ANALYSIS OF TOPSOIL QUALITY CHANGES ACROSS SOIL GROUPS IN VIETNAM

ABSTRACT

This study evaluates the changes in topsoil quality across various soil groups in Vietnam, including Acid Sulfate, Alluvial, Grey and Degraded, Red-Yellow, and Yellow-Red Humus soils. Over recent years, a general trend of soil degradation has been observed, particularly marked by increased soil acidity, reductions in organic matter, total nitrogen, and potassium levels. Phosphorus content, however, showed an increasing trend in some groups, likely due to the application of phosphate fertilizers. Notably, Yellow-Red Humus soils on mountains demonstrated improvements in soil quality, with increases in organic matter, nitrogen, and cation exchange capacity (CEC). The findings underscore the need for sustainable soil management practices to mitigate soil degradation in Vietnam's diverse agricultural regions.

Keywords: Topsoil Quality, Soil Groups, Vietnam, Land Use Change, Soil Management

INTRODUCTION

Soil quality plays a crucial role in determining the sustainability and productivity of agricultural systems [1]. In Vietnam, the diverse range of soil groups [2], each shaped by varying climatic, geographical, and human factors, has resulted in distinct trends in soil fertility and degradation [3]. The growing demand for agricultural production [4], combined with inconsistent land management practices, has led to significant changes in topsoil quality, impacting crop yields and long-term soil health [5].

Recent studies have highlighted the deterioration of soil conditions across different regions of Vietnam [6], with key indicators such as soil acidity, organic matter content, nitrogen levels, and potassium concentrations undergoing negative shifts [7,8]. This is particularly evident in intensively farmed areas, where over-reliance on chemical fertilizers and unsustainable agricultural practices have exacerbated soil degradation [9].

This paper aims to analyze the topsoil quality changes across five major soil groups in Vietnam: Acid Sulfate soils, Alluvial soils, Grey and Degraded soils, Red-Yellow soils, and Yellow-Red Humus soils on mountains. By examining key parameters such as pH, organic matter, nitrogen, phosphorus, potassium, and cation exchange capacity (CEC), this study seeks to

provide a comprehensive overview of how these soil types have evolved over time, offering insights into the factors driving soil degradation and highlighting areas where improvements have been made.

RESEARCH METHODOLOGY

Secondary investigation method: Collect information, documents, data, and maps related to natural conditions, socio-economic factors, current land use, and other relevant materials concerning soil quality and land potential from central government departments and local specialized agencies.

Primary investigation method: Review and adjust land boundary delineations on field survey maps; record information related to land plots based on field survey results. Compare and cross-reference land use status maps from the 2010-2017 period to record information about the current state and changes in land use.

Interpolation method (Kriging; IDW): Applied in the creation of maps (climate information layers: precipitation, temperature, humidity, number of dry months, etc.) by determining continuous values of precipitation, sunshine, temperature, and humidity distribution for the entire surveyed socio-economic regions.

Soil sampling and preservation method: Soil sampling for analysis is conducted according to TCVN 7538 - 2:2005 (ISO 10381 - 2:2002).

Soil Sample Analysis Method: The analysis of physical and chemical indicators is carried out according to Vietnamese Standards (as specified in Section 3, Appendix 1 issued with Circular No. 60/2015/TT-BTNMT).

RESULTS AND DISCUSSION

Topsoil is directly impacted by both natural factors and human activities and has a direct influence on crops [10].

To assess the changes in topsoil quality of different soil groups, the study compares the analysis results of various soil acidity indicators (pHKCl), total organic matter (OM%), total nitrogen (N%), total phosphorus (P2O5%), total potassium (K2O%), and cation exchange capacity (CEC) between past and present samples [11,12]. Specifically:

Past sample analysis results: Using analysis results from 2004 (inherited from the revised provincial soil maps created or revised by the Institute of Planning and Agricultural Design in 2004).

