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ASSESSMENT ON SOME OF SANDY SOIL PROPERTIES IN PHU VANG DISTRICT, THUA THIEN HUE PROVINCE

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Abstract. This study was conducted in Phu Da town and Vinh Xuan commune, Phu Vang district, Thua Thien Hue province, with the aim of evaluating and mapping soil properties, including pH_{KCl}, total nitrogen, electrical conductivity, total phosphorus, total potassium, and soil organic carbon. The results showed that most soil properties in the study area were low; the soil was poor in organic carbon and acidic, with a notable decrease in organic carbon content compared to previous studies (0.69% compared to 0.86%). Three out of six soil quality indicators—soil acidity, total nitrogen, and total phosphorus—showed statistically significant differences between land use types. This difference was observed between the two-season rice land use type and all other land use types. This study employs the Ordinary Kriging interpolation method for soil quality indicators mapping. However, the results indicate that the map's accuracy is relatively low. This finding suggests that conventional interpolation methods, which rely on distance and sample residuals, may not be appropriate for soil quality indicators mapping. Consequently, there is a need to explore and apply alternative methods to enhance mapping accuracy.

Keywords: sandy soil, lagoon, soil properties, Phu Vang district

1 Introduction

The sandy coastal and lagoon areas account for nearly 7% of the total natural area of Thua Thien Hue province. These areas are mostly concentrated in the districts of Quang Dien, Phong Dien, and Phu Vang, covering approximately 20,000 hectares. Of this, Phu Vang district encompasses about 5,000 hectares, primarily in the communes of Phu Xuan, Phu Da, Vinh Ha, and Vinh Xuan [1]. The sandy soil in this region has been mainly formed through long-term deposition processes at river mouths and coastal areas [2]. The soil texture is characterized by sandy, with sand amount accounting for 68.24% to 85.28%, resulting in rapid water infiltration and drainage. Basic soil nutrient indicators are low, making the land less suitable for agricultural development [3]. However, despite these challenges, agricultural production remains a key development direction for the locality alongside fishing and aquaculture. Therefore, the area of sandy soil still plays an important role in stabilizing local livelihoods. The long-term arrangement of agricultural land use types will impact soil quality indicators, while the development of new methods for managing and using sandy soil is crucial for improving crop productivity and contributing to sustainable land use [4].

Phu Da town plays a particularly important role as the location of Phu Vang district's government agencies and is currently hosting numerous projects and programs for socio-economic development. Consequently, the conversion of land use from agricultural to non-agricultural purposes is frequent, which places certain pressures on land use and agricultural production activities. Meanwhile, Vinh Xuan commune, with its unique location bordering both the sea and Tam Giang lagoon, features diverse land use types but also faces significant risks of land degradation. In recent years, the coastal and lagoon sandy areas in these two localities have undergone diverse land use changes, including the cultivation of short-term crops that yield low economic returns. Many areas of land used for single-crop rice production have been abandoned, leading to desertification. One of the main reasons for this issue is the lack of sufficient information among land users about soil quality, resulting in inadequate planning for fertilizer investment and soil improvement measures. Therefore, a study to evaluate some selected soil properties in Phu Da town and Vinh Xuan commune is of great significance, with the following specific objectives: (i) Determine soil properties including organic carbon content, total nitrogen, total phosphorus, total potassium, electrical conductivity, and soil pH; (ii) compare soil properties across different land use types; and (iii) develop a soil properties map for the study area.

Most research on soil properties in sandy soils focuses solely on the values of soil indicators. In our study, we not only determine the values of soil properties but also explore the differences among these properties across various land use types, as well as the potential for applying spatial interpolation techniques for soil mapping. This comprehensive approach provides valuable insights that can facilitate deeper investigations in future research.

2 Methodologies

2.1 Soil sampling and soil analysis

The study area encompasses the entire administrative boundary of Phu Da town and Vinh Xuan commune in Phu Vang district, Thua Thien Hue province. Phu Da town covers a total area of 2,966 hectares, with agricultural land comprising 1,542.54 hectares (52.04%), non-agricultural land 1,155.94 hectares (38.97%), and unused land 266.58 hectares (8.99%) [5]. The total population of Phu Da town is 11,696 people, with agricultural laborers constituting 60% of the working-age population [6]. A notable characteristic of Phu Da town is its extensive inland sandy land, influenced by the lagoon to the east of the town. Vinh Xuan commune has a total area of 1,809 hectares, with nearly 200 hectares dedicated primarily to rice production during the winterspring crop and 148 hectares used for growing various other crops [6]. The population of Vinh Xuan commune is 6,648 people, with the majority engaged in aquaculture and fishing [6].

