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Research Article

Evaluation and Mapping of Soil Quality in Bach Dang Commune, Tan Uyen Town, Binh Duong Province, Vietnam

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Abstract

Research and evaluation of soil quality is a scientific basis for agricultural production development, making an important contribution to socio-economic development and protection of natural resources and environment for the territory or country. The objective of this study is to survey, evaluate and build a soil agrochemical map and soil quality map for Bach Dang commune, an area that is converting production from traditional agriculture to developing production models with high economic efficiency in line with the process of urbanization and modernization under the general orientation of Binh Duong province. Methods of implementation include: secondary survey of information, documents and field survey to take 115 samples for soil quality analysis and direct interview with 207 farmers using printed questionnaires. Information and data collected on the status of agricultural production and factors affecting soil quality were statistically analyzed using Microsoft Excel software. The result of the research, a map of agrochemical soils has been developed with 6 criteria, including: Soil acidity (pHKCl); Organic matter (OM%); CEC (meq/100g soil) and Total Nitrogen (%); Easily digestible phosphorus (mg/100g soil); Easily digestible potassium (mg/100g soil). At the same time, it shows the distribution of soil types according to 5 terrain levels and 2 types of mechanical components. The study also built a soil quality map of 3 levels: high quality, medium quality and low quality, respectively, with the respective areas: 332.41ha (accounting for 30.82% of the total area); 346.10ha (32.09%) and 20.85ha (1.93%). The results of the research are a valuable scientific basis for the planning of local agricultural production development, contributing to economic and social development.

Keywords: Soil; Evaluation; Map; Analysis; Bach Dang Commune; Binh Duong Province

Introduction

Soil research, from the 1960s up to now, FAO has been very active in soil research, these activities are aimed at four main directions: (1) Survey and mapping of resources soil, soil quality eveluation; (2) Land assessment; (3) Research on land potential performance; and (4) Land use management and protection [1]. At the same time, providing very meaningful technical guidelines, which are being widely applied in the world, as well as in Vietnam.

The concept of soil, V.V. Dokuchaev, a pioneering Russian scientist in the field of soil science, said that: Soil as a natural entity with different origins and development histories, an entity with complex and diverse processes occurring out in it. Soil is considered distinct from rock. Rocks become soil under the influence of a variety of soil-forming factors such as climate, vegetation, region, topography, and age. According to him, soil can be called the uppermost strata of rock regardless of form; they are

naturally altered by the common effects of water, air, and a variety of forms of living and dead organisms [2].

The concept of soil quality, two of the most concise definitions of soil quality are: "suitable for use" [3] and "capacity of a soil to function" [4]. According to the United States Department of Agriculture (USDA), soil quality is the ability of a particular soil to function, within natural boundaries or manage ecosystems, to sustain crop and livestock productivity, to maintain or enhance water and air quality, and support human health and well-being. Soil organic matter and soil biology play an important role in soil quality [5]. Thus, soil quality is the ability of the soil to perform the function necessary for its intended use. Warkentin and Fletcher emphasize that: (1) Land resources are continuously evaluated for a variety of uses; (2) many stakeholder groups interested in land resources; (3) societal priorities and ever-changing needs for land resources and (4) land use and land resource decisions made in a human or institutional context. Since there are variations between soil types, no single measurement is useful for evaluating soil quality [6].

Land is degraded due to the impact of different areas of society including urbanization and industrialization. The main drivers of land degradation are deforestation, land use change, soil erosion, uncontrolled grazing, waste disposal and unscientific land management [7].

The need to evaluate soil quality, The need for systems to monitor soil quality changes has received increasing attention in recent times. In the studies of some authors, they have suggested the need to monitor soil quality as a basic component of national policies to protect land resources [8-12]. Larson and Pierce (1991) compared a soil quality measurement system with a medical clinic assessing human health. In this study, the evaluation studies were carried out focusing on "Soil".

However, soil is difficult to inventory and evaluate. Soil types vary greatly, with variations often occurring at distances of only a few meters. An overall difference can be seen or felt on the soil surface and usually reflects differences in organic matter, mineral content or texture. However, soil characteristics below normal tillage depth are often not carefully observed and determined, with the exception of soil experts [13].