Present sample analysis results: Using the analysis results from this project conducted during the 2016-2018 period (collectively referred to as the 2017 project analysis results), which include 1,494 topsoil samples from primary profiles and 5,976 topsoil samples from secondary profiles. A total of 6,152 topsoil samples (including both primary and secondary profile samples) were selected from alluvial soils, acid sulfate soils, grey and degraded soils, red and yellow soils, and yellow-red humus soils on mountains.

The study employs statistical processing methods to calculate the average values for topsoil samples of the same soil group.

TABLE 1: STATISTICAL ANALYSIS RESULTS OF TOPSOIL SAMPLES FOR THE ACID SULFATE SOIL GROUP FROM 2004 AND 2017

Indicator	**Parameter**	**Symbol**	**Value**	
			Data from 2004	**Data from 2017**
pH_{KCl}	Mean	▪	4.29	4.39
	Range	R	4.43	5.31
	Minimum Value	Min	2.97	2.54
	Maximum Value	Max	7.40	7.85
	Standard Deviation	S	0.85	0.97
	Variance	CV	19.91	21.97
OM%	Mean	▪	3.64	2.97
	Range	R	4.94	5.40
	Minimum Value	Min	0.37	0.30
	Maximum Value	Max	5.31	5.70
	Standard Deviation	S	1.28	1.45
	Variance	CV	35.23	48.74
N%	Mean	▪	0.23	0.19
	Range	R	0.42	0.33
	Minimum Value	Min	0.04	0.04

Indicator	Parameter	Symbol	Value	
			Data from 2004	Data from 2017
	Maximum Value	Max	0.46	0.37
	Standard Deviation	S	0.10	0.09
	Variance	CV	45.34	48.38
P_2O_5%	Mean	▪	0.10	0.12
	Range	R	0.22	0.38
	Minimum Value	Min	0.03	0.02
	Maximum Value	Max	0.25	0.40
	Standard Deviation	S	0.05	0.06
	Variance	CV	51.77	51.26
K_2O%	Mean	▪	1.23	1.03
	Range	R	1.22	2.18
	Minimum Value	Min	0.62	0.50
	Maximum Value	Max	1.84	2.68
	Standard Deviation	S	0.29	0.46
	Variance	CV	23.34	44.91
CEC (meq/100g soil)	Mean	▪	19.19	13.26
	Range	R	20.21	20.14
	Minimum Value	Min	6.29	5.76
	Maximum Value	Max	26.50	25.90
	Standard Deviation	S	5.40	3.92
	Variance	CV	28.14	29.60

Acid Sulfate Soil Group: The soil acidity tends to decrease (pHKCl value increases from 4.29 to 4.39); the total organic matter and total nitrogen content tend to decrease (organic matter decreases from 3.64% to 2.97%, total nitrogen decreases from 0.23% to 0.19%); the total

phosphorus content in the soil tends to increase (total phosphorus increases from 0.10% to 0.12%); total potassium tends to decrease from 1.23% to 1.03%; the cation exchange capacity (CEC) in the soil decreases from 19.19 meq/100g soil to 13.26 meq/100g soil.

TABLE 2: STATISTICAL ANALYSIS RESULTS OF TOPSOIL SAMPLES FOR THE ALLUVIAL SOIL GROUP FROM 2004 AND 2017

Indicator	**Parameter**	**Symbol**	**Value**	
			Data from 2004	**Data from 2017**
pH_{KCl}	Mean	▪	4.91	4.65
	Range	R	4.30	4.90
	Minimum Value	Min	3.40	2.55
	Maximum Value	Max	7.70	7.45
	Standard Deviation	S	0.89	0.94
	Variance	CV	18.14	20.27
OM%	Mean	▪	2.31	2.27
	Range	R	7.94	6.45
	Minimum Value	Min	0.55	0.53
	Maximum Value	Max	8.49	6.98
	Standard Deviation	S	1.19	1.13
	Variance	CV	51.32	49.56
N%	Mean	▪	0.14	0.13
	Range	R	0.49	0.43
	Minimum Value	Min	0.02	0.01
	Maximum Value	Max	0.51	0.44
	Standard Deviation	S	0.07	0.07
	Variance	CV	48.03	49.14
P_2O_5%	Mean	▪	0.11	0.13
	Range	R	0.38	0.48