The study collected 50 soil samples across five different land use types from February to March 2024, as detailed in Table 1 and illustrated in Figure 1.

The samples were taken from depths of 0 to 30 cm, naturally dried, and then analyzed in the laboratory of the University of Agriculture and Forestry, Hue University. The analytical methods employed in this study are presented in Table 2.

Table 1. Soil samples information

Land Use Types	**Phu Da**	**Vinh Xuan**	No of samples
Abandoned land, grass	7	3	10
Vegetables and annual crops	4	6	10
Acacia, melaleuca, and casuarina	5	5	10
Paddy rice (2 seasons)	10	0	10
Paddy rice (1 season)	3	7	10
Total	**29**	**21**	**50**

Table 2. Laboratory analysis methods

Indicators	**Unit**	**Method**	**Reference**
Soil pH_{KCl}		pH met	TCVN 5979:2007
Total nitrogen (N)	%	Kjeldahl	TCVN 6645:2000
Electrical Conductivity (EC)	mS/cm	HI98331 instrument	TCVN 6650:2000
Total phosphorus (P_2O_5)	%	Spectrophotometer	TCVN 8940:2011
Total potassium (K_2O)	%	Flame photometer	TCVN 8660:2011
Organic Carbon (OC)	%	Walkley-Black	TCVN 8941:2011