Bach Dang is a commune located in the south of Tan Uyen town and of Binh Duong province, about 22 km far from the center of Binh Duong province and about 4 km far from the center of Tan Uyen town. Bach Dang commune has a natural area of 1,075.90ha [14]. Bach Dang commune is surrounded by Dong Nai river, has relatively flat terrain, 20-30m altitude above sea level, convenient for agricultural production [15]. According to the land use planning previously made (period 2011-2020), Bach Dang is determined to develop the agricultural economy, bringing into play the soil, climate, hydrology and agricultural production traditions [15].

The current status of the commune's agricultural land in 2020 is: 614.79ha, accounting for 57% of the commune's natural area, the remaining area is non-agricultural land, accounting for 43% [14]. In recent years, along with the general development trend of Tan Uyen town, Bach Dang commune has gradually shifted its economic structure towards Agriculture - Services, in which the main focus is on agricultural production. This economic development goal is suitable to the specific conditions of the commune.

Before the problems analyzed above, the study: "Evaluation and mapping of soil quality in Bach Dang commune, Tan Uyen town, Binh Duong province, Vietnam" was carried out to inventory and monitor soil quality. At the same time, the results of this study will have practical value for planning agricultural production development and local land use planning for the period 2021-2030.

Materials and Methods

Secondary data collection method

Collect articles, books, reports on research results of topics and projects related to research content and research area. Specifically, documents on: natural conditions, socio-economic conditions, land use situation, land use planning and agricultural development planning. Thematic map on geology, hydrology, current land use, land resource map in previous research (in 2004).

The materials are collected centrally at: publishers, journals, libraries of Thu Dau Mot University, local professional management agencies and websites.

Apply research procedures and regulations

- Regulations on land survey and assessment techniques: Circular 60/2015/TT-BTNMT dated December 15, 2015 of the Ministry of Natural Resources and Environment.

- Regulations on technical procedures for soil environment monitoring: Circular 33 /2011/TT-BTNMT dated August 1, 2011 of the Ministry of Natural Resources and Environment.
- Process of surveying and mapping land with medium and large scale: Vietnam national standard (shortened name is: TCVN) 9487: 2012.

Materials, equipment and tools

For internal use: computers, A4 printers, ponds, scanners, map data of industrial land zoning are superimposed from collected thematic maps. Chemicals, laboratory instruments used for soil analysis. Digesters, heavy metal analyzers, and other machinery and equipment and their procedures are presented and described in the soil analysis methods section.

Use for field work: pre-printed land delineation map for field plotting, drilling, hoe, shovel, tape measure, soil sample box, soil profile label, plastic bag, carton cardboard for soil samples, experts, labor and vehicles to move.

Primary data collection method

Investigate production status and factors related to the formation and change of soil quality: geology, flora, climate, hydrology, minerals, crops, productivity, output.

Follow the prepared survey form. The number of samples to be surveyed was: 207 questionnaires calculated on the basis of the surveyed area (Circular 60/2015/TT-BTNMT), an average of 3 ha/site of survey and interview (TCVN 9487:2012). This result is similar to applying the formula for calculating the number of samples to be investigated when determining the total sample size of Yamane (1967-1986):

$n= N / [1+N*(e^2)]$------- (1)

In there:

N: Total sample size

n: Sample size to be investigated

e: Is the wrong number.

Through the data collected from the local specialized management agency, it was determined that N = 1,510 agricultural production households, with n = 207 (as calculated above), instead of formula (1), it is calculated e = 6.45%.

Field survey and soil sampling for analysis: According to the process of surveying and mapping land with medium and large scale (TCVN 9487:2012), Bach Dang commune with a natural area of 1,075.9ha will correspond to 1/5,000 scale map. Therefore, it is necessary to survey and take soil samples for analysis:

- **Survey by route:** Dig the soil profile and describe 23 main profiles, in which: Take soil samples for analysis according to the phylogenetic strata that arise from 4 profiles;
- **Detailed survey:** Drilling/excavating and describing 92 soil profiles, soil samples were taken for analysis of the surface layer, excluding the number of samples taken for analysis in the linear survey.

