizers (18). Plants quickly absorb chemical fertilizers but are susceptible to pests and diseases due to excessive spraying (22). They can be used in forms such as NH_4Cl, NH_4NO_3, $(NH_4)_2SO_4$ and organic fertilizer. The effect is slow but will increase nutrients, create porosity and fewer pests such as cattle manure and chicken manure, or can be from animal and plant residues (19).

According to the collected data and references for crop cultivation, after analyzing and assessing the soil constraints affecting crops, the study area has many advantages in agriculture, especially cultivation. Still, it needs to work on using and cultivating how to properly manage the soil because each crop type has a different adaptation range on the same land area. Synthesizing certain constraints for the main crops in the province and providing solutions to improve efficiency are shown in Table 5.

Conclusion

The main crops in Vinh Long, such as rice, sweet potatoes and fruit trees, tend to increase in output and area, especially fruit trees, due to their high economic value. As a result, short-term varieties resistant to pests, diseases, acid and toxicity are increasingly being used to replace local varieties.

All three crops, including rice, fruit trees and sweet potatoes, have low pH problems, leading to acidic soil, causing Al^{3+} toxicity and plants not absorbing nutrients. Soil properties, ranging from acidic to very acidic, affect plants' growth and

Table 5. Constraints and recommendations for major crops development in Vinh Long

Major crops	Constraints	Recommendations
Rice	$pH_{(H2O)}$: acidic soil is difficult for plants to absorb nutrients.	Apply lime and wash the soil with fresh water.
	OM: low, low nutrient supply	Apply organic fertilizers (buffaloes, chickens) or use animal and plant residues.
	P: Fixed, plants cannot absorb and there is a lack of phosphorus.	Apply phosphate fertilizers in chemical form (superphosphate, NPK, DAP) or organic fertilizers.
	K^+: lack of metabolic potassium	Apply chemical fertilizers (NPK) or organic fertilizers.
Fruit trees (Grapefruit)	$pH_{(H2O)}$: acidic soil is difficult for plants to absorb nutrients.	Apply lime and wash the soil with fresh water.
	CEC: low, poor nutrient metabolism	Apply Ca, Mg, N, K, or organic fertilizer.
	OM: low, low nutrient supply	Apply organic fertilizers (buffaloes, chickens) or use animal and plant residues.
	N: nitrogen deficiency affects plant growth.	Chemical fertilizers (NH_4NO_3, $(NH_4)_2SO_2$) or organic fertilizers (buffaloes, chickens) should be applied, or plant and animal residues should be made use of.
	P: fixed, plants cannot absorb, lack of phosphorus	Apply phosphate fertilizers in chemical form (superphosphate, NPK, DAP) or organic fertilizers.
	K^+: lack of metabolic potassium	Apply chemical fertilizers (NPK) or organic fertilizers.
Sweet potato	$pH_{(H2O)}$: acidic soil is difficult for plants to absorb nutrients.	Wash the soil with fresh water.
	CEC: low, poor nutrient metabolism	Apply Ca, Mg, N, K, or organic fertilizer.
	OM: low, low nutrient supply	Apply organic fertilizers (buffaloes, chickens) or use animal and plant residues.
	N: nitrogen deficiency affects plant growth.	Chemical fertilizers (NH_4NO_3, $(NH_4)_2SO_4$) or organic fertilizers (buffaloes, chickens) should be applied, or plant and animal residues should be made use of.
	P: fixed, plants cannot absorb, lack of phosphorus	Apply phosphate fertilizers in chemical form (superphosphate, NPK, DAP) or organic fertilizers.
	K^+: lack of metabolic potassium	Apply chemical fertilizers (NPK) or organic fertilizers.

development. Total P and exchangeable K are deficient. For rice, in addition to constraints in low pH, P and K^+, there are also constraints in organic matter. There were constraints in low organic matter and N for fruit trees and sweet potatoes, but little impact. It does not generally cause many problems; adding small amounts and focusing on overcoming constraints in pH and mineral nutrients will improve CEC, OM and N.

The study proposed the recommendation to effectively and sustainably use soil for farming. It is necessary to control the water level, prevent oxidizing sulfidic materials into active acid sulfate soils, drain water at the beginning of the rainy season to wash away toxins in the soil and fertilize N, phosphorus and supplement potassium for a long time, divided into several times of application, as recommended.

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Authors' contributions

ES participated in the design of the study and performed the statistical analysis. FG conceived of the study and participated in its design and coordination. MT participated in the alignment. FG conceived of the study and participated in its design and coordination. AB carried out the studies, participated in field data collection.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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