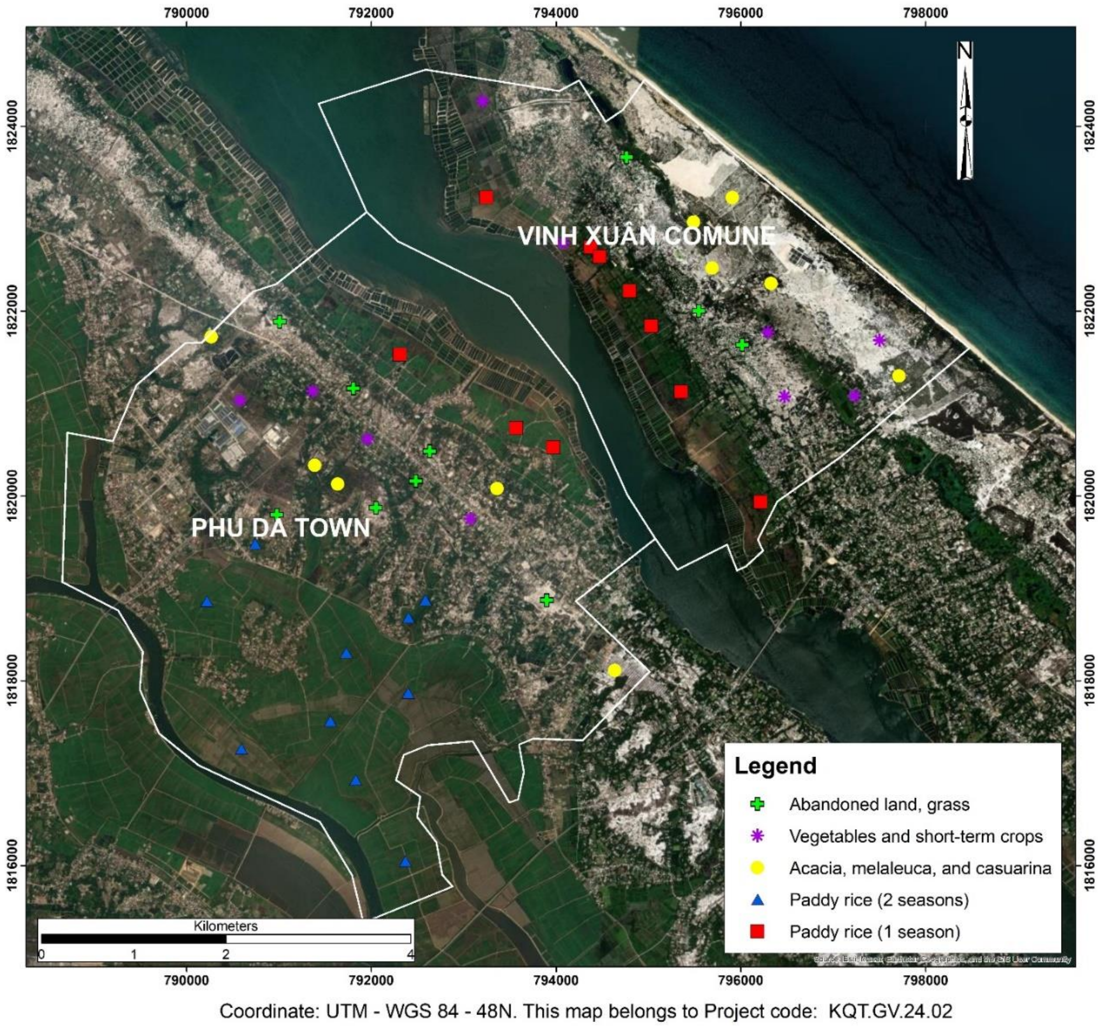

Figure 1. Soil sampling locations

2.2 Geographical Information System

The locations of soil samples are recorded as XY coordinates in the UTM coordinate system with the 48 North projection. Various spatial interpolation methods are available for constructing maps of soil quality indicators, each with its own advantages and disadvantages. The choice of method depends on factors such as the scale of the area, the distance between sampling points, and the number of samples [7, 8]. In this study, we used the Ordinary Kriging interpolation method to create maps of soil properties due to its availability and simplicity of implementation. A total of 35 samples were used for interpolation, while 15 samples were reserved for evaluating the interpolation results based on the Root Mean Square Error (RMSE) and the R^2 correlation coefficient.

2.3 Statistical Analysis

The study used SPSS 20 to analyze and process statistics, including the calculation of average values and standard deviations. Additionally, the ANOVA (post-hoc) method was employed to compare soil property values across different land use types. The Root Mean Square Error (RMSE) of the interpolated values was calculated using the following formula:

$$RMSE_i = \sqrt{\sum_1^n \frac{(V_m - V_p)^2}{n}} \quad (1)$$

Where $RMSE_i$ represents the Root Mean Square Error for soil property i; n is the total number of measured samples; V_m and V_p are the measured and interpolated values of soil property i at the same point, respectively. The closer the $RMSE$ value is to 0, the more accurate the interpolation results are.

Use R^2 to evaluate the accuracy of the interpolation results. The formula for calculating R^2 is as follows:

$$R_i^2 = 1 - \frac{\sum_1^n (V_m - V_p)^2}{\sum_1^n (V_m - \overline{V_m})^2} \quad (2)$$

Where $\overline{V_m}$ is the mean of the measured values of soil property i.

An R^2 value closer to 1 indicates a better fit between the measured and interpolated values, reflecting higher accuracy in the interpolation results.

3 Results and discussions

3.1 Soil properties in Phu Da town and Vinh Xuan commune in Phu Vang district, Thua Thien Hue province

The soil property indicators of the study area are detailed in Table 3. Compared to previous studies on sandy soils across Vietnam [9], the soil in the study area exhibits significantly lower levels of organic carbon and total potassium. Conversely, the total phosphorus content is higher, while other indicators remain largely unchanged. It is evident that the sandy soils in Phu Da town and Vinh Xuan commune are of low quality, characterized by poor humus content and high acidity, which is consistent with the general condition of sandy soils in Thua Thien Hue province [4]. This poor soil quality may be a key factor in why these areas are often abandoned, exacerbated by the inappropriate use of fertilizers that further degrades the soil.

Table 3. Soil property indicators

Soil property indicator	Value			
	Min	Max	Mean	Std
Soil pHKCl	4.41	4.75	4.53	0.06
Total nitrogen (N) %	0.05	0.09	0.07	0.007
Electrical Conductivity (EC) mS/cm	0.40	0.96	0.64	0.15
Total phosphorus (P2O5) %	0.09	0.14	0.12	0.01
Total potassium (K2O) %	0.03	0.07	0.05	0.006
Organic Carbon (OC) %	0.46	1.08	0.69	0.11

Soil acidity (pHKCl)

Soil acidity directly affects soil chemical parameters. The study found that soil acidity in Phu Da town and Vinh Xuan commune ranges from 4.41 to 4.75. This level indicates that the soil in the study area is acidic, which presents significant challenges for agricultural production. These findings are consistent with previous studies on coastal sandy soils in Thua Thien Hue province [10].