Methods of excavating profile, taking soil specimens, taking soil samples:

- **Digging soil profile:** The main soil profile is excavated with a width of 70 - 80 cm, a length of 120 - 200 cm.

The main face of the profile faces the direction of the sun; dig to hard layer, parent rock or to a depth of 125 cm (if hard layer has not been encountered); the maximum depth of subsection is 100 cm; Probe section with a maximum depth of 70 cm (can be excavated or used a specialized drill);

- **Take soil specimen:** Take the soil from the generation layers and put it in each corresponding compartment of the specimen box. The soil put in the box must keep its natural state and be characteristic for all soil layers.
- **Record soil samples:** Next to each slide, clearly record the thickness of the generated soil layer. The top of the lid and the face of the cover of the sample box record the number of sections, symbols of the sections.
- **Soil sampling for analysis:** For the main profile taken at the bottom of the profile, then gradually taken up to the upper floors; for sub-sections and contaminated soil samples taken from the topsoil, the depth is not more than 30 cm.
- Each soil sample for analysis must weigh from 1kg to 1.5kg, put it in a separate bag. The outside of the sample bag must have a label stating the number of sections, depth of soil layer, and sampling layer.

Data analysis and processing methods

Synthesize and process household survey data: Data and information on production status, impacts on land quality collected

by pre-printed questionnaires (207 questionnaires) are compiled, Analysis using Excel software.

Soil analysis method: performed according to Vietnamese standards and industry standards of natural resources and environment, details in table 1.

No.	Content	Method	Note
I.	Indicators of soil quality and agrochemical		
1	Density	Cylindrical method	TCVN 6860:2001
2	$pH_{(KCL)}$	Measure with a pH meter	TCVN 5979:2007
3	$pH_{(H2O)}$	Measure with a pH meter	TCVN 5979:2007
4	OM total	The Walkley - Black Method	TCVN 8941:2011
5	Mechanical components (3 levels)	Pipette method	TCVN 8567:2010
6	CEC	Ammonacetate method pH = 7	TCVN 8568:2010
7	N total	Kjeldahl's method	TCVN 6498:1999
8	K_2O total	Flame photometric method	TCVN 8660:2011
9	P_2O_5 total	Colorimetric method	TCVN 4052- 1985
10	N easy to digest	Distillation method	TCVN 5255:2009
11	P easy to digest	Olsen's method	TCVN 8661:2011
12	K easy to digest	Emission spectroscopy method	TCVN 8662:2011
II	Exchanged cations (4 indicators), solutes (3 indicators) and heavy metals in the soil (5 parameters)		
13	K^+	Method of using ammonium acetate	TCVN 8569:2010
14	Na^+	Method of using ammonium acetate	TCVN 8569:2010
15	Ca^{2+}	Method of using ammonium acetate	TCVN 8569:2010
16	Mg^{2+}	Method of using ammonium acetate	TCVN 8569:2010
17	Al^{3+} conversion	Flame atomic absorption spectroscopy	TCVN 8246:2009 (EPA Method 7000B)
18	Fe^{3+}, Fe^{2+} dissolve	Flame atomic absorption spectroscopy	TCVN 8246:2009 (EPA Method 7000B)
19	SO_4^{2-}	Mass method	TCVN 6656:2000 (ISO 11048:1995);
20	As	Atomic absorption spectroscopy by thermoelectric or hydride generation	TCVN 8467:2010; TCVN 10916-2015
21	Cd	Flame and thermoelectric (flameless) atomic absorption spectroscopy	TCVN 6496:2009; Ref. AOAC 986.15
22	Pb	Flame and thermoelectric (flameless) atomic absorption spectroscopy	TCVN 6496:2009; Ref. AOAC 986.15
23	Cu	Flame and thermoelectric (flameless) atomic absorption spectroscopy	TCVN 6496:2009; TCVN 10916-2015
24	Zn	Flame and thermoelectric (flameless) atomic absorption spectroscopy	TCVN 6496:2009; TCVN 10916-2015
III	Soil biology		
25	Total aerobic bacteria	Quantitative method of microorganisms on agar plates	TCVN 4884:2005 TCVN 4884-1:2015
26	Total number of anaerobic bacteria	Colony counting and techniques MPN	TCVN 6847 : 2001 TCVN 7902:2008

Table 1: Indicators and analytical methods.

