ASSESSMENT OF SOIL PHYSICOCHEMICAL PROPERTIES IN PRIMARY VEGETABLE CROP AREAS OF THE MEKONG RIVER

Nguyen Thi Phuong
Dong Thap University

ARTICLE INFO

Received: 04/01/2025
Revised: 29/6/2025
Published: 29/6/2025

KEYWORDS

Organic matter
Soil structure
pH index
Soil texture
Vegetable crop cultivation

ABSTRACT

Vegetable crops account for a large portion of the total agricultural area in the Mekong Delta. Over time, the quality of soil can be changed, so it is necessary to assess the primary physico-chemical soil properties in these cultivations. In some areas where vegetables have been cultivated continuously for many years (over 10 years), soil samples were collected in depth of 0-20 cm to analyze soil properties such as structural aggregation, soil texture, pH, and organic matter content. Research results indicate that pH values fluctuated from acidic to slightly acidic. The organic matter content was evaluated as poor. Soil textures are predominantly composed of clay particles. Structural aggregate stability varies according to the cultivation area, with the highest stability found in vegetable-growing soil in Long My district, and the lowest overall in Lap Vo district. Overall, the soil quality tends to adversely affect vegetable crop cultivation, hearby people need to supplement with organic fertilizers or return plant residues to help stabilize cultivation for subsequent crops.

ĐÁNH GIÁ ĐẶC TÍNH LÝ HÓA HỌC ĐẤT TRÊN MỘT SỐ VÙNG TRỒNG RAU MÀU KHU VỰC ĐỒNG BẰNG SÔNG CỬU LONG

Nguyễn Thị Phương
Trường Đại học Đồng Tháp

THÔNG TIN BÀI BÁO

Ngày nhận bài: 04/01/2025
Ngày hoàn thiện: 29/6/2025
Ngày đăng: 29/6/2025

TỪ KHÓA

Chất hữu cơ
Cấu trúc đất
pH đất
Sa cấu đất
Canh tác rau màu

TÓM TẮT

Cây rau màu chiếm một phần lớn diện tích đất nông nghiệp ở vùng Đồng bằng sông Cửu Long. Qua thời gian, chất lượng đất có thể bị thay đổi, vì vậy cần phải đánh giá các thuộc tính vật lý - hóa học của đất trong những vụ trồng này. Ở một số vùng mà cây rau/màu đã được trồng liên tục trong nhiều năm (trên 10 năm), mẫu đất đã được thu thập ở độ sâu 0-20cm để phân tích các đặc tính của đất như độ bền đoàn lạp, thành phần cơ giới đất, pH và hàm lượng chất hữu cơ. Kết quả nghiên cứu cho thấy giá trị pH dao động từ chua đến hơi chua. Hàm lượng chất hữu cơ được đánh giá là nghèo. Sa cấu đất chủ yếu là đất sét. Độ bền đoàn lạp của đất thay đổi tùy theo vùng canh tác, đất có độ bền cao nhất là đất rau màu tại huyện Long Mỹ-Hậu Giang và thấp nhất là tại huyện Lấp Vò-Đồng Tháp. Nhìn chung, chất lượng đất có xu hướng ảnh hưởng bất lợi cho canh tác rau, màu do đó người dân cần bổ sung thêm phân hữu cơ hoặc trả lại các dư lượng cây trồng để giúp ổn định canh tác cho các vụ sau.

DOI: https://doi.org/10.34238/tnu-jst.11812

Email: ntphuong@dthu.edu.vn

1. Introduction

The Mekong Delta (MKD) is an area blessed with favorable natural conditions for agricultural production, spanning nearly 4 million hectares of natural land. However, in recent years, the demand for food and agricultural products has been steadily increasing [1]. Consequently, there has been a growing trend of intensive farming models to meet both domestic and export food demands [2].

The expansion of intensive farming systems, including continuous rice cultivation, rice–vegetable rotations, and monoculture vegetable production, in combination with the limited use of organic fertilizers, has significantly contributed to soil degradation. This degradation is characterized by increased soil compaction and weakened structural integrity, which constrain root development. Moreover, reduced water retention capacity and limited soil aeration further impair the physical condition of the soil. Collectively, these factors result in a notable decline in crop productivity [3].