Total nitrogen (N)

The nitrogen (N) content in the soil of the 50 samples ranged from 0.05% to 0.09%, with an average value of 0.07% and a standard deviation of 0.007%. Most samples had values between 0.06% and 0.08% (accounting for 88% of the total samples), indicating a fairly even distribution of N values. Compared to recent studies [11], the variation in these samples was smaller. This reduced variation may be attributed to the study's limited scope, focusing only on the administrative boundaries of the two communes, which resulted in less variation in N content between the samples.

Electrical Conductivity (EC)

The electrical conductivity (EC) index is crucial for assessing soil salinity, which directly impacts crop yield and quality. EC values are closely related to the concentration of dissolved salt ions in the soil solution. Our result indicates that the EC values in the study area range from 0.40 mS/cm to 0.96 mS/cm, suggesting that the soil is relatively low in nutrients. Some studies recommend that the optimal EC value for most crops is between 0.8 mS/cm and 2.2 mS/cm [12].

Total phosphorus (P_2O_5)

The P_2O_5 content in the soil of the study area ranges from 0.09% to 0.14%, with an average value of 0.12%. This is higher compared to the average P_2O_5 content of 0.04% found in sandy soils across Vietnam [13]. The variation in P_2O_5 content in the study area indicates that this parameter has increased significantly, exceeding 2 to 3 times [3] compared to 20 years ago and approximately 1.2 to 1.4 times compared to results from 5 years ago [11]. Thus, it is evident that the P_2O_5 content in the soil of the study area has increased over time. The increase in P_2O_5 content may be attributed to fertilizer application during land use. Previous studies have noted a positive correlation between P_2O_5 levels in the soil and the amount of chemical fertilizers applied [14]. In a study conducted in another coastal area, the total phosphorus content of the soil increased by 66% over a 10-year period, rising from 0.12% to 0.20% due to the effects of cultivation practices [15].

Total potassium (K_2O)

The total potassium content ranges from 0.03% to 0.07%, with an average value of 0.05%. Most samples with low K_2O content (<0.05%) are concentrated in the southeastern part of the study area. Compared to previous studies [3], [11], this indicates a significant reduction in K_2O content, by approximately 2 to 3 times. Farming practices, particularly the cultivation of short-term crops, may be a contributing factor to this decline, as noted by recent study [16].

Organic Carbon (OC)

The research results show that the organic carbon (OC) content in the soil of the study area ranges from 0.46% to 1.08%, with the majority of samples falling between 0.6% and 0.8% (33 out of 50 samples). Twelve samples have values below 0.6%, and only 5 samples exceed 0.8%. Bui Thi Phuong Loan analyzed the OC content of 86 sandy soil samples from the North Central region, including Thua Thien Hue, finding that OC content ranged from 0.29% to 0.99% [11]. Similarly, Nguyen Truong Giang's analysis of 42 sandy soil samples in Quang Ngai province showed OC content ranging from 0.29% to 1.11% [17]. Thus, the OC content in coastal and lagoon sandy soils in Phu Da town and Vinh Xuan commune is quite comparable to that of the North Central region as a whole. Notably, the current OC values show a decreasing trend compared to previous studies in the same area, with a reduction of approximately 0.15% to 0.2% [3]. This decline may be attributed to the sandy texture of the soil, which limits the formation and accumulation of organic matter. Additionally, agricultural practices may contribute to the reduction in OC content over time. Therefore, measures are needed to restore OC content in the study area.

3.2 Soil properties and land use types

The values of soil properties by land use type and commune are presented in Table 4. In this table, the mean values differ from those of the entire study area due to the varying number of soil samples collected in each commune. Consequently, these values cannot be used to make direct comparisons between communes.

The ANOVA technique was used to analyze soil property indicators in the study area based on land use types. The results indicate that, at a 95% confidence level, there are statistically significant differences in the indicators of pH (KCl), total nitrogen, and total phosphorus among different land use types. The remaining indicators did not show statistically significant differences.