Source: Circular 33/2011/TT-BTNMT; Vietnam standard and synthesis

Method of building agrochemical soil map

From the results of analysis of the criteria of agrochemical characteristics of soil, building a hierarchical scale of agrochemical criteria. Using the Geography Information System (GIS) technique to run interpolation combined with the current land use map, the soil map builds information layers on 6 agrochemical indicators, including: Soil acidity (pH_{KCl}), Substance quality organic (OM%); CEC (meq/100g soil) and Total Nitrogen (%); Easily digestible phosphorus (mg/100g soil); Easily digestible potassium (mg/100g soil).

Applying GIS techniques to overlay and interpolate information layers of 6 agrochemical criteria to build agrochemical map for Bach Dang commune with 3 levels of soil fertility evaluation, including: high, moderate obesity and low obesity.

Method of building a soil quality map: Identifying and decentralizing the set of criteria for evaluation soil quality: The soil quality of Bach Dang commune is calculated through the method of calculating the soil quality index (SQI), according to the formula:

SQI= w1.(SPP) + w2.(SCP) + w3.(SBP) -------- (2)

In there:

w1, w2, w3: is the weight of the soil properties;

SPP: Is the physical properties of the soil;

SCP: Is the chemical property of the soil;

SBP: Is the biological property of the soil.

To calculate the weights of the weights of the soil properties, apply Principal Component Analysis (PCA) and at the same time evaluate the importance of the criteria in the soil properties. The indicators included in the conversion scale follow the principle of being positive with the soil quality score, that is, a high indicator score corresponds to a high soil quality score.

Results and Discussion

The presented research results include: agrochemical soil mapping and soil quality mapping in Bach Dang commune.

Building agrochemical soil map of bach dang commune

Soil formation process

According to the construction document of soil map which was additionally investigated and revised in 2004 of Binh Duong province, Bach Dang commune has only one group of alluvial soils with two main types of soil: Alluvial soil is not allowed to form. Alluvial soil with red-yellow patchy layer (Pf) [16].

Classification and characteristics of soil types in Bach Dang commune: In this study, additional survey and adjustment of the land map for Bach Dang commune were carried out, the results compared to 2004 were to separate each main land unit into 2 sub-unit of land with morphological features arising during land use. In which, alluvial soil that has not been accreted and has not been differentiated is divided into: Alluvial soil that has not been accreted and has not been differentiated (symbolized by P) and Alluvial soil that has not been accreted with rust spots (symbolized by P-dg). Alluvial soil with red-yellow patchy layer is divided into: Alluvial soil with red-yellow patchy layer (symbolized by Pf) and Alluvial soil with red-yellow patchy layer - glay (symbolized by Pf-g) (Table 2 and Figure 1).

No.	Soil type	Symbol	Area (ha)	Ratio (%)
	Total area		1,078.60	100
I	The alluvial soil has not been accreted and has not yet differentiated its profile		261.87	24.28
1	The alluvial soil has not been accreted and has not yet differentiated its profile	P	176.15	16.33
2	Alluvial soil that is not accreted has rust spots	P-dg	85.71	7.95
II	Alluvial soil has red and yellow patchy layers		437.49	40.56
3	Alluvial soil has red and yellow patchy layers	Pf	258.64	23.98
4	Alluvial soil with red and yellow patchy layers - gley	Pf-g	178.85	16.58
III	Area of land not investigated		379.24	35.16
5	Rivers, streams, canals	RSC	149.58	13.87
6	Other non-agricultural land (residential land, specialized land)	NAL	229.66	21.29

Table 2: Summary of land classification in Bach Dang commune.
Survey data, 2020.