The application of farming practices such as monoculture, intensive cropping, and the excessive use of various types of chemical fertilizers, pesticides, and dike systems over an extended period has led to multiple negative consequences. These include the depletion of the soil's natural fertility, a decline in soil quality and productivity, and a reduction in biodiversity [4]. Moreover, changes and inconsistencies in soil preparation or land management measures have also affected the fluctuations in [5]. The commonly applied farming techniques by farmers, such as dry plowing, increasing mechanization, and the application of inorganic fertilizers, have led to negative changes in the physical and chemical soil properties. This has resulted in nutrient depletion, soil acidification, soil exhaustion, decline of crop productivity and a hindrance to the sustainable development of the agricultural sector in the region [6].

However, there have been rarely comprehensive surveys and analyses of the physicochemical characteristics of the cultivated soils in several intensive vegetable crops of the MKD region. Therefore, this paper aims to evaluate some indicators of soil physical and chemical properties in vegetable cropping areas of the MKD.

2. Materials and methods

2.1. Soil sample collection

Soil samples were collected from June to November 2023 (after harvest) from vegetable crop fields. The samples were collected in five positions from each experimental field at depth of 0 - 20 cm by using a metal core (Figure 1). Thereafter, five soil samples for fields were mixed to make a final sample. The selected soil sampling areas are regions with large vegetable cultivation areas in the province, including Lap Vo district in Dong Thap province (Lap Vo-Dong Thap), Vinh Hung district in Long An province (Vinh Hung-Long An), Binh Minh district in Vinh Long province (Binh Minh-Vinh Long), Cai Lay district in Tien Giang province (Cai Lay-Tien Giang), My Xuyen district in Soc Trang province (My Xuyen-Soc Trang), Cho Moi district in An Giang province (Cho Moi-An Giang), Binh Thuy district in Can Tho city (Binh Thuy-Can Tho), Cau Ke district in Tra Vinh province (Cau Ke-Tra Vinh), and Long My district in Hau Giang province (Long My-Hau Giang). Each cropping region, there were 15 soil samples collected. A total of 135 soil samples of vegetable crops were collected in this report.

Figure 1. *Soil sample collection in crop fields*

All sampled soils were air-dried except bulk density, passed through a 2 mm sieve for analysis of the different chemical properties of the soil. For the soil samples analyzed for structural aggregable stability, they were air-dried, crushed, and sieved by filter rail of 8mm, 2mm, 1mm, 0.5mm diameter, respectively.

2.2. Measurement of soil physico-chemical properties

The pH of the soil samples were measured with the pH meter, using a soil to water ratio of 1:5 for pH value [7], [8]. All soil samples were collected and analyzed for soil texture through a measurement of Robinson [9]. Soil organic matter (% C) was measured by Walkley- Black method [10]. Stability quotient (SQ) of soil structure is determined using the dry sieve and wet sieve method according to the procedure of Ghent University, Belgium. The method is based on the fact that the initial aggregate size distribution is compared to the final distribution of the material being subjected to well defined and reproducible forces [11], [12]. The soil structural SQ of major soil group can initially be grouped into 03 classes: low (<60), moderate (60-85), and high (> 85) [13]-[15].

2.2.3. Statistical analysis

All soil samples were carried out at the laboratory. Microsoft Excel version 365 was used to analysis and calculate data. Data was analyzed using Analysis of Variance (ANOVA) in a Completely Randomized Design framework. Differences between means were evaluated using the Duncan test ($P < 0.05$). All statistical analysis was carried out using SPSS software version 22.0.

3. Result and Discussion

3.1. pH

The pH analysis results of the soil are presented in Table 1, showing that the pH ranged from 4.0 to 6.0 and differed significantly ($p < 0.05$) in the following order: Lap Vo-Dong Thap/ Vinh Hung-Long An/ Binh Minh-Vinh Long/ Long My-Hau Giang < Cai Lay-Tien Giang/ Cho Moi-An Giang < Binh Thuy-Can Tho < Cau Ke-Tra Vinh/ My Xuyen-Soc Trang. The high pH values that were statistically significantly different from other areas in the study ($P < 0.05$) were in My Xuyen-Soc Trang and Cau Ke-Tra Vinh. However, these pH values for vegetable crops were lower than the optimal pH range for vegetable crops, with the optimal range being 6 to 7 [12].

In addition, soils with a pH below 4.5 can be unfavorable for the growth and development of crops, because it could lead to less available nutrients and reduced activity of beneficial microorganisms. In addition, Ganeshamurthy [16] found that when soil pH reaches 5.0 or lower, aluminum, iron manganese, and/or zinc solubility in soil solution becomes toxic to most vegetable crops.