A detailed post-hoc analysis of the indicators with significant differences among land use types is presented in Table 5.

Table 4. The value of soil properties by land use types and communes

Land Use Type	Soil pH		N (%)		EC (mS/cm)		P_2O_5 (%)		K_2O (%)		OC (%)	
	Phu Da	Vinh Xuan	Phu Da	Vinh Xuan	Phu Da	Vinh Xuan	Phu Da	Vinh Xuan	Phu Da	Vinh Xuan	Phu Da	Vinh Xuan
Abandoned land, grass	4.48	4.53	0.071	0.064	0.62	0.64	0.12	0.13	0.051	0.056	0.58	0.83
Vegetables and annual crops	4.51	4.52	0.074	0.072	0.69	0.59	0.12	0.13	0.052	0.056	0.60	0.70
Acacia, melaleuca, and casuarina	4.51	4.55	0.070	0.065	0.67	0.64	0.11	0.13	0.051	0.056	0.60	0.76
Paddy rice (2 seasons)	4.59	N/A	0.076	N/A	0.68	N/A	0.11	N/A	0.051	N/A	0.75	N/A
Paddy rice (1 season)	4.48	4.53	0.076	0.064	0.58	0.66	0.12	0.12	0.050	0.049	0.68	0.71

Table 5. The value of soil properties that have significant differences by land use type

Land Use Types	Soil properties		
	pHKCl	N (%)	P_2O_5 (%)
Abandoned land, grass	4,50[a]	0,068[ab]	0,12[a]
Vegetables and annual crops	4,52[ab]	0,073[ab]	0,13[a]
Acacia, melaleuca, and casuarina	4,53[ab]	0,067[a]	0,13[a]
Paddy rice (2 seasons)	4,58[b]	0,075[b]	0,10[b]
Paddy rice (1 season)	4,51[a]	0,068[ab]	0,13[a]

Table 5 shows that there are significant differences in soil acidity between abandoned land without agricultural cultivation and land used for two-season rice cultivation. In the study area, rice farmers commonly use lime to raise soil pH, creating a more favorable environment for nutrient absorption by rice plants. Additionally, areas used for two-season rice cultivation are often flooded during the rainy season, which can leach soil acids annually and reduce soil acidity compared to other regions in the study area. This result is consistent with the findings of recent publication [15].

The total nitrogen content in soil is highest in two-season rice fields and lowest in areas with Acacia, Melaleuca, and Casuarina. This is due to several factors, such as the use of fertilizers and the practice of incorporating crop residues into the soil, which continuously adds organic matter and contributes to increased total nitrogen content, given the strong correlation between organic matter and total nitrogen in the soil [18]. However, the total nitrogen content in sandy soils in Thua Thien Hue does not have a strong correlation with available nitrogen content, so this factor alone cannot be used to conclude that higher total nitrogen indicates better soil quality for crops [19].

The total phosphorus content in two-seasons rice fields is lower compared to all other land use types. Although this land use type involves applying a complete N-P-K fertilizer, some studies suggest that over time, rice cultivation can lead to phosphorus deficiency in the soil as rice plants absorb phosphorus during root development and tillering. Therefore, selecting an appropriate fertilization formula is essential to ensure adequate phosphorus supply for rice, with a minimum recommendation of 50 kg P2O5/ha/season [20].

3.3 Soil properties mapping

The Ordinary Kriging spatial interpolation method, integrated into ArcGIS 10.3, was used to interpolate soil indicators for Phu Da town and Vinh Xuan commune based on measurements from 35 points (with 7 randomly selected samples from each land use type out of 10 total samples). The results are shown in Figure 2, and the accuracy of the interpolation model is presented in Table 6.

Table 6 shows that the interpolation results for soil indicators in the study area have medium accuracy. This is because the Ordinary Kriging method only considers two factors for interpolation: the distance between points and the spatial distribution of data among points for the same indicator. However, soil properties are influenced by additional factors such as topography, hydrology, and land use [21]. Therefore, selecting the appropriate interpolation model is crucial when creating soil property maps. While several models that incorporate correlations between environmental factors are widely used, it is essential to identify and select

Table 6. The accuracy parameters of spatial interpolation

Soil properties	RMSE	R^2
pH_{KCl}	0.05	0.47
N (%)	0.006	0.40
EC (mS/cm)	0.09	0.58
P_2O_5 (%)	0.009	0.59
K_2O (%)	0.002	0.54
OC (%)	0.05	0.55