According to topographic factors	Soil grain level composition	Total area (ha)	Ratio (%)	Soil type			
				P	P-dg	Pf	Pf-g
Surveyed land area		699.36	64.84	176.15	85.71	258.64	178.85
High	Medium grain soil (d)	42.77	3.97	42.77	-	-	-
Medium high terrain	Medium grain soil (d)	219.10	20.31	133.38	85.71		
Midium terrain	Medium grain soil (d)	105.89	9.82	-	-	83.86	22.03
	Heavy soil grain (e)	188.17	17.45	-	-	140.06	48.11
Low average terrain	Heavy soil grain (e)	83.37	7.73	-		34.72	48.64
Low	Heavy soil grain (e)	60.06	5.57	-	-	-	60.06
Area of land not investigated		397.24	35.16				-
Rivers, streams, canals		149.58	13.87	-	-	-	-
Other non-agricultural land		229.66	21.29	-	-	-	-
Total		1,078.60	100				

Table 3: Types of soil in Bach Dang commune according to relative topography and mechanical composition.
Note: (-) No data; Survey data, 2020.

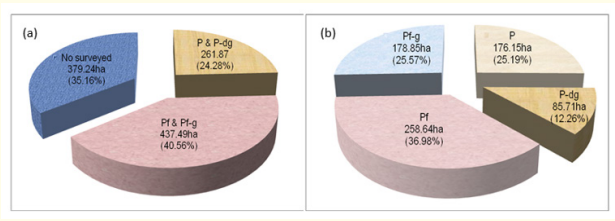

Figure 1: Structure of soil classification according to main soil groups (a) and soil types (b).

The results of the field survey and the data in table 3 show that:

- **The alluvial soil has not been accreted and has not yet differentiated its profile:** Distribution at the edge of the commune, with high terrain, drainage, no groundwater up and down in the depth of 0-50 or 100 cm; soils with almost no distinct accumulation layer (B horizon), the AA(B)-C or A-AC-C profile is classified into this notational unit, equivalent to the Othi-Dystric Fluvisols soil unit, according to the FAO/UNESCO classification.
- **Alluvial soil has red and yellow patchy layers:** Distributed in low terrain in the center of the commune, well drained, with shallow up and down groundwater levels. However, the time of groundwater saturation is short, so at a depth of 0-50 cm or 100 cm, oxidation is dominant. Therefore, soils that form red-yellow patchy strata in the above depth range are included in this notation, which is equivalent to the soil unit Dysti-Gleyic Fluvisols according to the FAO/UNESCO classification. Morphology of A-AB-Bwg type. In which changes in color and structure (Bwg layer) appear in the depth of 30-70 cm, some profiles have a weak Gley level.
- **Building agrochemical soil map:** Through the evaluation of the analytical criteria of 115 agrochemical soil samples (92 detailed samples and 23 survey samples by line) of Bach Dang commune, the results are summarized in 6 agrochemical characteristics for the agrochemical soil map (Table 4 and Figure 2).

Building soil quality map of Bach Dang commune

Input information is a data set consisting of 3 criteria: soil physical properties (SPP), soil chemical properties (SCP) and biological properties of soil (SBP). Apply principal component analysis (PCA) to avaluate the importance of soil quality criteria.

Evaluation criteria	Area (ha)	Ratio (%)	Soil type			
			P	P-dg	Pf	Pf-g
pH_{KCl}						
Neutrality (6-7)	5.57	0.52	5.57	-	-	-
Less acid (5-6)	335.09	31.07	146.89	74.62	72.65	40.93
Acid (4-5)	285.16	26.44	23.69	11.09	137.19	113.19
High acid (<4)	73.54	6.82	-	-	48.81	24.73
No surveyed	379.24	35.16	-	-	-	-
OM						
High humus content (>2)	425.93	39.49	79.13	35.69	150.70	160.41
Medium (1-2)	242.24	22.46	75.40	50.02	98.38	18.44
Poor (<1)	31.19	2.89	21.63	-	9.57	-
No surveyed	379.24	35.16	-	-	-	-
CEC						
High (20-30)	55,06	5,10	25.78	3.37	25.90	-
Medium (10-20)	552.34	51.21	142.36	75.31	174.94	159.73
Low (<10)	91.96	8.53	8.02	7.03	57.81	19.11
No surveyed	379.24	35.16	-	-	-	-
N total						
Rich in easily digestible nitrogen (>6)	329.33	30.53	52.18	36.14	131.01	110.00
Medium (4-6)	349.91	32.44	123.16	36.10	121.79	68.85
Poor (<4)	20.12	1.87	0.81	13.47	5.84	-
No surveyed	379.24	35.16	-	-	-	-
P easy to digest						
Rich in easily digestible phosphorus (>15)	318.65	29.54	99.11	73.41	143.98	2.15
Medium (10-15)	268.19	24.86	57.32	8.93	69.83	132.11
Poor (<10)	112.53	10.43	19.72	3.37	44.84	44.59
No surveyed	379.24	35.16	-	-	-	-
K easy to digest						
Rich in easily digestible potassium (>20)	511.67	47.44	164.97	72.24	195.98	78.48
Medium (15-20)	164.01	15.21	11.18	13.47	51.81	87.55
Poor (<15)	23.68	2.20	-	-	10.85	12.83
No surveyed	379.24	35.16	-	-	-	-