Table 1. *Primary soil properties of vegetable crops in Mekong Delta*

Region	pH_{H2O}	OM (%C)	% Sand	% Silt	%Clay	Soil Texture	SQ
Lap Vo - Dong Thap	4.1^{d}	1.3^{e}	5.0	56.0	39.0	Silty Clay loam	43.0^{f}
Vinh Hung - Long An	4.0^{d}	1.2^{e}	23.5	55.5	21.0	Silt Loam	70.0^{e}
Cai Lay - Tien Giang	4.3^{cd}	1.8^{cd}	8.0	37.0	55.0	Clay	113.9^{b}
Binh Minh - Vinh Long	4^{d}	4.0^{b}	7.0	48.0	45.0	Silty Clay	86.0^{d}
Binh Thuy - Can Tho	5.2^{b}	4.9^{a}	9.0	38.5	52.5	Clay	114.9^{b}
Long My - Hau Giang	4.1^{d}	4.2^{b}	5.0	44.0	51.0	Silty Clay	145.0^{a}
Cho Moi - An Giang	4.7^{c}	1.9^{c}	10.0	37.0	53.0	Clay	90.0^{c}
My Xuyen - Soc Trang	6^{a}	1.6^{de}	10.0	43.0	47.0	Silty Clay	91.8^{c}
Cau Ke - Tra Vinh	5.9^{a}	2.1^{c}	13.0	37.0	50.0	Clay	113.9^{b}

Note: Means followed by same letter along columns for each region were not significantly different at 5% level

Based on the results, the pH values at all vegetable crop cultivation fields in the Mekong Delta mostly tend to be low. With a pH range of 4.0 - 4.7, the soil pH in the vegetable-growing provinces of Dong Thap, Long An, Tien Giang, Vinh Long, Hau Giang and An Giang is lower than the threshold suitable for vegetable growth. Therefore, farmers should supplement with lime, organic

fertilizer, and balanced chemical fertilizers during farming. It is not recommended to use ammonium sulfate (SA) or sulfur-containing chemical fertilizers, which can easily cause acidification of the soil. This is caused by the release of H^+ ions from plant roots and the accumulation of H^+ ions from various chemical and biological processes in the soil [17], [18].

3.2. Soil organic matter

The organic matter content in the soil of the vegetable crops across different regions is illustrated in Table 1. Soils in Vinh Long, Can Tho, and Hau Giang were assessed to have moderate organic matter content, while the remaining regions displayed poor organic matter content. The organic matter content at Lap Vo-Dong Thap and Vinh Hung-Long An reached the lowest values, showing a statistically significant difference compared to other areas in MKD. The reason is that during the cultivation process, farmers mainly cover the soil with a thin layer of straw and use chemical fertilizers as the primary type of fertilizer in the farming process.

Additionally, the habitual lack of annual organic matter supplementation by most crop owners has led to a significant reduction in soil organic matter over time [19]. Thus, the organic matter content of crop soil in some provinces of MKD demonstrates a trend similar to the overall cultivation practices in the MKD region [20], [21]. Specifically, the organic matter content tends to decrease with pH value. The primary cause is the lack of emphasis on restoring or replenishing natural organic matter to the soil [22]. Numerous studies have indicated that organic matter content can decrease by 25% under continuous cultivation for over 20 years without additional organic fertilizer supplementation and can decrease by up to 50% after cultivation for more than 50 years with little to no organic fertilizer supplementation [23]. Therefore, to help stabilize and maintain the soil's desirable characteristics, farmers need to supplement additional organic fertilizer to restore the soil's current state [24], [25].

3.3. Soil texture

The results presented in Table 1 also show that the sand fraction in the soil is relatively low compared to the silt and clay components. The clay content varies from 21 to 55%, and the silt content ranges from 37 to 56% in the 0-20 cm soil layer. Based on the USDA soil texture triangle [26], the soil in the vegetable cultivation areas belongs to the group of soils with a medium texture of silty clay loam, silt loam, silty clay or clay. In general, due to the relatively high clay content, the soil in vegetable crops has the capacity to supply and retain abundant nutrients, exhibit good water retention capabilities. However, in areas with high clay content, it may lead to disadvantages in water permeability and runoff during periods of high rainfall or irrigation.

3.4. Stability quotient of soil structure

Soil stability is considered one of the key indicators to assess the quality of land. The stability of the soil can strongly affect both its chemical and physical properties. The structural stability of soil depends on the content of organic matter, clay content, and iron oxides [27].