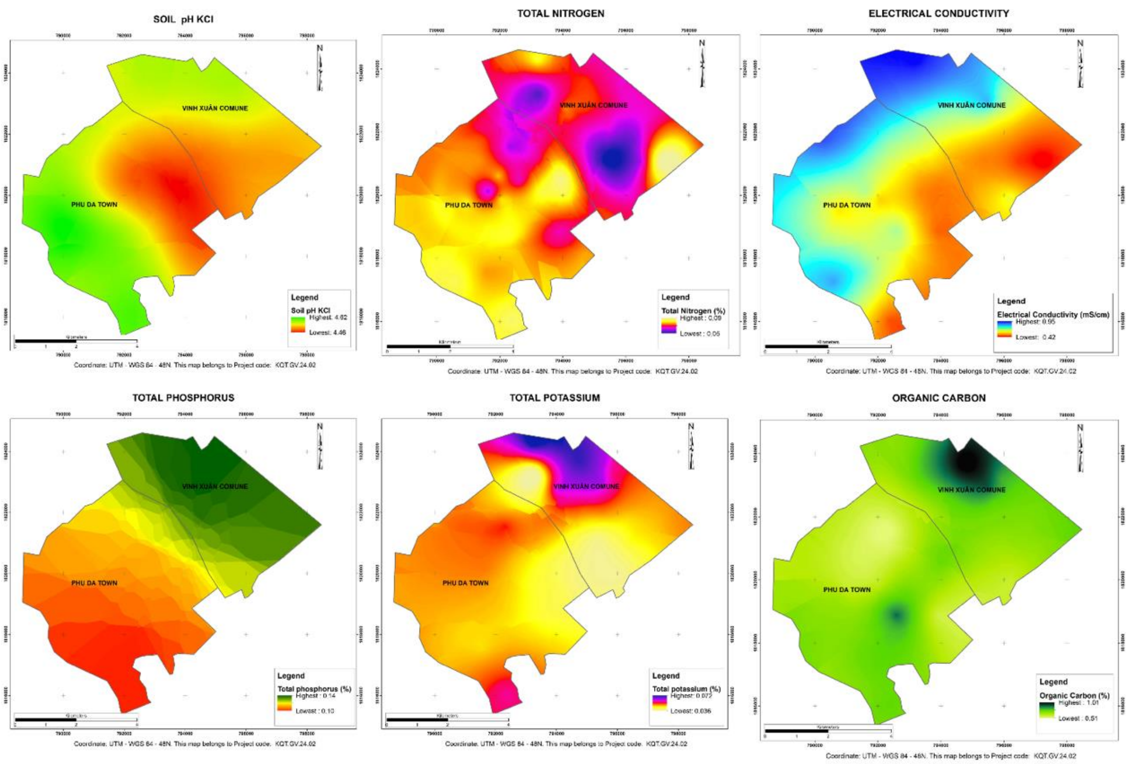

Figure 2. Soil properties maps of Phu Da and Vinh Xuan

the relevant environmental variables using techniques such as principal component analysis or correlation analysis [8].

Figure 2 shows that the soil pH in the study area is relatively low, ranging from 4.46 to 4.82. The Northeastern Phu Da town has the lowest soil pH, corresponding to the highest TN content. Our findings also agree with [22] suggesting that low soil pH leads to higher nitrogen content due to the decomposition of acidic organic matter. On the other hand, the highest pH led to the highest OC content in the North of Vinh Xuan commune. It would be explained by the reduced microbial decomposition, in which, the rate of organic matter decomposition slows down due to higher pH, resulting in more OC accumulation. Besides, [23] demonstrated that as a value < 4.5 or > 8.0, pH had a negative correlation with soil organic carbon due to corresponding degradation. However, soil pH showed negligible effect on the soil TN, and OC in other areas. The interpolation of soil quality criteria values often yields varying results, depending on the chosen interpolation method and the characteristics of the data. This topic remains a subject of ongoing debate. However, numerous studies have indicated that relying solely on the Ordinary Kriging (OK) method may not be suitable for interpolating values such as electrical conductivity (EC), pH, or soil moisture [8, 24, 25]. The primary limitation of this method is its heavy dependence on the number of samples and their spatial distribution. This highlights the need for geoscientists to carefully select appropriate interpolation methods for each soil parameter within the study area.