Indicator	Parameter	Symbol	Value	
			Data from 2004	Data from 2017
	Minimum Value	Min	0.02	0.02
	Maximum Value	Max	0.40	0.50
	Standard Deviation	S	0.07	0.07
	Variance	CV	60.80	53.61
K_2O%	Mean	▪	1.11	0.97
	Range	R	2.30	2.71
	Minimum Value	Min	0.05	0.06
	Maximum Value	Max	2.35	2.77
	Standard Deviation	S	0.59	0.60
	Variance	CV	52.57	61.97
CEC (meq/100g soil)	Mean	▪	13.39	10.11
	Range	R	32.65	33.45
	Minimum Value	Min	3.28	3.04
	Maximum Value	Max	35.93	36.49
	Standard Deviation	S	6.09	4.44
	Variance	CV	45.49	43.87

Alluvial Soil Group: Soil acidity tends to increase (pHKCl value decreases from 4.91 to 4.65); the total organic matter and total nitrogen content tend to decrease due to a reduction in the use of organic fertilizers in cultivation (organic matter decreases from 2.31% to 2.27%, total nitrogen decreases from 0.14% to 0.13%); the total phosphorus content in the soil tends to increase due to the use of phosphate fertilizers during cultivation (total phosphorus increases from 0.11% to 0.13%); total potassium tends to decrease from 1.11% to 0.97%; the cation exchange capacity (CEC) in the soil decreases from 13.39 meq/100g soil to 10.11 meq/100g soil.

TABLE 3: STATISTICAL ANALYSIS RESULTS OF TOPSOIL SAMPLES FOR THE GREY AND DEGRADED SOIL GROUP FROM 2004 AND 2017

Indicator	Parameter	Symbol	Value	
			Data from 2004	Data from 2017
pH_{KCl}	Mean	▪	4.49	4.24
	Range	R	2.15	3.61
	Minimum Value	Min	3.70	3.24
	Maximum Value	Max	5.85	6.85
	Standard Deviation	S	0.50	0.64
	Variance	CV	11.12	15.09
OM%	Mean	▪	1.65	1.60
	Range	R	4.27	3.88
	Minimum Value	Min	0.09	0.14
	Maximum Value	Max	4.36	4.02
	Standard Deviation	S	0.99	0.77
	Variance	CV	60.25	48.06
N%	Mean	▪	0.11	0.10
	Range	R	0.20	0.41
	Minimum Value	Min	0.02	0.02
	Maximum Value	Max	0.22	0.43
	Standard Deviation	S	0.05	0.05
	Variance	CV	51.82	56.13
P_2O_5%	Mean	▪	0.05	0.06
	Range	R	0.16	0.31
	Minimum Value	Min	0.01	0.01
	Maximum Value	Max	0.17	0.32
	Standard Deviation	S	0.04	0.05
	Variance	CV	76.57	86.10

Indicator	Parameter	Symbol	Value	
			Data from 2004	Data from 2017
K_2O%	Mean	▪	0.28	0.26
	Range	R	1.67	2.26
	Minimum Value	Min	0.02	0.01
	Maximum Value	Max	1.69	2.27
	Standard Deviation	S	0.35	0.29
	Variance	CV	125.32	109.19
CEC (meq/100 g soil)	Mean	▪	7.52	6.56
	Range	R	15.41	19.00
	Minimum Value	Min	2.59	2.00
	Maximum Value	Max	18.00	21.00
	Standard Deviation	S	3.36	3.80
	Variance	CV	44.64	57.99

Grey and Degraded Soil Group: Soil acidity tends to increase (pHKCl value decreases from 4.49 to 4.24); the total organic matter and total nitrogen content generally decrease (organic matter decreases from 1.65% to 1.60%, total nitrogen decreases from 0.11% to 0.10%); the total phosphorus content in the soil tends to increase from 0.05% to 0.06%; total potassium tends to decrease from 0.28% to 0.26%; the cation exchange capacity (CEC) in the soil decreases from 7.52 meq/100g soil to 6.56 meq/100g soil.