Table 4: Areas of soil types according to agrochemical criteria summarized in the map.
Note: (-) No data.

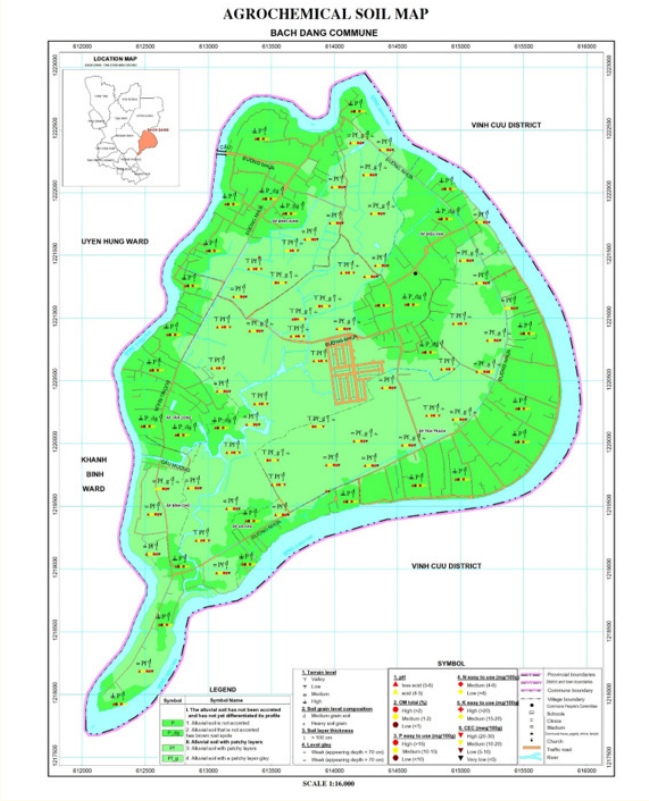

Figure 2: Agrochemical map of Bach Dang commune.

Checking the correlation of the 3 criteria above is shown in table 5.

Criteria	SPP	SCP	SBP
SPP	1		
SCP	0.393949	1	
SBP	0.393949	1	1

Table 5: Correlation of soil quality criteria.

Through the data in table 5, all indicators are positively correlated with each other (positive correlation coefficient). The pairs of indicators with weak correlation (absolute value of correlation coefficient <0.4) are pairs of PPS and SCP; SPP and SBP pairs; absolute correlation (linear correlation, with correlation coefficient = 1) is the pair SCP and SBP.

The importance of the 3 soil biological parameters included in the analysis of the main components is arranged in descending order as follows: SBP>SCP>SPP corresponding to the percentage of sample data present in the main component: 96.8%; 96.6%; and 61.5 (rate >40% is statistically significant). Thus over 96% of the properties of the soil quality (at high or low level) in Bach Dang commune depend the most on the level of two criteria, namely the biological properties of the soil and the chemical properties of the soil (Table 6).

Criteria	Thành phần chính
SPP	.274
SCP	.430
SBP	.431

Table 6: Analysis results of the main components of soil quality.

Integrate weights and soil quality hierarchy (SQ) into 3 levels: high, medium and low; then connect the results of soil quality calculation (SQ) with agrochemical map of each commune to build a soil quality map for each commune (Table 7 and Figure 3).