4 Conclusions

This study provides quantitative data on six physical and chemical soil properties, serving as a foundation for agricultural policymakers and land users to implement appropriate actions aimed at improving soil fertility and ensuring sustainable, rational land use. The analysis reveals differences in certain soil indicators across various land use types; however, further research utilizing multi-temporal data is necessary to determine how these land use types interact with one another.

Currently, the maps produced have an acceptable level of accuracy, with an R^2 value of approximately 50%, which limits their utility to reference purposes in agricultural planning at a moderate scale. For more detailed planning, such as agricultural production zoning, it is essential to increase the number of samples. Additionally, future studies should compare different interpolation methods to identify the most suitable approach.

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References

1. Thua Thien Hue Provincial Committee (2005), *Geography of Thua Thien Hue: Natural part*, Hanoi: Social Science Publishing House. *(Vietnamese)*
2. Nguyen Viet (2004), Hydro-climatic conditions of the inland sand area of Thua Thien-Hue province, *Journal of Hydrometeorology*, 523, 41–50. *(Vietnamese)*
3. Tran Van Minh (2002), Assessing the current status of some types of soil and crops after the great flood in Thua Thien Hue province and proposing solutions to overcome the situation, in *Collection of research works of Hue University of Agriculture and Forestry*, *Hue*. *(Vietnamese)*
4. Hoang Thi Thai Hoa (2008), *Soil characteristics, cropping patterns, and use of organic resources in the coastal sandy area of Thua Thien Hue province, Central Vietnam, PhD Thesis at Université catholique de Louvain*, https://dial.uclouvain.be/pr/boreal/en/object/boreal%3A20029/fnrs.
5. Department of Natural resources and Environment of Phu Vang district (2023), *Report of annual land statistics of the year 2023. (Vietnamese)*
6. Office of Statistic of Phu Vang district (2023), *Statistical Yearbook*. *(Vietnamese)*
7. Chuong Van Huynh, Tung Gia Pham, Linh Hoang Khanh Nguyen, Hai Trung Nguyen, Phuong Thuy Nguyen, Quy Ngoc Phuong Le, Phuong Thi Tran, Mai Thi Hong Nguyen, Tuyet Thi Anh Tran (2022), *Application GIS and remote sensing for soil organic carbon mapping in a farm-scale in the hilly area of central Vietnam, Air, Soil and Water Research*, 15, ID117862212211147, doi: 10.1177/11786221221114777.
8. T. Gia Pham, M. Kappas, C. Van Huynh, và L. Hoang Khanh Nguyen (2019), Application of Ordinary Kriging and Regression Kriging Method for Soil Properties Mapping in Hilly Region of Central Vietnam, *ISPRS International Journal of Geo-Information*, 8(3), ID 147, doi: 10.3390/ijgi8030147.
9. Pham Quang Ha, Bui Huy Hien, Hoang Thi Thai Hoa, Pham Quang Tu, Bui Thi Phuong Loan, Dusey Joseph (2005), *Overview of sandy soils management in Vietnam*, *Oral communication at International symposium on the management of tropical sandy soils for sustainable agriculture*, Khon Kaen, Thailand, https://www.fao.org/4/ag125e/AG125E26.htm#26.2.
10. Truong Thi Dieu Hoa, Tran Thanh Duc, Hoang Thi Thai Hoa (2023), *Situation of crop residues reuse and paddy soil characteristics in Quang Dien district, Thua Thien Hue province*, *Hue University Journal of Science: Agriculture and Rural Development*, 132(3B), 143–155, doi: 10.26459/hueunijard.v132i3B.7188. *(Vietnamese)*
11. Bui Thi Phuong Loan (2018), *Research on organic status and measures to improve carbon fixation capacity in sandy soil in the North Central region, PhD Thesis at Vietnam Academy of Agricultural Sciences*. https://thuvienso.quochoi.vn/handle/11742/79162. *(Vietnamese)*

12. Thi Kim Loan Nguyen, Moon-Sun Yeom, Myung-Min Oh (2021), *Effect of a Newly-Developed Nutrient Solution and Electrical Conductivity on Growth and Bioactive Compounds in Perilla frutescens var. crispa, Agronomy*, 11(5), ID 932, doi: 10.3390/agronomy11050932.