SQ has changed among different vegetable cultivation areas in the MKD region. The classification of SQ gained over 85 comprise 77.8% of all observed vegetable crops in the MKD, concentrating in the regions of Cau Ke-Tra Vinh, Cai Lay-Tien Giang, Binh Minh-Vinh Long, Binh Thuy-Can Tho, Long My-Hau Giang, Cho Moi-An Giang and My Xuyen-Soc Trang districts. The lowest SQ was recognized for vegetable crop in Lap Vo-Dong Thap district. At Dong Thap province, because long-term farming practices combined with insufficient replenishment of organic matter content can lead to a reduction in the formation of soil aggregates. Additionally, the mechanical composition of this land has predominant clay content, accounting for 39% of the total three-level particle composition. Therefore, when cultivating on silty clay loam soil under soil preparation conditions, it is easy to disrupt the soil structure [28]. According to Tran et al.[11], application of organic fertilizers has increased the soil's stability. Organic fertilizer supplements

have demonstrated significantly higher soil stability compared to the treatments with only chemical fertilizers. This application has made soil more porous and less compact, maintaining a good soil structure, preventing surface crusting and hardening, improving water holding capacity, nutrient retention, and creating favorable aeration conditions for crop growth. In addition, because the organic matter content in the surveyed soil was poor to medium, which had reduced the SQ.

4. Conclusions

Based on the analysis of the physical and chemical properties in vegetable crop cultivation areas in the Mekong Delta, the following conclusions can be drawn:

The pH values of the research sites vary from acid to slightly acid. The organic matter content was assessed from poor to moderate. The soil texture in vegetable cropping areas has high silt and clay contents. The structural stability in vegetable cropping areas varies between moderate to high, except structural stability in Dong Thap crop region. Therefore, it is necessary to supplement organic fertilizers to maintain sustainable vegetable cropping cultivation and soil structure aggregation stability.

Acknowledgement

This research is supported by the project B2025-SPD-02.

REFERENCES

[1] P. Schneider and F. Asch, "Rice production and food security in Asian Mega deltas—A review on characteristics, vulnerabilities and agricultural adaptation options to cope with climate change," *J. Agronomy Crop Science*, vol. 206, no. 4, pp. 491-503, 2020, doi: 10.1111/jac.12415.

[2] M. Piesse, *The Mekong Delta: land subsidence threatens Vietnam's 'food basket'*, Strategic Analysis Paper, 2019.

[3] M. Pulido-Moncada, B. C. Ball, D. Gabriels, D. Lobo, and W. M. Cornelis, "Evaluation of soil physical quality index S for some tropical and temperate medium-textured soils," *Soil Science Society of America Journal*, vol. 79, no. 1, pp. 9-19, 2015.

[4] R. E. Masto, P. K. Chhonkar, D. Singh, and A. K. Patra, "Alternative soil quality indices for evaluating the effect of intensive cropping, fertilisation and manuring for 31 years in the semi-arid soils of India," *Environmental Monitoring and Assessment*, vol. 136, no. 1-3, pp. 419-435, 2008.

[5] A. Belay, A. S. Claassens, and F. C. Wehner, "Soil nutrient contents, microbial properties and maize yield under long-term legume-based crop rotation and fertilization: A comparison of residual effect of manure and NPK fertilizers," *South African Journal of Plant and Soil*, vol. 19, no. 2, pp. 104-110, 2002.

[6] M. Welemariam, D. Wako, and G. Kitila, "Effect of Land Use Change on Soil Carbon Stock and Selected Soil Properties in Gobu Sayyo, Western Ethiopia," In Review, preprint, Jun. 2021, doi: 10.21203/rs.3.rs-586121/v1.

[7] J. R. Landon, *Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics*. Routledge, 2014.

[8] L. P. van Reeuwijk, *Procedures for soil analysis*, 6th ed. Technical paper/ International Soil Reference an Information Centre, no. 9. Wageningen: International Soil Reference and Information Centre, 2002.

[9] J. Ashworth, D. Keyes, R. Kirk, and R. Lessard, "Standard procedure in the hydrometer method for particle size analysis," *Communications in Soil Science and Plant Analysis*, vol. 32, no. 5-6, pp. 633-642, Apr. 2001, doi: 10.1081/CSS-100103897.