The data in table 7 and figure 3 show that the area with high and medium quality land accounts for the majority with 62.91% of the commune's natural area. The area with high quality soil is distributed mainly in Tan Trach hamlet, in the eastern area of the commune, adjacent to Dong Nai river. The reason is that this area has canals and canals connected to Dong Nai River and receives alluvial deposition during high tides.

Classification of soil quality criteria	Area (ha)	Ratio (%)	Soil type			
			P	P-đg	Pf	Pf-g
High	332.41	30.82	146.39	61.15	96.60	28.27
Medium	346.10	32.09	29.76	24.56	159.64	132.13
Low	20.85	1.93	-	-	2.41	18.44
No surveyed	379.24	35.16	-	-	-	-
Total	1,078.60	100	176.15	85.71	258.64	178.85

Table 7: Summary of area distribution of soil quality indicators by soil types.

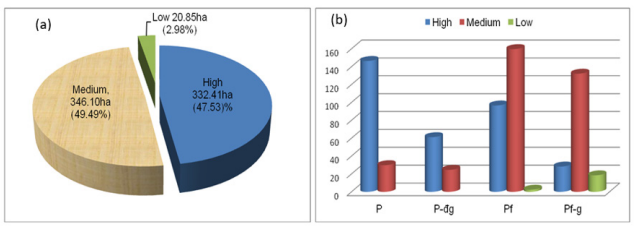

Figure 3: Soil quality classification diagram (a) and classification by soil type (b).

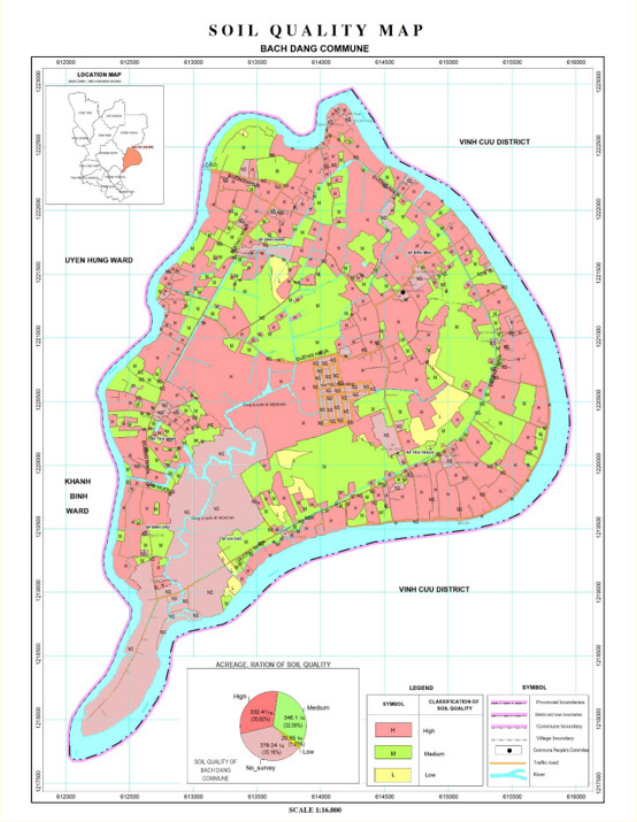

Figure 4: Map of soil quality in Bach Dang commune.

Conclusion

The study has built a map of agrochemical soils consisting of 6 agrochemical characteristics that are aggregated into 3 levels: rich, medium and poor. At the same time, it shows the distribution of soil types according to 5 terrain levels: high, high, medium, low and lowland; There are two types of body composition: medium meat and heavy meat. In the soil quality map, the total area of the commune's land quality criteria distribution for all types of soils is divided into 3 levels: high quality, medium quality and low quality.

The results of the study provide a scientific and practical basis for the management of the agricultural and natural resources and environment sectors, and are a valuable scientific basis for land use planning and agricultural production planning period up to 2030. Research directions need to be developed: the impact of agricultural practices and fertilizer use on soil quality.

Acknowledgements

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Volume 5 Issue 11 November 2021