13. Ministry of Science and Technology of Vietnam (2004), *Technical Standards of Viet Nam TCVN 7374:2004 about soil quality – Index values of total phosphorus content in the soils of Vietnam*. *(Vietnamese)*

14. Do Thi Xuan Thuy, Pham Vu Bao, Truong Thi Thuan, Phan Thi Phuong Nhi (2021), *Effects of nitrogen and phosphorus rates on growth and yield of LDH.09 peanut variety cultured on coastal sandy soil in Binh Dinh province, Hue University Journal of Science: Agriculture and Rural Development*, 130(3B), doi: 10.26459/hueunijard.v130i3B.6059. *(Vietnamese)*

15. Tran Ba Linh, Tran Sy Nam, Huynh Cong Khanh, Lam Van Hau, Mitsunori Tarao (2021), *Assessing fertility of problem soils inside and outside the full dike system used for rice cultivation in An Giang province, Can Tho University Journal of Science*, 57(1), 51–66, doi: 10.22144/ctu.jsi.2021.029. *(Vietnamese)*

16. Luu The Anh (2017), *The Status and Fluctuation of Macronutrients of Nitrogen, Phosphorus and Potassium in Paddy Soils of Thai Binh Province, VNU Journal of Science: Earth and Environmental Sciences*, 33(3), 1–10. *(Vietnamese)*

17. Nguyen Truong Giang, Le Duc Dung, Vu Van Khue (2021), *Physical and chemical properties of sandy soil cultivating upland crops in Quang Ngai province, Journal of Vietnam Agricultural Science and Technology*, 8(129), 105–110. *(Vietnamese)*

18. Vo Thi Guong, Tran Ba Linh, Chau Thi Anh Thy (2010), *Improving soil fertility and rice yield on land with lost cultivation layer in Chau Thanh district, Tra Vinh province, Can Tho University Journal of Science*, 16b, 107–116. *(Vietnamese)*

19. Hoang Thi Thai Hoa, Thai Thi Huyen, Tran Thi Tam, Hoang Van Cong, Do Dinh Thuc, Chiang Naikan Claude, Dufey Joseph (2005), *Nitrogen mineralization capacity of coastal sandy soils of the Thua Thien Hue Province, Central Vietnam, Oral communication at International symposium on the mamangement of tropical sandy soils for sustainable agriculture*, Khon Kaen, Thailand. https://dial.uclouvain.be/pr/boreal/object/boreal:82669.

20. Vu Van Long, Nguyen Van Qui, Nguyen Minh Dong, Chau Minh Khoi (2016). Effect of reducing phosphate fertilizer amount on soil available phosphate and rice yield on three-crop rice land in Hoa Binh district, Bac Lieu province, *Can Tho University Journal of Science*, 43, 61–67. *(Vietnamese)*

21. Sigua, G. C., Hudnall, W. H. (2008), Kriging analysis of soil properties, *Journal of Soils and Sediments*, 8(3), 193–202, doi: 10.1007/s11368-008-0003-7.

22. Zhou, W., Han, G., Liu, M., và Li, X. (2019), Effects of soil pH and texture on soil carbon and nitrogen in soil profiles under different land uses in Mun River Basin, Northeast Thailand, *PeerJ,* 7(e7880), doi: 10.7717/peerj.7880.

23. Paradelo, R., Virto, I., Chenu, C. (2015), *Agriculture, Ecosystems and Environment Net effect of liming on soil organic carbon stocks : A review, Agriculture, Ecosystems and Environment,* (202), 98–107, doi: 10.1016/j.agee.2015.01.005.

24. Zhu, Q., Lin, H. S. (2010), *Comparing Ordinary Kriging and Regression Kriging for Soil Properties in Contrasting Landscapes, Pedosphere,* 20(5), 594–606, doi: 10.1016/S1002-0160(10)60049-5.

25. Huang, Y., Li, Z., Ye, H., Zhang, S., Zhuo, Z., Xing, A., Huang, Y. (2019), *Mapping Soil Electrical Conductivity Using Ordinary Kriging Combined with Back-propagation Network, Chin Geogr Sci,* 29(2), 270–282, doi: 10.1007/s11769-019-1027-1.