TABLE 4: STATISTICAL ANALYSIS RESULTS OF TOPSOIL SAMPLES FOR THE RED-YELLOW SOIL GROUP FROM 2004 AND 2017

Indicator	Parameter	Symbol	Value	
			Data from 2004	Data from 2017
pH_{KCl}	Mean	▪	4.79	4.19
	Range	R	3.31	3.98

Indicator	Parameter	Symbol	Value	
			Data from 2004	Data from 2017
	Minimum Value	Min	3.49	3.01
	Maximum Value	Max	6.80	6.99
	Standard Deviation	S	0.64	0.69
	Variance	CV	13.46	16.55
OM%	Mean	▪	2.75	2.73
	Range	R	7.62	7.64
	Minimum Value	Min	0.22	0.23
	Maximum Value	Max	7.84	7.86
	Standard Deviation	S	1.20	1.12
	Variance	CV	43.52	40.92
N%	Mean	▪	0.18	0.17
	Range	R	0.17	0.25
	Minimum Value	Min	0.11	0.09
	Maximum Value	Max	0.28	0.33
	Standard Deviation	S	0.05	0.06
	Variance	CV	26.56	31.55
P_2O_5%	Mean	▪	0.16	0.14
	Range	R	0.76	0.85
	Minimum Value	Min	0.06	0.06
	Maximum Value	Max	0.82	0.91
	Standard Deviation	S	0.12	0.10
	Variance	CV	77.30	71.62
K_2O%	Mean	▪	0.79	0.76
	Range	R	2.37	2.91

Indicator	Parameter	Symbol	Value	
			Data from 2004	Data from 2017
	Minimum Value	Min	0.12	0.08
	Maximum Value	Max	2.49	2.99
	Standard Deviation	S	0.51	0.57
	Variance	CV	64.09	74.64
CEC (meq/100 g soil)	Mean	▪	10.49	10.06
	Range	R	16.16	16.94
	Minimum Value	Min	3.17	3.00
	Maximum Value	Max	19.33	19.94
	Standard Deviation	S	3.70	3.80
	Variance	CV	35.30	37.79

Red-Yellow Soil Group: This is the largest soil group in the country and has versatile land use potential. Among the 4,102 topsoil samples used to calculate the average values of indicators in this group, 1,932 samples are from agricultural land, 1,902 samples are from forest land, and the remainder are from other agricultural uses and aquaculture.

The general trend in topsoil quality changes for the Red-Yellow Soil Group is as follows: the soil shows a tendency to increase in acidity (pHKCl value decreases from 4.79 to 4.19); the total organic matter and total nitrogen content tend to decrease (total organic matter decreases from 2.75% to 2.73% and total nitrogen decreases from 0.18% to 0.17%); the total phosphorus content tends to decrease (from 0.16% to 0.14%); total potassium also shows a decreasing trend (from 0.79% to 0.76%); and the cation exchange capacity (CEC) in the soil decreases from 10.49 meq/100g soil to 10.06 meq/100g soil.