[10] L. E. Allison, "Organic Carbon," in *Agronomy Monographs*, A. G. Norman, Ed., Madison, WI, USA: American Society of Agronomy, Soil Science Society of America, 2016, pp. 1367-1378, doi: 10.2134/agronmonogr9.2.c39.

[11] B. L. Tran, T. G. Vo, and M. P. Nguyen, "The effect of organic fertilizer in improving soil bulk density and aggregate stability in the Mekong Delta," *Can Tho University Journal of Science,* no. 10, pp. 145-150, 2008.

[12] T. P. Nguyen, N. T. A. Lu, and T. H. L. Nguyen, "Effects of the dyke systems on upland crops and rice soil properties in Dong Thap province," *Journal of Vietnam Agricultural Science and Technology*, vol. 10, no. 131, pp. 106-112, 2021.

[13] W. D. Kemper and R. C. Rosenau, "Aggregate stability and size distribution," *Methods of soil analysis: Part 1 Physical and mineralogical methods*, vol. 5, pp. 425-442, 1986.

[14] L. D. Leenheer and M. D. Boodt, "Determination of aggregate stability by the change in mean weight diameter," *International Symposium on Soil Structure, Gent. Proceeding*, vol. 24, pp. 290-300, 1959.
[15] M. P. Moncada, D. Gabriels, W. Cornelis, and D. Lobo, "Comparing Aggregate Stability Tests for Soil Physical Quality Indicators," *Land Degrad. Dev.*, vol. 26, no. 8, pp. 843-852, Nov. 2015, doi: 10.1002/ldr.2225.
[16] A. Ganeshamurthy, D. Kalaivanan, and G. Satisha, "Management of vegetable crops in acid soils of India," *Innovations in Horticultural Sciences*, vol.12, pp. 559-584, 2016.
[17] A. T. Tat and V. T. Nguyen, "Assessment of soil properties of three raised bed types for pineapple cultivation in the dyke-protected areas of the Tan Lap 1 village, Tan Phuoc district, Tien Giang province," *Can Tho University Journal of Science*, vol. 49, 2017, doi: 10.22144/ctu.jvn.2017.022.
[18] D. Zhuo, L. Liu, H. Yu, and C. Yuan, "A national assessment of the effect of intensive agro-land use practices on nonpoint source pollution using emission scenarios and geo-spatial data," *Environmental Science and Pollution Research*, vol. 25, no. 2, pp. 1683-1705, 2018.
[19] C. A. Laboski, J. B. Peters, and L. G. Bundy, *Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin*. Division of Cooperative Extension of the University of Wisconsin-Extension, 2006.
[20] J. J. Hoorman, *Using cover crops to improve soil and water quality,* Agriculture and Natural Resources. The Ohio State University Extension Press, Lima, Ohio, 2009, pp. 1-4.
[21] T. H. L. Nguyen, T. P. Nguyen, N. T. A. Lu, A. N. Dang, and H. Nguyen, "Effect of Agricultural Land-Use Patterns on Soil Organic Carbon Stock in the Upper Vietnamese Mekong Delta," *Polish Journal of Environmental Studies*, vol. 31, no. 6, pp. 5793-5804, 2022.
[22] D. Curtin and G. Wen, "Organic matter fractions contributing to soil nitrogen mineralization potential," *Soil Science Society of America Journal*, vol. 63, no. 2, pp. 410-415, 1999.
[23] F. E. Allison, *Soil organic matter and its role in crop production*, vol. 3. Elsevier, 1973.
[24] C. D. Berdanier and L. A. Berdanier, *Advanced nutrition: macronutrients, micronutrients, and metabolism*. CRC press, 2015.
[25] T. M. P. Bui, C. K. Huynh, V. T. Pham, and H. C. Nguyen, "Study on the quantity and nutrients content of sediment in the full-dyke and semi dyke systems in An Giang province," *Can Tho University Journal of Science. Special issue: Environment and Climate Change*, vol.1, pp. 146-152, 2017.
[26] USDA, *Soil survey manual*, no. 18. US Department of Agriculture, 1993.
[27] V. De Laurentiis, M. Secchi, U. Bos, R. Horn, A. Laurent, and S. Sala, "Soil quality index: Exploring options for a comprehensive assessment of land use impacts in LCA," *Journal of Cleaner Production*, vol. 215, pp. 63-74, 2019.
[28] I. Vanicek and M. Vanicek, *Earth structures: in transport, water and environmental engineering,* vol. 4. Springer Science & Business Media, 2008.