TABLE 5: STATISTICAL ANALYSIS RESULTS OF TOPSOIL SAMPLES FOR THE YELLOW-RED HUMUS SOIL GROUP ON MOUNTAINS FROM 2004 AND 2017

Indicator	Parameter	Symbol	Value

			Data from 2004	**Data from 2017**
pH_{KCl}	Mean	▪	4.55	4.14
	Range	R	2.99	4.21
	Minimum Value	Min	3.79	2.77
	Maximum Value	Max	6.78	6.98
	Standard Deviation	S	0.80	0.77
	Variance	CV	17.49	18.57
OM%	Mean	▪	4.95	5.10
	Range	R	7.10	9.22
	Minimum Value	Min	1.94	2.51
	Maximum Value	Max	9.04	11.73
	Standard Deviation	S	1.67	2.01
	Variance	CV	33.66	39.33
N%	Mean	▪	0.23	0.24
	Range	R	0.27	0.39
	Minimum Value	Min	0.13	0.10
	Maximum Value	Max	0.40	0.49
	Standard Deviation	S	0.07	0.07
	Variance	CV	30.27	28.90
P_2O_5%	Mean	▪	0.16	0.16
	Range	R	0.56	0.60
	Minimum Value	Min	0.09	0.08
	Maximum Value	Max	0.65	0.68
	Standard Deviation	S	0.15	0.09
	Variance	CV	94.24	52.14
K_2O%	Mean	▪	0.90	0.79

Indicator	Parameter	Symbol	Value	
			Data from 2004	Data from 2017
	Range	R	1.92	2.96
	Minimum Value	Min	0.16	0.10
	Maximum Value	Max	2.08	3.06
	Standard Deviation	S	0.58	0.61
	Variance	CV	64.95	76.93
CEC (meq/100 g soil)	Mean	▪	13.47	14.04
	Range	R	15.84	14.40
	Minimum Value	Min	9.86	12.00
	Maximum Value	Max	25.70	26.40
	Standard Deviation	S	3.47	2.85
	Variance	CV	25.79	20.29

Yellow-Red Humus Soils on Mountains: The soil tends to show an increase in acidity (pHKCl value decreases from 4.55 to 4.14); the total organic matter and total nitrogen content tend to increase (OM% rises from 4.95% to 5.10% and total nitrogen increases from 0.23% to 0.24%); the total phosphorus content tends to remain stable (at 0.16%); total potassium shows a decreasing trend (from 0.90% to 0.79%); and the cation exchange capacity (CEC) in the soil increases from 13.47 meq/100g soil to 14.04 meq/100g soil.

Thus, the trend in topsoil quality changes across soil groups generally indicates a deterioration, characterized by increased soil acidity (decrease in pHKCl values); decreasing levels of organic matter, total nitrogen, and total potassium. However, the total phosphorus content shows an increasing trend in the Acid Sulfate, Alluvial, Grey, and Degraded Soil Groups due to the application of phosphate fertilizers in annual crop cultivation. In contrast, the Yellow-Red Humus Soils on Mountains exhibit an improvement in soil quality, with increases in organic matter, total nitrogen, and cation exchange capacity (CEC); the phosphorus content remains stable as these soils are primarily used for forestry purposes and are less affected by agricultural practices, facilitating the accumulation of organic matter in the soil.

CONCLUSION

The analysis of topsoil quality across various soil groups in Vietnam reveals a general trend of deterioration, particularly in the Acid Sulfate, Alluvial, Grey and Degraded, and Red-Yellow soil groups. These soils exhibit increasing acidity, declining levels of organic matter, nitrogen, and potassium, which are critical for maintaining soil fertility. The increase in phosphorus content, especially in agricultural soils, can be attributed to the heavy use of phosphate fertilizers, yet it does not fully compensate for the overall soil degradation.

In contrast, Yellow-Red Humus soils on mountains show an improvement in quality, with increases in organic matter, nitrogen, and CEC, attributed to minimal agricultural disturbance and enhanced forest coverage. These findings highlight the urgent need for more sustainable land management practices to protect soil health in Vietnam's agricultural regions. Further research and policy intervention are necessary to prevent further degradation and ensure the long-term productivity of the nation's soils.

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